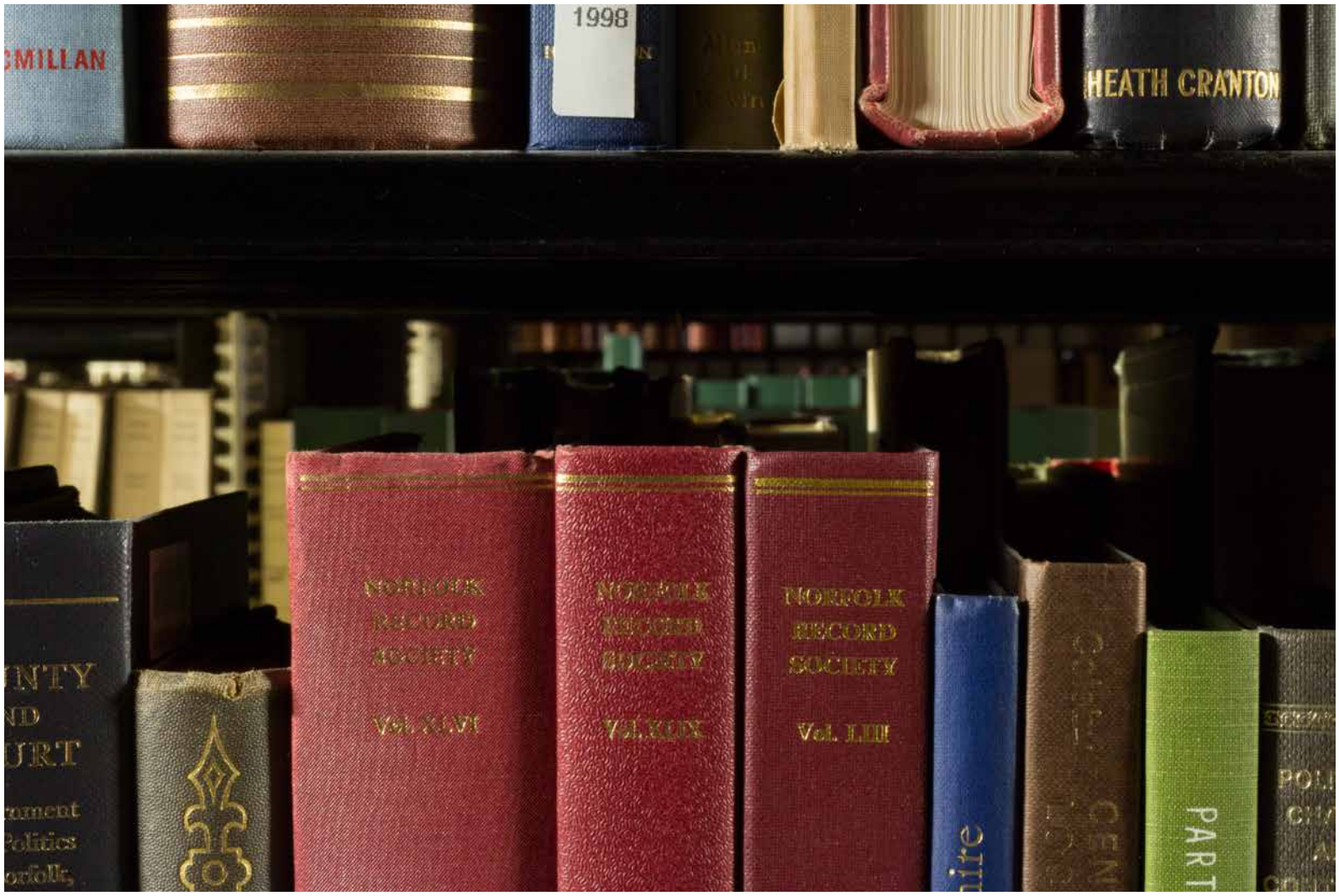
SCHOLARS' DAY REVIEW

An E-Journal Featuring Student Scholarship



Monroe Community College
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Volume 2

SCHOLARS' DAY
REVIEW
VOLUME 2, 2014

Letter from the Editor

Dear Readers,

Good ideas come and go through all of our minds. Mostly they're forgotten, but sometimes we capture them, maybe write them down or tell somebody. Occasionally we act on them with greater effort. *Scholars' Day Review* (*SDR*) embodies that effort in a variety of ways. The papers you will read in this volume began, of course, as good ideas in students' minds, and the faculty who mentored those students took significant time out of their own routines hoping that committing to Scholars' Day was a good idea. And the very existence of this publication is indebted to such a process.

SDR originated last year as an idea of my co-editor-in-chief, Verdis Robinson, and it sounded so good I couldn't pass up playing a role in it. In the meantime, Professor Robinson found himself with a plate too full, and as the surviving editor-in-chief, so to speak, I've promoted two members of the editorial board to the lofty title of associate editor, which perhaps unbeknownst to them meant a good deal more work at a time in the semester when it wouldn't be easy. Both of them, Scott Rudd from the English/Philosophy Department and Daniel Tyree from Anthropology, agree that *SDR* is an idea worth the effort. Or at least I plan on seeing their names again next year, on Volume 3's credits.

Scholars' Day Review is a faculty-juried journal showcasing the exceptional presentation papers of student scholars who participated in Monroe Community College's Scholars' Day. This year's volume includes seven papers, ranging from an engineering report on a truss tower design for wind turbines to an evolution-based argument about primate diet based on the salivary amylase gene; in-between are literary, chemical, and dental-storage analyses. These papers reflect the diversity of the work being done here at Monroe Community College and exhibited at Scholars' Day.

Finally, before I leave you with the papers themselves, I want to express my heartfelt gratitude to everyone who has participated in this venture, from the editors listed at right, to the faculty who mentored student projects, to the students who submitted their papers, including those who weren't published in this volume and were notified ever so late, and to the entire Scholars' Day Committee. And to you, dear readers, for taking the time to read these papers. I hope you enjoy them.

Michael S. Ofsowitz
Editor-in-Chief

http://web.monroecc.edu/scholarsday/SDRhome

Cover Design, Photo
Jesse Ofsowitz

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Down to the Bristles: The Best Storage Method for Your Toothbrush

Tina Barnett
Stephanie Iascone
Tricia Wilson

Faculty Sponsors: Profs. Marsha Bower (Health Professions) and Suzanne Long (Biology)

ABSTRACT

Based on new technology, often dental hygienists are faced with the question of, "What is the best storage method for toothbrushes?" It is important for dental patients to know how to properly store their toothbrushes to prevent exposure to other harmful environmental bacteria, such as *Escherichia Coli* (*E. coli*). The purpose of this experiment was to assess the most effective storage method by determining which one produced the least amount of environmental bacteria. This simple experiment utilized six methods of storage: American Dental Association's recommendation to keep stored in a dry, upright environment, dipped in antiseptic mouth rinse then placed in a holder in the bathroom, a Steri-Pod, a traditional travel holder, a UV sanitizer, and one simply placed in a toothbrush holder. Each toothbrush was unused and placed in the same bathroom within the designated storage method. One brush was cultured at the start of the experiment to determine a baseline for the amount of bacteria naturally occurring on packaged toothbrushes. After two weeks, a culture was taken from each of the brushes and allowed ample time to grow. The growth was visually measured, counted, and compared. We hypothesize that the toothbrush dipped in antiseptic mouthwash will produce the least amount of bacterial growth.

Editor's note: Tina Barnett, Stephanie Iascone, and Tricia Wilson won a 1st place scholarship award at the 2014 Scholars' Day for their presentation on this topic.

MLA Citation

Barnett, Tina, Stephanie Iascone, and Tricia Wilson. "Down to the Bristles: The Best Storage Method for Your Toothbrush." *Scholars' Day Review* 2 (2014): 1-5. Web. Date of access

Down to the Bristles: The Best Storage Method for Your Toothbrush

Our mouth is filled with many different types of bacteria. Most are harmless and simply find the mouth a welcoming place to reside. Two of the most common harmful types of bacteria in our mouth are *Streptococcus mutans* (*S. mutans*) and *Porphyromonas gingivalis* (*P. gingivalis*). *S. Mutans* is responsible for tooth decay and *P. gingivalis* is responsible for periodontal disease. There are also bacteria in the environment that have the possibility of landing on your toothbrush if not stored properly. Like the bacteria in your mouth, they can be harmful or have no effect on your body. People often want to know what the best method is for storing your toothbrush. Depending on what storage method you choose, there are differences in the amount of environmental bacterial growth on your toothbrush.

METHOD

While looking up previous research on the subject, we found that companies are not mandated to sterilize toothbrushes before packaging. We were interested to see how much environmental bacteria would be on a toothbrush straight from the package. A modified standard plate count was conducted on the toothbrush straight from the package.

A modified standard plate count is often used in microbiology so it is easier to count the number of colonies that grew. In our case, there were five different dilutions that were made for that one toothbrush. The dilutions were as follows: 1:10, 1:100, 1:1,000, 1:10,000, and 1:100,000. In order to do the dilutions, we needed to make a wash so we were able to spread it onto an agar. We added 10mL of sterile water to a 50mL conical tube. The toothbrush head was aseptically placed in the conical tube, wrapped with parafilm, and vortexed for one minute to create the wash. The agar that we chose to use for this part of our experiment was the Trypticase Soy Agar (TSA). From the 10mL wash that we created, 1mL was dispensed onto a TSA agar (1:10). From the wash, 1mL was dispensed into a 9mL blank (A), and 1mL was dispensed into a 99mL blank. From the wash, 0.1mL was dispensed onto a TSA agar (1:100). From blank A, 0.1mL was dispensed onto a TSA agar (1:1,000). From the 99mL blank, 0.1mL was dispensed onto a TSA agar (1:10,000). From the 99mL blank, 1mL was dispensed into a 9mL blank (B). From blank B, 0.1mL was dispensed onto a TSA agar (1:100,000). Each of the dilutions was spread onto the plate using a glass hockey stick spreader. The plates were then incubated for three days at room temperature and two days at 35°C. The plates were assessed and the results were gathered from the 1:10 dilution plate. The toothbrush that came straight from the package ended up having 90 environmental bacterial colonies on it (see Figure 1).

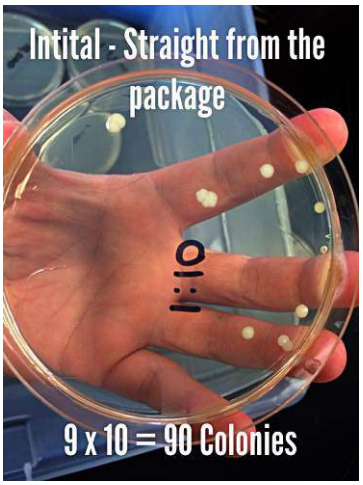

Figure 1: Bacterial colonies on an unsterilized, new toothbrush

For our experiment to find the best storage method for your toothbrush, we used six different toothbrushes and six different storage methods. The six toothbrushes were sterilized before the experiment was started to make sure that each toothbrush started out with zero colonies of bacteria. The storage methods we used were as follows: to keep stored in a dry, upright environment (American Dental Association's (ADA) recommendation), dipped in antiseptic mouth rinse and then placed in a holder in the bathroom, a Steri-Pod, a traditional travel holder, a UV sanitizer, and one simply placed in a toothbrush holder. The toothbrushes were stored in their designated storage methods in the same bathroom for two weeks. Each day the toothbrushes were run under tap water to simulate daily brushing and routine environmental exposure.

The reason we picked the storage methods that we did was because they seemed like some of the most popular storage methods and we wanted to test how some of the new technology works. One of the more popular storage methods was the American Dental Association's recommendation to keep the toothbrush stored in a dry, upright environment. If more than one brush is stored in the same holder or area, it is important to keep the brushes separated to prevent cross-contamination. For the first storage method, the toothbrush was stood upright in a cabinet with the door shut (Council of Scientific Affairs, 2011).

The second storage method used Listerine, an antiseptic that comes from a formula of four essential oils that kill millions of bacteria on contact. The fixed combination of eucalyptol, menthol, methyl salicylate, and thymol does not compare to others. Because of the antiseptic properties in the mouth, we decided to try it on a toothbrush and see if it would have the same results. After the toothbrush was run under tap water, it was dipped in Listerine and placed in a holder in the bathroom (Listerine, 2014).

The Steri-pod is a relatively new technology that kills bacteria with vapors. Inside each Steri-pod toothbrush sanitizer is a laboratory formulated thymol compound. The compound is encapsulated in plastic with small holes that allow the thymol vapors to escape and surround the toothbrush bristles. All you have to do is clip the Steri-pod to the head of your brush and it will begin to work. The manufacturer recommends replacing the Steri-pod every three months. For our experiment, the third toothbrush was stored in a holder on the sink and the Steri-pod was clipped to the head (Bonfit America Inc., 2011).

The fourth storage method used a traditional travel holder with holes to allow moisture to escape. The toothbrush was placed inside and the holder was laid on the counter. For the fifth storage method, a UV sanitizer was used. UV sanitizers work by penetrating thin-walled bacteria. The light alters the genetic structure and the bacteria die. UV light is not visible to the naked eye, and because of its frequency, has germicidal properties. When the nucleus is penetrated, the DNA is irreparably damaged which results in bacterial death or the inability to reproduce itself. The technology of the UV sanitizer is the same technology used in hospitals. For the machine we used, the toothbrush head was placed in the sanitizer and ran for its allotted time before turning off automatically (Guardian Technologies, 2008).

The last storage method was a toothbrush placed in a holder. There was nothing covering the toothbrush and it was about three feet away from the toilet just sitting in the holder.

A modified standard plate count was done on these six toothbrushes after two weeks of storage in their specified methods. The standard plate count was done the same way on these six toothbrushes as it was done on the toothbrush straight from the package. The only change was that instead of five dilutions, there were six. The dilutions were as follows: 1:10, 1:100, 1:1,000, 1:10,000, 1:100,000, and 1:1,000,000. The wash was created the same way as done previously. The agars that we chose to use for this part of our experiment were the TSA and the Eosin-Methylene Blue Agar (EMB). The dilutions were made in the following ways. From the 10mL wash, 1mL was dispensed onto a TSA agar (1:10). From the wash, 1mL was dispensed into a 9mL blank (A) and 1mL was dispensed into a 99mL blank. From the wash, 0.1mL was dispensed onto a TSA and EMB agar (1:100). From blank A, 0.1mL was dispensed onto a TSA agar (1:1,000). From the 99mL blank, 0.1mL was dispensed onto a TSA and EMB agar (1:10,000). From the 99mL blank, 1mL was dispensed into a 9mL blank (B). From blank B, 0.1mL was dispensed onto a TSA agar (1:100,000). From blank B, 1mL was put into a 9mL blank which created blank C. From blank C, 0.1mL was dispensed onto a TSA agar (1:1,000,000). Each of the dilutions was spread onto the plate using a glass hockey stick spreader. The plates were then incubated for three days at room temperature and two days at 35°C.

RESULTS

The data were collected and analyzed. Based on the growth consistency on the TSA plates, the dilutions 1:10 and 1:100 were used to determine the best storage method. The toothbrush with no storage had 330 environmental bacterial colonies on the 1:10 dilution and 140 on the 1:100 dilution. The toothbrush that was dipped in antiseptic mouthwash had 30 environmental bacterial colonies on the 1:10 dilution and zero on the 1:100 dilution. The toothbrush that was stored in the Steri-pod had 1,200 environmental

bacterial colonies on the 1:10 dilution and 190 colonies on the 1:100 dilution. The toothbrush that was stored in the travel holder had 30 environmental bacterial colonies on the 1:10 dilution and 10 on the 1:100 dilution. The toothbrush stored in the UV sanitizer had too many environmental bacterial colonies to count on the 1:10 dilution and 50 on the 1:100 dilution. The toothbrush that was stored in a dry, upright environment (ADA recommendation) had 10 environmental bacterial colonies on the 1:10 dilution and 150 colonies on the 1:100 dilution. However, because there should be more colonies on the 1:10 dilution and not the 1:100 dilution, we believe the plates for the ADA recommendation were switched. We believe that there were actually 150 environmental bacterial colonies on the 1:10 dilution and 10 on the 1:100 dilution.

The EMB plates were used to test for fecal matter. The results show no growth on any of the EMB plates. Figures 2 through 7 show the environmental bacterial growth on all six storage method plates for the 1:10 dilution. Figure 8 shows the results of the experiment. As mentioned above, the UV sanitizer 1:10 dilution plate had too many colonies to count, so for the visual purposes of the graph, we put 2,000 as the number of colonies on the plate.

Based on our results, the best way to store your toothbrush is to dip it in an antiseptic mouth rinse after brushing. The essential oils and alcohol kill the bacteria and therefore, that toothbrush had the least number of environmental bacterial growths. The dilution of 1:10 had 30 bacterial colonies on it and the 1:100 had zero colonies. The plastic travel case was a close second with 30 environmental bacterial colonies on the 1:10 dilution and 10 on the 1:100 dilution. Since both of the 1:10 dilutions had 30 colonies on them, we had to decide which storage method was better. We decided since the 1:100 dilution of the toothbrush dipped in antiseptic mouthwash had zero colonies, it is considered the best storage method.

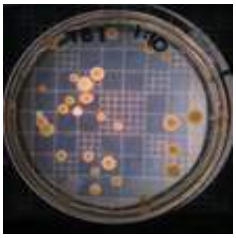
Fig. 2: No Storage

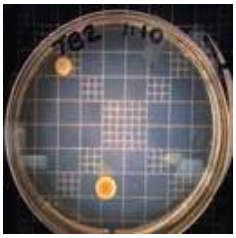
Fig. 3: Dipped in antiseptic

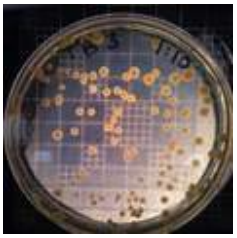
Fig. 4: Steri-pod

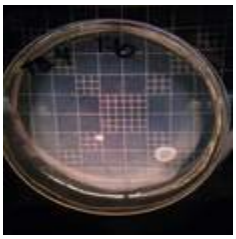
Fig. 5: Carry case

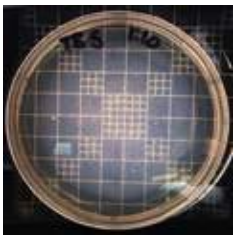
Fig. 6: ADA recommendation

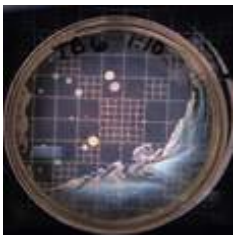
Fig. 7: UV sanitizer

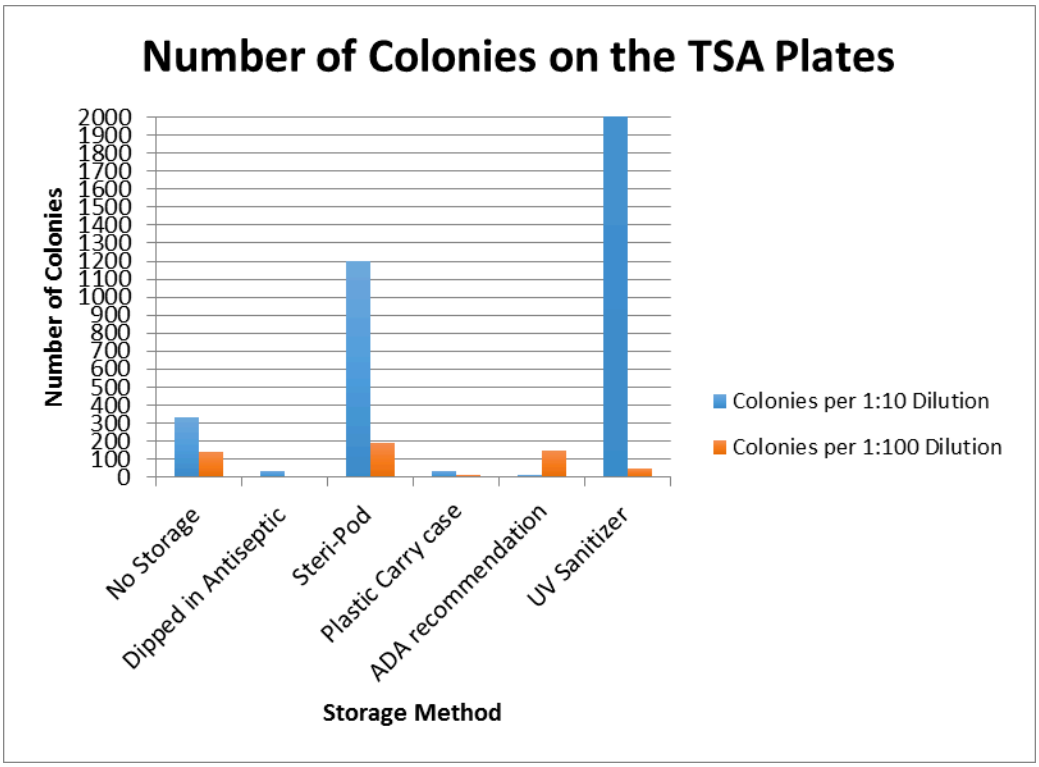

Figure 8: Colonies per 1:10 and 1:100 dilution by storage method

CONCLUSION

In the future, we would like to expand on this knowledge and include the actual use of each toothbrush within the oral cavity and then have the brushes placed in their designated storage method. We would then test if the oral cavity bacteria increases or decreases in each storage method. This would follow the same processes as our initial experiment. We would include a larger sample size in which people who have active periodontal disease and active decay will use the brushes. The brushes would then be tested for the specific oral bacteria, *P. gingivalis* and *S. mutans*, which are responsible for these diseases. Our goal is to determine the best storage solution so patients can avoid reintroducing disease causing bacteria into their oral cavity and for early prevention of these bacteria in the oral cavity in children.

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Truss Tower Analysis: Static Analysis of a Truss Tower used to Support a Wind Turbine

John Trout
Carrie Phillips

Faculty Sponsor: Prof. Christopher Kumar (Engineering Sciences)

ABSTRACT

Due to the massive size of modern day wind turbines, the stability of their support towers is critical. This project examines structural forces present in a four-sided truss tower modeled as a support system for a wind turbine. Case I examined only forces due to the weight of the nacelle and rotor, while Case II also incorporated lateral wind force. All forces were idealized as concentrated forces and theoretic analysis was completed using static equilibrium concepts and truss/frame analysis techniques. A PASCO Structure kit was used to construct a model and validate theoretical findings. Weights were applied to the model and the resulting axial forces were measured using load cells. Experimental data concurred with the theoretical analysis within the measured uncertainty, indicating the tower was accurately analyzed as a frame/truss structure. Case I found support forces were isolated to only the vertical members while Case II showed significant axial forces on both vertical and diagonal members local to the applied wind force. Findings indicate that several considerations should be taken into account when designing such support systems, including tower geometry, length of structural members, nacelle orientation, and environmental conditions. Future analysis should incorporate tower dynamics and material properties.

Editor's note: John Trout and Carrie Phillips won a 2nd-place scholarship award at the 2014 Scholars' Day for their presentation on this topic.

MLA Citation
Trout, John, and Carrie Phillips. "Truss Tower Analysis: Static Analysis of a Truss Tower used to Support a Wind Turbine." *Scholars' Day Review* 2 (2014): 7-25. Web. Date of access.

Truss Tower Analysis: Static Analysis of a Truss Tower used to Support a Wind Turbine

Wind turbines consist of massive components and experience extreme weather conditions and forces due to wind. If the structure supporting the turbine were to be constructed without fully analyzing the possible forces acting on it, the outcome could be failure of the tower and damage to the equipment it supports. Wind turbines are highly intelligible systems, containing technology and mechanisms that are quite costly. Damage caused from a breakdown or misalignment of the most basic component (the tower) could affect the function of all components of the system. The result would be complicated and expensive at the very least. The first step in erecting a wind turbine is, therefore, careful consideration of the tower itself.

A typical wind turbine system consists of certain basic components. There are the blades and rotor cap, which make up the rotor assembly (referred to as the rotor henceforth). These components capture energy from the wind and convert it into rotation motion (i.e., torque). This rotational motion is directed to the turbine generator, which converts mechanical energy into electrical energy via electromagnetic induction. In larger turbines, 50kW or above, a gearbox is sometimes used between the rotor shaft and generator. The gearbox converts the typically modest RPM of the rotor to a higher RPM desirable for the production of electricity. The gearbox and generator are housed in a structure called a nacelle, which sits atop the tower. In addition to the mechanical features of a wind turbine, there is also an electrical controller, such as a converter or inverter that acts to couple the power produced by the generator with the electrical grid the turbine is connected to. Most larger, modern wind turbines utilize a monopole style tower; however, lattice-style towers are still widely used because of their cost effectiveness and ease of construction.

Method

This project examined a four-sided lattice tower structure that could potentially support a wind turbine. The tower was modeled as a truss tower. The support forces of several members (wood pieces that make up the frame) were examined in order to get a better understanding of the distribution of forces. The members experiencing the greatest force due to static weight or constant wind loading were considered. Case I examined only forces due to the weight of the nacelle and rotor, while Case II also incorporated a horizontal force due to wind. Joint reactions to stress were evaluated using static equilibrium concepts and frame and truss analyses.

Based on published information, the nacelle is approximately 1.5 times the weight of the rotor and is positioned with the center of mass along the central axis of the tower. Weight components in both cases were idealized as a ratio of two forces acting on two separate joints (A and B; see Figure 3.2). This ratio was 3:2, with more weight being applied to Point B (Figure 3.2). Case II was analyzed with an additional force concentrated at Joint H (Figure 3.2), modeling the lateral force due to wind. All idealized points were calculated using the theory of equivalent force systems.

Theoretical analysis was completed using the method of joints technique. Method of joints analysis treats each joint as a particle, with the assumption that if the entire truss is in equilibrium then each joint must also be in equilibrium. The structure was analyzed assuming the turbine was not in motion in order to keep the system in static equilibrium (zero acceleration). The method of joints is an effective way to analyze a truss structure by allowing for separate analysis on each joint. Analysis is completed through free body diagrams for each joint, employing equations of equilibrium to solve for unknown forces. Although this method is longer and more tedious than other analytical methods, it is a simple and effective way to solve for unknown forces. In order to use this method, the structure being analyzed must be able to be treated as a truss tower. Space trusses must contain only two force members, where forces are applied only at the joints. Member weight must also be negligible and the connection joints should be idealized as ball and socket. The structure used in this project fit all requirements and so was considered a truss tower during all analyses.

Experimental data were collected on a model of the truss tower constructed using a PASCO Structure kit and load cells. Weights of magnitudes 1500g and 1000g were applied to the model to simulate the nacelle and rotor, respectively. Forces were measured three-at-a-time and load cells were then rotated for subsequent analyses of points throughout the model. Case II contained a pulley system horizontally attached to the tower loaded with a 9.8 N force on the other end. This system was used to model a lateral force due to wind.

All experimental data concurred with theoretical analyses within the measured uncertainty. These findings indicated that the theoretical tower was accurately analyzed as a truss and frame system and accurately modeled using the structure constructed. Case I found support forces in only the vertical members, due to the downward force of the weight of the nacelle and rotor due to gravity. The joints located toward the front of the nacelle showed greater support reactions than members located toward the back. All diagonal members were zero force members.

Case II, which incorporated a horizontal force idealized as a single force on a single joint, showed significant impact on the diagonal joints below the joint where the force was applied. Intuitively, it is surprising to see that the diagonal member extending upward (HI) from this joint did not share the distribution from the tension force (T_{HI}). The only diagonal member extending from this joint supporting the force was the diagonal member extending downward (T_{HL}). Theoretically this is expected using a top-down analysis using method of joints. Being that the top of the structure contained no support forces in the XZ plane, analysis at Joint I supports the finding that T_{HI} would be zero.

METHODS: THEORETICAL ANALYSIS

Configuration of lattice towers used as support structures, such as for wind turbines, are typically designed to be statically indeterminate. This provides an additional safety factor in the event of component failure, such that additional load paths may exist to support the structure and avoid total failure. However, in order to effectively design a truss tower that can be analyzed using static equilibrium techniques, such as method of joints or method of sections, certain assumptions regarding the operation of the wind turbine, and simplifications to the tower configuration are necessary.

First, we must ensure our truss is a statically determinate system. By rule of thumb, if the number of members plus the number of reactionary forces is equal to the number of joints times three, the system is statically determine if it has full fixity. This rule is shown in **Equation 3.1**

$$m + r = 3j \qquad (3.1)$$

where m is the number of joints, r is the number of reaction forces, and j is the number of joints. The truss tower we designed and analyzed is modeled below in **Figure 3.1**.

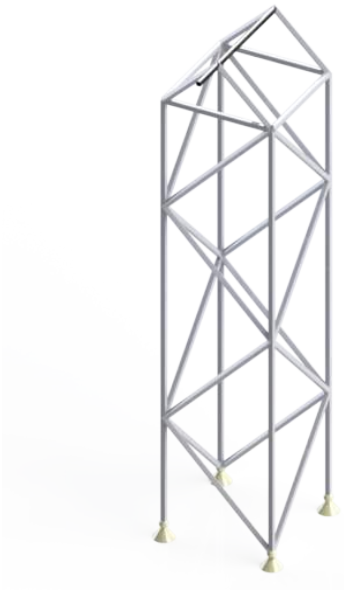

FIGURE 3.1: 3D MODEL OF DESIGNED TRUSS TOWER

There are 35 members, 12 reaction forces due to four ball and socket supports, and 16 joints, which suggests partial fixity of the tower (fig 3.1). It is visually apparent that the location of partial fixity is isolated to the top sections of the tower, and although simply adding a member at some other location below this point may satisfy **Equation 3.1**, it would not address the potential for movement in this area. To address this issue we first note that the very top member, shown in black, was treated as a frame (a member experiencing force at a location other than at its joints) due to the location of nacelle and rotor weight force (explained below). This allowed for separating this member from the rest of the tower and analyzing it separately. With

this member removed, we further assumed that there is no applied force in the x direction, and that any moments created at the joints are negligible and therefore no movement is experienced. This assumption is further supported by the fact that the structural kit used to construct our model provided sufficient rigidity at joint connections to adequately restrain any unwanted movement in the x direction, keeping our analysis approach valid. Thus we removed the frame member as well as the two joints and the four joint support members (two at each joint), which lowered our member count to 30 and our joint count to 14. Thus **Equation 3.1** was satisfied, and since the remaining structure has full fixity we concluded the system was statically determinate. We also concluded that forces acting on the tower do so only at the joints and that the tower consists of only two force members, as required for treatment of the tower as a truss. Furthermore, we assumed that all members are connected to each other with frictionless ball and socket joints and the weight of each member is negligible. To further simplify the analysis, all diagonal members were designed to be at ±45° as measured from the horizontal.

In addition to ensuring our model was statically determinate, we also ensured the system was in static equilibrium (i.e., zero acceleration). A wind turbine is a machine and thus has moving parts. For our analysis we assumed the wind turbine was not in operation (i.e., the rotor is locked and not moving) and completely immobile. In addition to the dynamic loading that occurs during operation due to rotation of the rotor, a wind turbine and its associated support structure will experience wind loading. Under laminar (parallel even air flow) conditions, this is experienced as a distributed force incident on the tower and turbine that increases in magnitude the further you get from the ground. As we were limited in our ability to experimentally test the effects of such a distributed force and limited to truss analysis techniques, we analyzed two simplified loading cases. Case I was the weight of the rotor and nacelle acting in the negative z direction (Figure 3.2). Based on publically available information, it is approximated that the mass of the nacelle is 1.5 times the mass of the rotor, thus we chose to model the nacelle and rotor as 1.5kg and 1kg masses respectively. Furthermore, the nacelle's center of mass (COM) was located at the xy centroid of the tower, while the rotor's COM was assumed to be some distance offset from the front face of the tower (distance established by measurement of constructed model). For Case II, we added a single horizontal force at one particular joint to simulate the effect of wind loading. Although this situation is a vast simplification of the effect of wind loading, it demonstrates the wind loading effects on member forces local to the applied force and provides some insight on how the system might behave under full loading conditions (when the entire truss towel is subjected to stress forces).

With our assumptions and simplifications in place, our strategies for theoretically determining the member forces present throughout the tower were as follows:

1. Sketch the model showing the forces present and develop a Free Body Diagram (FBD)
2. Determine model parameters as measured from the experimental design model
3. Apply method of joints technique for solving for unknown member forces
    a. Treat each joint as a particle and draw a FBD for each joint
    b. Apply static equilibrium concepts at each joint and write equilibrium equations in the x, y, and z directions
    c. Solve for unknown forces

Due to the sheer volume of equations developed by our approach, MATLAB, a computational solver, was used to solve the set linear equations determined at each tower joint.

CASE I: NACELLE AND ROTOR WEIGHT ONLY

A model of the designed truss tower showing the applied forces due to the nacelle and rotor is shown in **Figure 3.2**.

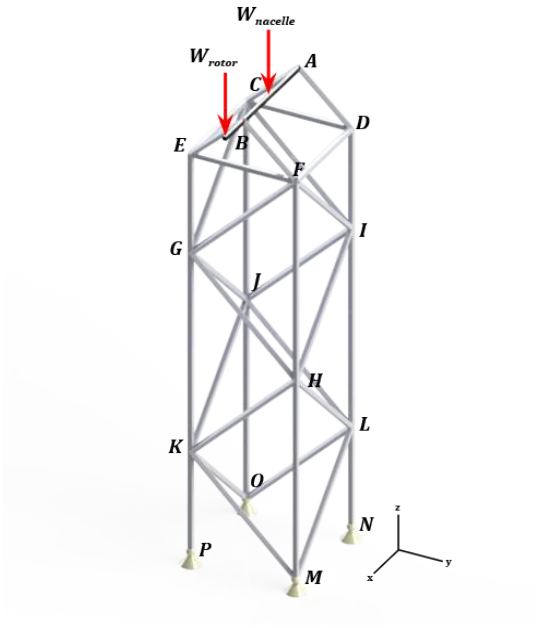

FIGURE 3.2: 3D MODEL OF TRUSS TOWER WITH APPLIED FORCES (CASE I)

The tower joints as labeled are used to identify the structural members of interest. Before proceeding with the method of joints analysis we first removed Member AB and translated the weight forces into an equivalent force system that acts only at Joint A and Joint B. This approach neglects the fact that Member AB could experience bending, which may reduce the actual forces experienced at Joint A and B due to internal forces. However, for the purpose of this analysis, we assumed that the internal forces of the member were negligible and that the systems were sufficiently equivalent. A step-by-step explanation of this process is shown in **Figure 3.3**.

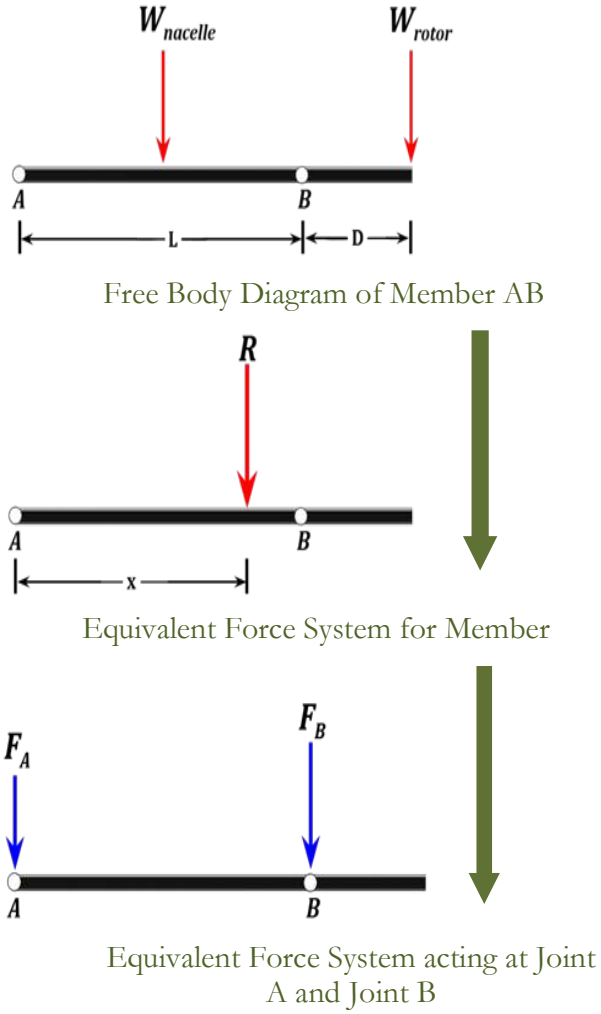

FIGURE 3.3: PROCESS FOR FINDING EQUIVALENT FORCE SYSTEM ACTING AT JOINTS

To determine the values of R, x, F_A, and F_B, we first determined values for the nacelle and rotor weight, and the distances L and D, from our constructed model. These parameter values are shown in **Table 3.1**.

TABLE 3.1: MEASURED PARAMETERS OF MODEL FOR CASE I

Parameter	Measured Value	Measurement Uncertainty
Weight of Nacelle	14.7 N	± 0.05 N
Weight of Rotor	9.8 N	± 0.05 N
L	179mm	± 5mm
D	62mm	± 5mm

Knowing that two systems of forces are equivalent if and only if they produce an equal sum of forces and moments about any point in the system, we can determine the resulting equivalent force, *R* and the point at which it acts, *x*.

$$\sum \vec{F}_{z,System\,1} = \sum \vec{F}_{z,System\,2} \quad (3.2)$$

$$-W_{rotor} - W_{nacelle} = -R \quad (3.3)$$

$$-9.8\ N - 14.7\ N = -24.5\ N \quad (3.4)$$

$$\sum \vec{M}_{A,\,System\,1} = \sum \vec{M}_{A,\,System\,2} \quad (3.5)$$

$$-W_{rotor}\left(\frac{L}{2}\right) - W_{nacelle}(L + D) = -R(x) \quad (3.6)$$

$$-9.8\left(\frac{179}{2}\right) - 14.7(179 + 62) = -24.5(x) \quad (3.7)$$

$$x = 150\ mm \quad (3.8)$$

With *R* and *x* determined, we can distribute this force to Joint A and Joint B based on their respective distances from *R*.

$$F_A = \left(1 - \frac{x}{L}\right)R \quad (3.9)$$

$$F_A = \left(1 - \frac{150}{179}\right)(-24{,}5) = -3.96\ N \quad (3.10)$$

$$F_B = \left(\frac{x}{L}\right)R \quad (3.11)$$

$$F_A = \left(\frac{150}{179}\right)(-24{,}5) = -20.5\ N \quad (3.12)$$

With the rotor and nacelle weight force concentrated at Joints A and B, we revised **Figure 3.2** and included the reactionary forces at Joints M, N, O, and P. The revised figure is shown in **Figure 3.4**.

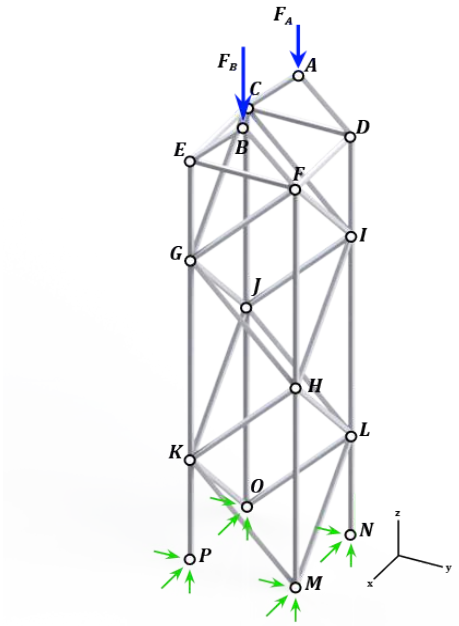

FIGURE 3.4: 3D MODEL OF TRUSS TOWER WITH JOINT FORCES ONLY (CASE I)

With the frame removed, we analyzed the structure as a truss tower. Proceeding with the Method of Joints technique, we treated each joint as a particle and created a free body diagram for the member forces acting at each joint as shown in **Figure 3.5**.

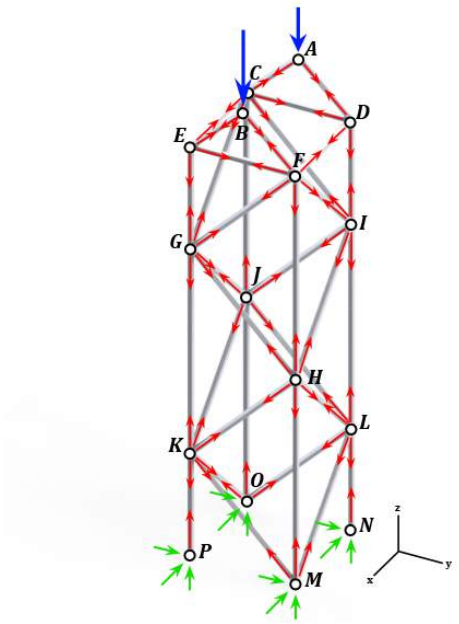

FIGURE 3.5: FREE BODY DIAGRAM OF FORCES ACTING AT EACH JOINT (CASE I)

To determine the unknown member forces and reaction forces, we applied the concept of static equilibrium and wrote equilibrium equations for each joint. The equations utilized for each joint are listed below.

JOINT A

$$\sum F_y = 0: \; T_{AD}\cos 45° - T_{AC}\cos 45° = 0 \tag{3.13}$$

$$\sum F_z = 0: \; -F_A - T_{AD}\sin 45° - T_{AC}\sin 45° = 0 \tag{3.14}$$

JOINT B

$$\sum F_y = 0: \; T_{BF}\cos 45° - T_{BE}\cos 45° = 0 \tag{3.15}$$

$$\sum F_z = 0: \; -F_B - T_{BF}\sin 45° - T_{BE}\sin 45° = 0 \tag{3.16}$$

JOINT C

$$\sum F_x = 0: \; T_{CG}\cos 45° + T_{CE} = 0 \tag{3.17}$$

$$\sum F_y = 0: \; T_{DC} + T_{CI}\cos 45° + T_{AC}\cos 45° = 0 \tag{3.18}$$

$$\sum F_z = 0: \; T_{AC}\sin 45° - T_{CJ} - T_{CG}\sin 45° = 0 \tag{3.19}$$

JOINT D

$$\sum F_x = 0: \; T_{DF} = 0 \tag{3.20}$$

$$\sum F_y = 0: \; -T_{DC} - T_{AD}\cos 45° = 0 \tag{3.21}$$

$$\sum F_z = 0: \; T_{AD}\sin 45° - T_{DI} = 0 \tag{3.22}$$

JOINT E

$$\sum F_x = 0: \; -T_{CE} = 0 \tag{3.23}$$

$$\sum F_y = 0: \; T_{EF} + T_{BE}\cos 45° = 0 \tag{3.24}$$

$$\sum F_z = 0: \; T_{BE}\sin 45° - T_{EG} = 0 \tag{3.25}$$

JOINT F

$$\sum F_x = 0: \; -T_{FI}\cos 45° - T_{DF} = 0 \tag{3.26}$$

$$\sum F_y = 0: \; -T_{EF} - T_{BF}\cos 45° - T_{BF}\cos 45° = 0 \tag{3.27}$$

$$\sum F_z = 0: \; T_{BF}\sin 45° - T_{FH} - T_{FI}\sin 45° - T_{FG}\sin 45° = 0 \tag{3.28}$$

JOINT G

$$\sum F_x = 0: \ -T_{CG}\cos 45° - T_{gj}\cos 45° = 0 \quad (3.29)$$

$$\sum F_y = 0: \ T_{FG}\cos 45° + T_{GH}\cos 45° = 0 \quad (3.30)$$

$$\sum F_z = 0: \ T_{FH} - T_{GK} - T_{GH}\sin 45° + T_{FG}\sin 45° - T_{GJ}\sin 45° + T_{CG}\sin 45° = 0 \quad (3.31)$$

JOINT H

$$\sum F_x = 0: \ -T_{IH}\cos 45° - T_{HL}\cos 45° = 0 \quad (3.32)$$

$$\sum F_y = 0: \ -T_{GH}\cos 45° - T_{HK}\cos 45° = 0 \quad (3.33)$$

$$\sum F_z = 0: \ T_{FH} - T_{MH} + T_{IH}\sin 45° + T_{GH}\sin 45° - T_{HL}\sin 45° - T_{HK}\sin 45° = 0 \quad (3.34)$$

JOINT I

$$\sum F_x = 0: \ T_{IH}\cos 45° + T_{FI}\cos 45° = 0 \quad (3.35)$$

$$\sum F_y = 0: \ -T_{CI}\cos 45° - T_{IJ}\cos 45° = 0 \quad (3.36)$$

$$\sum F_z = 0: \ T_{DI} - T_{IL} + T_{CI}\sin 45° + T_{FI}\sin 45° - T_{IJ}\sin 45° - T_{IH}\sin 45° = 0 \quad (3.37)$$

JOINT J

$$\sum F_x = 0: \ T_{JK}\cos 45° + T_{FI}\cos 45° = 0 \quad (3.38)$$

$$\sum F_y = 0: \ T_{IJ}\cos 45° + T_{JL}\cos 45° = 0 \quad (3.39)$$

$$\sum F_z = 0: \ T_{CJ} - T_{JO} + T_{GJ}\sin 45° + T_{IJ}\sin 45° - T_{JK}\sin 45° - T_{JL}\sin 45° = 0 \quad (3.40)$$

JOINT K

$$\sum F_x = 0: \ -T_{JK}\cos 45° - T_{KO}\cos 45° = 0 \quad (3.41)$$

$$\sum F_y = 0: \ T_{HK}\cos 45° + T_{KM}\cos 45° = 0 \quad (3.42)$$

$$\sum F_z = 0: \ T_{GK} - T_{KP} + T_{JK}\sin 45° + T_{HK}\sin 45° - T_{KO}\sin 45° - T_{KM}\sin 45° = 0 \quad (3.43)$$

JOINT L

$$\sum F_x = 0: \ T_{HL}\cos 45° + T_{LM}\cos 45° = 0 \quad (3.44)$$

$$\sum F_y = 0: \ -T_{JL}\cos 45° - T_{LO}\cos 45° = 0 \quad (3.45)$$

$$\sum F_z = 0: \ T_{IL} - T_{LN} + T_{JL}\sin 45° + T_{HL}\sin 45° - T_{LO}\sin 45° - T_{LM}\sin 45° = 0 \quad (3.46)$$

JOINT M

$$\sum F_x = 0: \; M_x - T_{LM}\cos 45° = 0 \tag{3.47}$$

$$\sum F_y = 0: \; M_y - T_{KM}\cos 45° = 0 \tag{3.48}$$

$$\sum F_z = 0: \; T_{HM} + T_{LM}\sin 45° + T_{KM}\sin 45° + M_z = 0 \tag{3.49}$$

JOINT N

$$\sum F_x = 0: \; N_x = 0 \tag{3.50}$$

$$\sum F_y = 0: \; N_y = 0 \tag{3.51}$$

$$\sum F_z = 0: \; T_{LN} + N_z = 0 \tag{3.52}$$

JOINT O

$$\sum F_x = 0: \; O_x + T_{KO}\cos 45° = 0 \tag{3.53}$$

$$\sum F_y = 0: \; O_y + T_{LO}\cos 45° = 0 \tag{3.54}$$

$$\sum F_z = 0: \; T_{JO} + T_{KO}\sin 45° + T_{LO}\sin 45° + O_z = 0 \tag{3.55}$$

JOINT P

$$\sum F_x = 0: \; P_x = 0 \tag{3.56}$$

$$\sum F_y = 0: \; P_y = 0 \tag{3.57}$$

$$\sum F_z = 0: \; T_{KP} + P_z = 0 \tag{3.58}$$

With 45 equations and 45 unknowns, all the unknown member forces can be determined. Although these calculations could be done by hand, this would be quite tedious and time consuming. Instead, the equations and known values were inputted into MATLAB and the unknown forces solved computationally. A summary of the Case I analysis results are shown in **Table 3.2** along with the uncertainty associated with a measurement uncertainty of ±5mm.

TABLE 3.2: THEORETICAL ANALYSIS RESULTS FOR CASE I

Force	Calculated Force Value (N)	Measurement Uncertainty (N)	Theoretical Value (N)
F_A	3.96	± 0.28	3.96 ± 0.28
F_B	20.54	± 0.28	20.54 ± 0.28
T_{BF}	-14.53	± 0.19	-14.53 ± 0.19
T_{BE}	-14.53	± 0.19	-14.53 ± 0.19
T_{AC}	-2.80	± 0.19	-2.80 ± 0.19
T_{AD}	-2.80	± 0.19	-2.80 ± 0.19
T_{DF}	0.00	± 0.00	0.00 ± 0.00
T_{DC}	1.98	± 0.14	1.98 ± 0.14
T_{DI}	-2.38	± 0.16	-2.38 ± 0.16
T_{CE}	0.00	± 0.00	0.00 ± 0.00
T_{CI}	0.00	± 0.00	0.00 ± 0.00
T_{CJ}	-2.38	± 0.16	-2.38 ± 0.16
T_{CG}	0.00	± 0.00	0.00 ± 0.00
T_{EF}	10.27	± 0.14	10.27 ± 0.14
T_{EG}	-12.36	± 0.16	-12.36 ± 0.16

T_{FI}	0.00	± 0.00	0.00 ± 0.00
T_{FG}	0.00	± 0.00	0.00 ± 0.00
T_{FH}	-12.36	± 0.16	-12.36 ± 0.16
T_{GJ}	0.00	± 0.00	0.00 ± 0.00
T_{GH}	0.00	± 0.00	0.00 ± 0.00
T_{GK}	-12.36	± 0.16	-12.36 ± 0.16
T_{IH}	0.00	± 0.00	0.00 ± 0.00
T_{IJ}	0.00	± 0.00	0.00 ± 0.00
T_{IL}	-2.38	± 0.16	-2.38 ± 0.16
T_{JK}	0.00	± 0.00	0.00 ± 0.00
T_{JL}	0.00	± 0.00	0.00 ± 0.00
T_{JO}	-2.38	± 0.16	-2.38 ± 0.16
T_{HL}	0.00	± 0.00	0.00 ± 0.00
T_{HK}	0.00	± 0.00	0.00 ± 0.00
T_{MH}	-12.36	± 0.16	-12.36 ± 0.16
T_{KO}	0.00	± 0.00	0.00 ± 0.00
T_{KM}	0.00	± 0.00	0.00 ± 0.00
T_{KP}	-12.36	± 0.16	-12.36 ± 0.16
T_{LM}	0.00	± 0.00	0.00 ± 0.00
T_{LO}	0.00	± 0.00	0.00 ± 0.00
T_{LN}	-2.38	± 0.16	-2.38 ± 0.16
N_x	0.00	± 0.00	0.00 ± 0.00
N_y	0.00	± 0.00	0.00 ± 0.00
N_z	2.38	± 0.16	2.38 ± 0.16
O_x	0.00	± 0.00	0.00 ± 0.00
O_y	0.00	± 0.00	0.00 ± 0.00
O_z	2.38	± 0.16	2.38 ± 0.16
M_x	0.00	± 0.00	0.00 ± 0.00
M_y	0.00	± 0.00	0.00 ± 0.00
M_z	12.36	± 0.16	12.36 ± 0.16
P_x	0.00	± 0.00	0.00 ± 0.00
P_y	0.00	± 0.00	0.00 ± 0.00
P_z	12.36	± 0.16	12.36 ± 0.16

CASE II: WIND FORCE ADDED AT JOINT H

The system assumptions established for Case I and equivalent force analysis performed for Member AB remain valid for Case II. However, we added an additional horizontal applied force on the tower to represent lateral wind loading. The force applied was simulated by the gravitational weight of a 1kg mass, or 9.8 N. The force was only applied to Joint H and acted in the negative *x* direction. The experimental setup for this configuration is described in Section 3. A 3D model of Case II is shown in **Figure 3.6**.

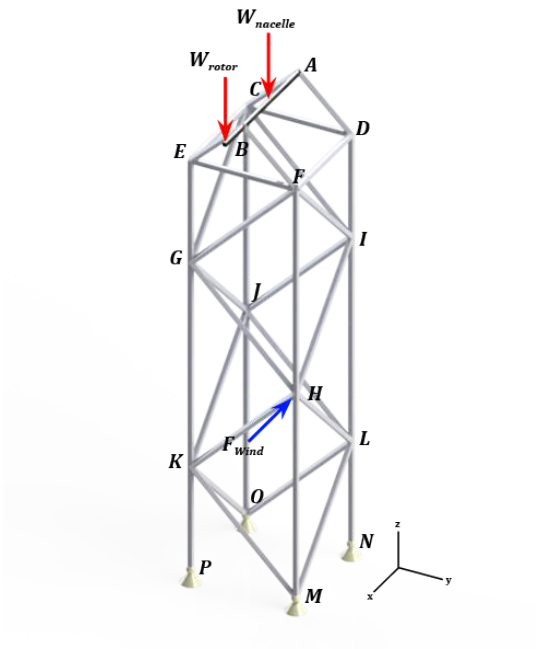

FIGURE 3.6: 3D MODEL OF TRUSS TOWER WITH JOINT FORCES ONLY (CASE II)

The updated free body diagram showing the forces acting at each joint is shown in **Figure 3.7**.

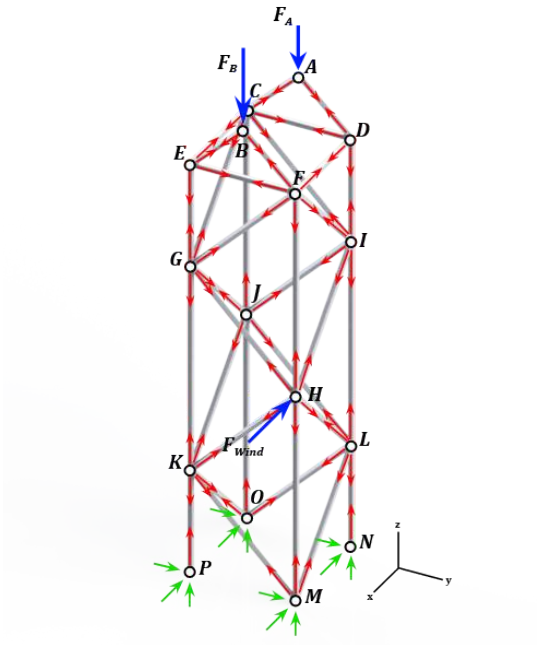

FIGURE 3.7: FREE BODY DIAGRAM OF FORCES ACTING AT EACH JOINT (CASE II)

As seen in **Figure 3.7**, the equilibrium equations determined in Case I were still applicable for Case II, with the exception for Joint H. The wind force was

included in the sum of the forces acting in the x direction. The revised equilibrium equations for Joint H are shown below.

JOINT H

$$\sum F_x = 0: \; -T_{IH}\cos 45° - T_{HL}\cos 45° - F_W = 0 \qquad (3.59)$$

$$\sum F_y = 0: \; -T_{GH}\cos 45° - T_{HK}\cos 45° = 0 \qquad (3.60)$$

$$\sum F_z = 0: \; T_{FH} - T_{MH} + T_{IH}\sin 45° + T_{GH}\sin 45° - T_{HL}\sin 45° - T_{HK}\sin 45° = 0 \qquad (3.61)$$

Again, MATLAB was used to solve the set of updated equations and determine the unknown forces. A summary of the Case II analysis results are shown in **Table 3.3**, along with the uncertainty associated with a dimension measurement uncertainty of 5mm.

TABLE 3.3: THEORETICAL ANALYSIS RESULTS FOR CASE II

Force	Calculated Force Value (N)	Measurement Uncertainty (N)	Theoretical Value (N)
F_A	-3.96	± 0.28	3.96 ± 0.28
F_B	-20.54	± 0.28	20.54 ± 0.28
T_{BF}	-14.53	± 0.19	-14.53 ± 0.19
T_{BE}	-14.53	± 0.19	-14.53 ± 0.19
T_{AC}	-2.80	± 0.19	-2.80 ± 0.19
T_{AD}	-2.80	± 0.19	-2.80 ± 0.19
T_{DF}	0.00	± 0.00	0.00 ± 0.00
T_{DC}	1.98	± 0.14	1.98 ± 0.14
T_{DI}	-2.38	± 0.16	-2.38 ± 0.16
T_{CE}	0.00	± 0.00	0.00 ± 0.00
T_{CI}	0.00	± 0.00	0.00 ± 0.00
T_{CJ}	-2.38	± 0.16	-2.38 ± 0.16
T_{CG}	0.00	± 0.00	0.00 ± 0.00
T_{EF}	10.27	± 0.14	10.27 ± 0.14
T_{EG}	-12.36	± 0.16	-12.36 ± 0.16
T_{FI}	0.00	± 0.00	0.00 ± 0.00
T_{FG}	0.00	± 0.00	0.00 ± 0.00
T_{FH}	-12.36	± 0.16	-12.36 ± 0.16
T_{GJ}	0.00	± 0.00	0.00 ± 0.00
T_{GH}	0.00	± 0.00	0.00 ± 0.00
T_{GK}	-12.36	± 0.16	-12.36 ± 0.16
T_{IH}	0.00	± 0.00	0.00 ± 0.00
T_{IJ}	0.00	± 0.00	0.00 ± 0.00
T_{IL}	-2.38	± 0.16	-2.38 ± 0.16
T_{JK}	0.00	± 0.00	0.00 ± 0.00
T_{JL}	0.00	± 0.00	0.00 ± 0.00
T_{JO}	-2.38	± 0.16	-2.38 ± 0.16
T_{HL}	-13.86	± 27.72	-13.86 ± 27.72
T_{HK}	0.00	± 0.00	0.00 ± 0.00
T_{MH}	-2.56	± 19.76	-2.56 ± 19.76
T_{KO}	0.00	± 0.00	0.00 ± 0.00
T_{KM}	0.00	± 0.00	0.00 ± 0.00
T_{KP}	-12.36	± 0.16	-12.36 ± 0.16
T_{LM}	13.86	± 27.72	13.86 ± 27.72
T_{LO}	0.00	± 0.00	0.00 ± 0.00
T_{LN}	-21.98	± 39.36	-21.98 ± 39.36
N_x	0.00	± 0.00	0.00 ± 0.00
N_y	0.00	± 0.00	0.00 ± 0.00
N_z	21.98	± 39.36	21.98 ± 39.36
O_x	0.00	± 0.00	0.00 ± 0.00
O_y	0.00	± 0.00	0.00 ± 0.00
O_z	2.38	± 0.16	2.38 ± 0.16
M_x	9.80	± 19.60	9.80 ± 19.60
M_y	0.00	± 0.00	0.00 ± 0.00
M_z	-7.24	± 39.36	-7.24 ± 39.36
P_x	0.00	± 0.00	0.00 ± 0.00
P_y	0.00	± 0.00	0.00 ± 0.00
P_z	12.36	± 0.16	12.36 ± 0.16

SUMMARY

A summary of the force values found in Case I and Case II can be found in **Table 3.4**.

TABLE 3.4: SUMMARIZATION OF THEORETICAL VALUES

Force	Case I (N)	Case II (N)	Change in Value (N)
F_A	3.96 ± 0.28	3.96 ± 0.28	-
F_B	20.54 ± 0.28	20.54 ± 0.28	-
T_{BF}	-14.53 ± 0.19	-14.53 ± 0.19	-
T_{BE}	-14.53 ± 0.19	-14.53 ± 0.19	-
T_{AC}	-2.80 ± 0.19	-2.80 ± 0.19	-
T_{AD}	-2.80 ± 0.19	-2.80 ± 0.19	-
T_{DF}	0.00 ± 0.00	0.00 ± 0.00	-
T_{DC}	1.98 ± 0.14	1.98 ± 0.14	-
T_{DI}	-2.38 ± 0.16	-2.38 ± 0.16	-
T_{CE}	0.00 ± 0.00	0.00 ± 0.00	-
T_{CI}	0.00 ± 0.00	0.00 ± 0.00	-
T_{CJ}	-2.38 ± 0.16	-2.38 ± 0.16	-
T_{CG}	0.00 ± 0.00	0.00 ± 0.00	-
T_{EF}	10.27 ± 0.14	10.27 ± 0.14	-
T_{EG}	-12.36 ± 0.16	-12.36 ± 0.16	-
T_{FI}	0.00 ± 0.00	0.00 ± 0.00	-
T_{FG}	0.00 ± 0.00	0.00 ± 0.00	-
T_{FH}	-12.36 ± 0.16	-12.36 ± 0.16	-
T_{GJ}	0.00 ± 0.00	0.00 ± 0.00	-

T_{GH}	0.00 ± 0.00	0.00 ± 0.00	-
T_{GK}	-12.36 ± 0.16	-12.36 ± 0.16	-
T_{IH}	0.00 ± 0.00	0.00 ± 0.00	-
T_{IJ}	0.00 ± 0.00	0.00 ± 0.00	-
T_{IL}	-2.38 ± 0.16	-2.38 ± 0.16	-
T_{JK}	0.00 ± 0.00	0.00 ± 0.00	-
T_{JL}	0.00 ± 0.00	0.00 ± 0.00	-
T_{JO}	-2.38 ± 0.16	-2.38 ± 0.16	-
T_{HL}	0.00 ± 0.00	-13.86 ± 27.72	**13.86**
T_{HK}	0.00 ± 0.00	0.00 ± 0.00	-
T_{MH}	-12.36 ± 0.16	-2.56 ± 19.76	**-9.80**
T_{KO}	0.00 ± 0.00	0.00 ± 0.00	-
T_{KM}	0.00 ± 0.00	0.00 ± 0.00	-
T_{KP}	-12.36 ± 0.16	-12.36 ± 0.16	-
T_{LM}	0.00 ± 0.00	13.86 ± 27.72	**-13.86**
T_{LO}	0.00 ± 0.00	0.00 ± 0.00	-
T_{LN}	-2.38 ± 0.16	-21.98 ± 39.36	**19.60**
N_x	0.00 ± 0.00	0.00 ± 0.00	-
N_y	0.00 ± 0.00	0.00 ± 0.00	-
N_z	2.38 ± 0.16	21.98 ± 39.36	**-19.60**
O_x	0.00 ± 0.00	0.00 ± 0.00	-
O_y	0.00 ± 0.00	0.00 ± 0.00	-
O_z	2.38 ± 0.16	2.38 ± 0.16	-
M_x	0.00 ± 0.00	9.80 ± 19.60	**-9.80**
M_y	0.00 ± 0.00	0.00 ± 0.00	-
M_z	12.36 ± 0.16	-7.24 ± 39.36	**19.60**
P_x	0.00 ± 0.00	0.00 ± 0.00	-
P_y	0.00 ± 0.00	0.00 ± 0.00	-
P_z	12.36 ± 0.16	12.36 ± 0.16	-

METHODS: MATERIALS

The materials used to construct and perform the experiment are listed below with quantities in parenthesis.

- PASCO Advanced Structures Set (1)
- PASCO 100N Load Cell – PS2200 (3)
- PASCO Load Cell Amplifier – PS2198 (1)
- PASCO USB Link – PS2100 (1)
- PASCO Data Studio Software Suite (1)
- Logger Pro Data Analysis Software(1)
- 1000g mass (2)
- 500g mass (1)

SETUP

The designed truss tower structure was constructed using the PASCO Advanced Structure Set. Using simple triangle geometry, a 72cm tall, four-sided tower was constructed, which included an 8cm tall triangular top section. In addition to the vertical members, 24cm long diagonal cross members were added between every other joint. Across the top tower joints (Joints A and B as defined previously), a metal rod was placed through the center of each joint component. The geometry of the tower can be seen in **Figure 3.1**. To simulate the weight of the nacelle, a 1kg and 0.5kg mass was hooked in the center of the metal rod (Member AB). The weight of the rotor was simulated by a 1kg mass connected near the end of the rod (Member AB), approximately 62mm from Joint B. To measure member forces, load cells were placed in-between the particular member of interest. Since we had only three load cells, they were periodically moved to various locations throughout experimentation. The load cells were connected to the PASCO Load Cell Amplifier, which then connected to a computer via the PASCO USB Link. Data Studio was used to calibrate the sensors and collect data. An image of the experimental setup showing key model components is shown in **Figure 4.1**.

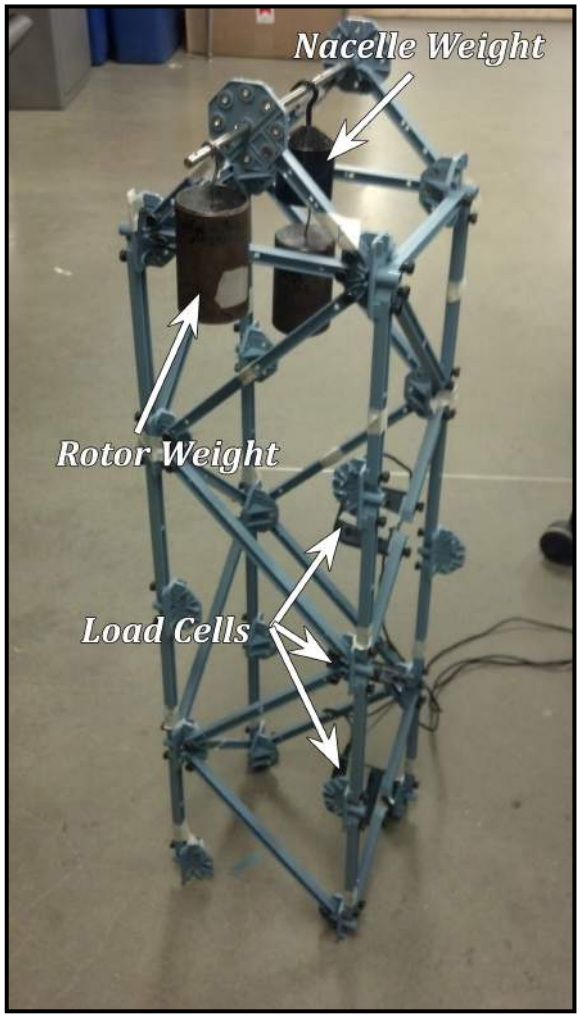

FIGURE 4.1: EXPERIMENTAL SETUP (CASE I)

EXECUTION

Before commencing with any data collection, the load cell sensors were calibrated using Data Studio and the 1kg mass in accordance with load cell manual instructions. Three member forces of interest were chosen and replaced with load cells. For Case I, data collection was begun and after a short time the nacelle and rotor masses were applied. Approximately 30 to 40 seconds of data were collected. The load cells were then relocated on three different members and data were collected again. This was completed for twelve different members. Next, for Case II, a pulley system was set up so that a 1kg mass could be applied to a cable such that the tension would be transferred and applied horizontally to Joint H. The nacelle and rotor masses remained and were applied in the exact same location as in Case I. The load cells were connected along Members IH, HL, and LM, which are diagonal members along the xz plane located near Joint H. Data were collected as before beginning with no applied force, then adding the forces a few seconds into collection. During data collection, the tower was firmly held in place at the bottom joints. This was critical as the theoretical analysis assumed these joints to be completely fixed. The experimental setup for this configuration is shown in **Figure 4.2**.

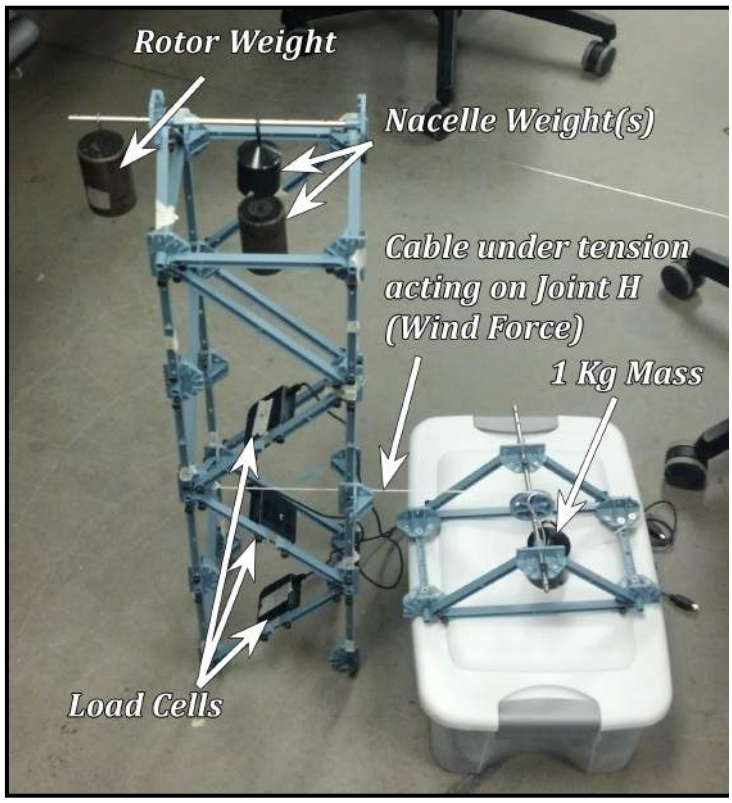

FIGURE 4.2 EXPERIMENTAL SETUP (CASE II)

To analyze the data and determine the experimental values for the measured forces, the data were exported from Data Studio and imported into Logger Pro. Using data analysis tools, mean values and standard deviations were found for each data set in each case. To better visualize the data and choose the most appropriate points, graphs were created.

RESULTS

Fifteen member forces were measured and graphed (twelve for Case I and three for Case II). The data were broken into the following sub-sections: Top Members (Case I), Horizontal Members (Case I),

Vertical Members (Case I), Diagonal Members (Case I), and Diagonal Members (Case II). Refer to **Figure 3.2** for identifying referenced member locations.

TOP MEMBERS (CASE I)

Top members include the applied weight forces acting on Joints A and B and the short diagonal members extending from these joints. **Figure 5.1** and **Figure 5.2** below show the measured force vs. time for F_A and F_B.

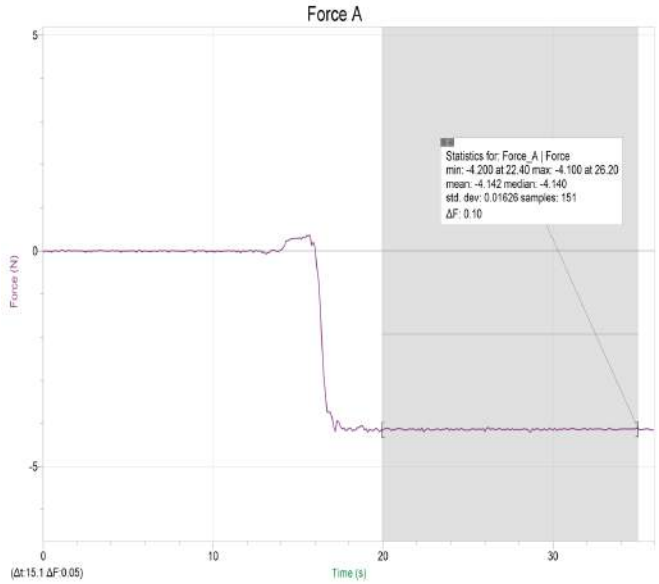

FIGURE 5.1: FORCE VS. TIME FOR F_A

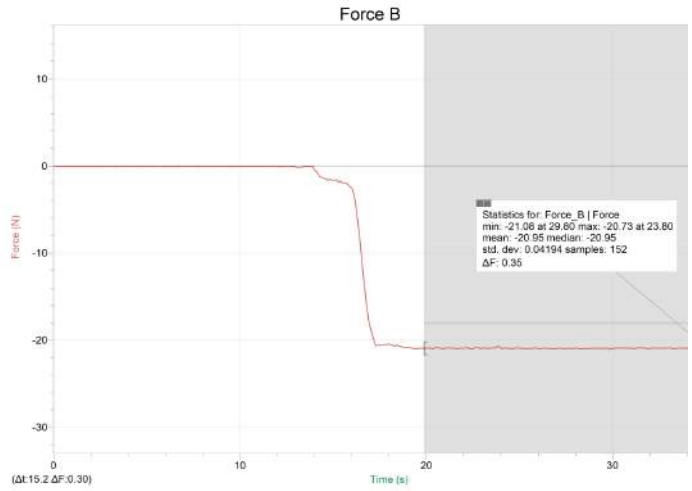

FIGURE5.2: FORCE VS. TIME FOR F_B

As seen from the graphs above, data were collected for approximately 15 seconds before applying the nacelle and rotor masses and an additional 20 seconds with the weights applied. The graphs show a mean value for F_A and F_B of -4.14 ± 0.02 and = -20.95 ± 0.04, respectively. These values are negative since the force is acting in the negative direction. For comparison proposes, however, we are only concerned with the absolute value.

In addition to the applied force on the top structure, the force T_{AC}, experienced by Member AC, and the force T_{BF}, experienced by Member BF, is shown below in **Figure 5.3** and **Figure 5.4**.

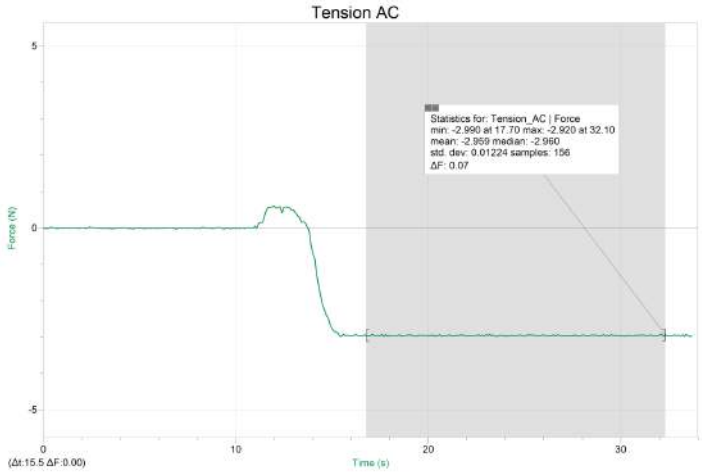

FIGURE 5.3: FORCE VS. TIME FOR MEMBER AC

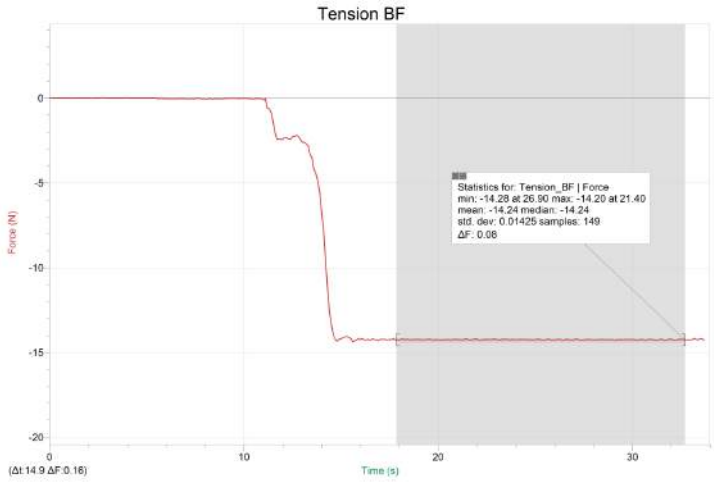

FIGURE 5.4: FORCE VS. TIME FOR MEMBER BF

The mean values found for T_{AC} and T_{BF} are -2.96 ± 0.01 N and -14.24 ± 0.01 N, respectively.

HORIZONTAL MEMBERS (CASE I)

The horizontal members include the four top members that connect horizontally between Joints C,

D, E, and F. However, only Member EF and Member DC were measured experimentally. Graphs of the measured data are shown below in **Figure 5.5** and **Figure 5.6**.

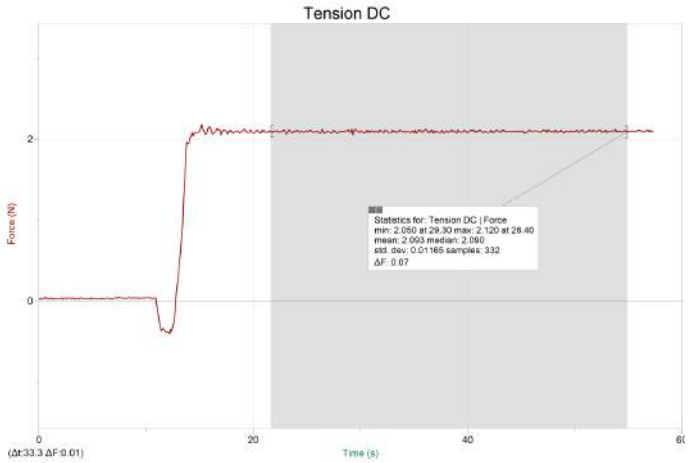

FIGURE 5.5: FORCE VS. TIME FOR MEMBER DC

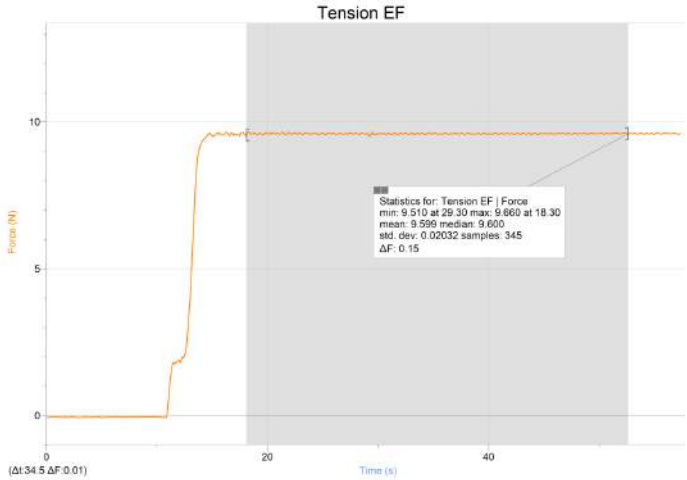

FIGURE 5.6: FORCE VS. TIME FOR MEMBER EF

The mean values found for T_{DC} and T_{EF} are 2.09 ± 0.01 N and 9.60 ± 0.02 N, respectively.

VERTICAL MEMBERS (CASE I)

Vertical members include the members that make up the four vertical legs of the structure. There are ten total vertical members and the tension forces present in Members CJ, EG, and MH were measured experimentally. Graphs of the measured forces vs. time are shown below in **Figure 5.7**, **Figure 5.8**, and **Figure 5.9**.

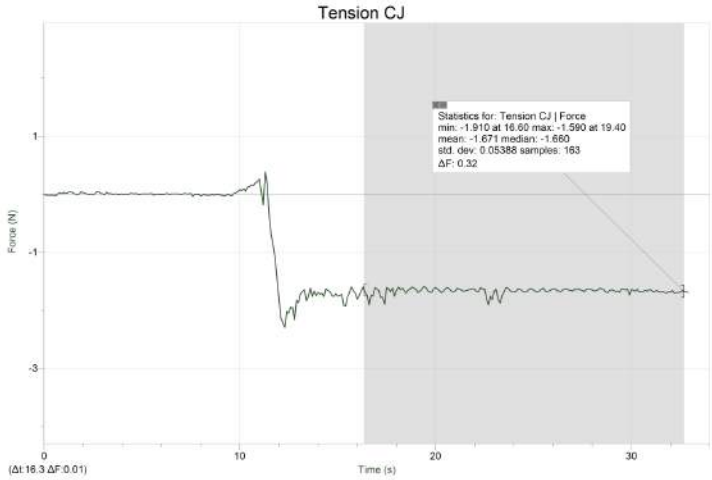

FIGURE 5.7: FORCE VS. TIME FOR MEMBER CJ

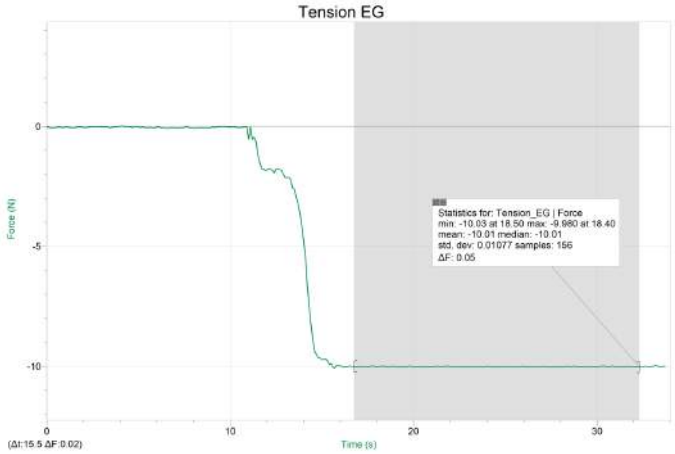

FIGURE5.8: FORCE VS. TIME FOR MEMBER EG

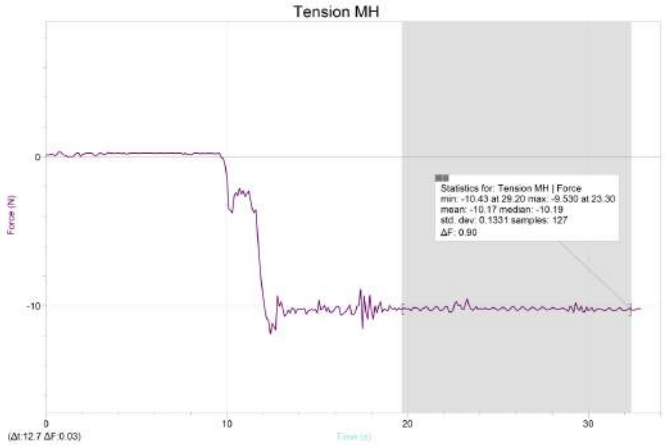

FIGURE5.9: FORCE VS. TIME FOR MEMBER MH

The mean values found for T_{CJ}, T_{EG}, and T_{MH} are -1.67 ± 0.05 N, -10.01 ± 0.01 N, and -10.17 ± 0.13 N, respectively.

DIAGONAL MEMBERS (CASE I)

Diagonal members include the members connected diagonally between the vertical legs of the tower. There are 16 total diagonal members (four per side) and the tension forces present in Members IH, HL, and LM were measured experimentally. Graphs of the measured tension forces vs. time are shown below in **Figure 5.10**, **Figure 5.11**, and **Figure 5.12**.

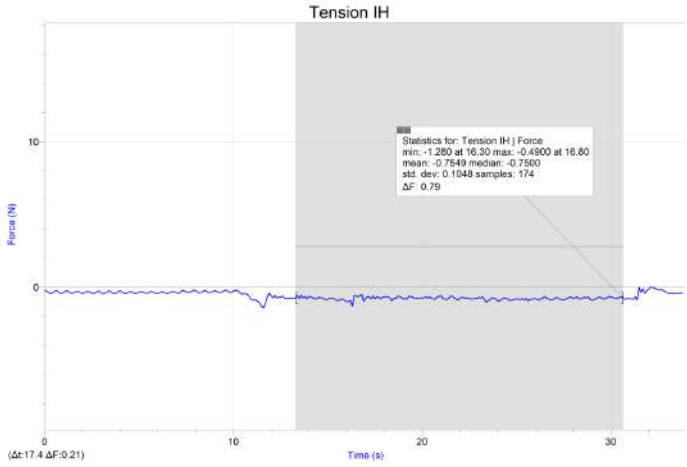

FIGURE 5.10: FORCE VS. TIME FOR MEMBER IH

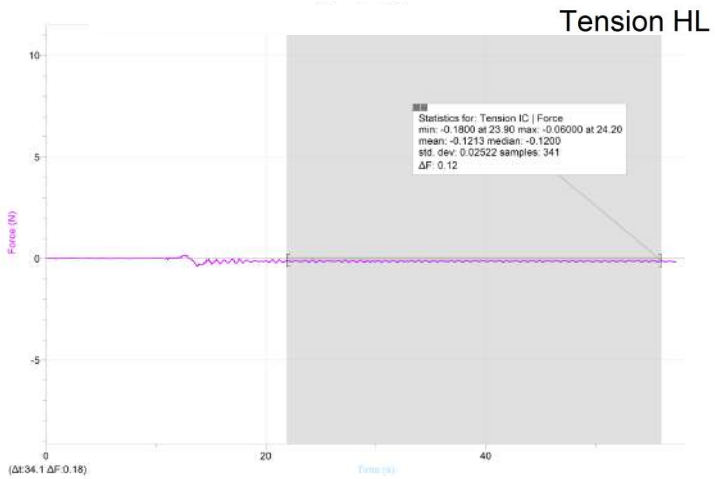

FIGURE5.11: FORCE VS. TIME FOR MEMBER HL

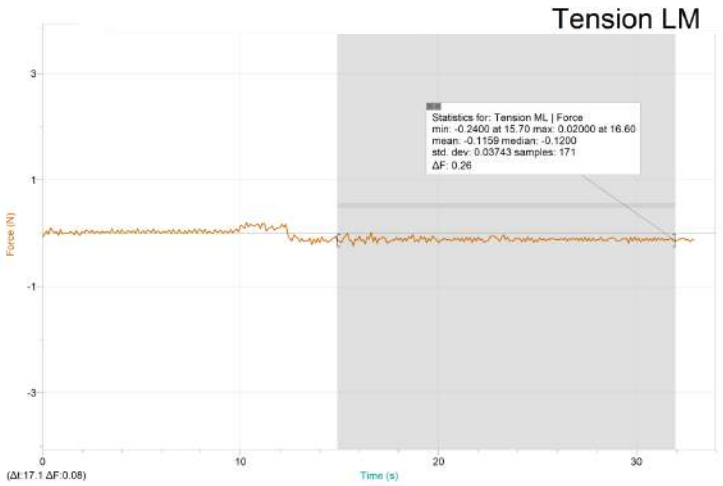

FIGURE 5.12: FORCE VS. TIME FOR MEMBER LM

The mean values found for T_{IH}, T_{HL}, and T_{LM} are -0.75 ± 0.10 N, -0.12 ± 0.03 N, and -0.12 ± 0.04 N, respectively.

A summary of the data analysis for Case I is shown in **Table 5.1**.

TABLE 5.1: ANALYSIS RESULTS FROM CASE I

Force	Avg. Force Value (N)	Data Uncertainty (N)	Load Cell Accuracy (N)[2]	Experimental Value (N)
F_A	-4.14	± 0.02	± 1	-4.14 ± 1.02
F_B	-20.95	± 0.04	± 1	-20.95 ± 1.04
				-2.96 ± 1.01
T_{BF}	-14.24	± 0.01	± 1	-14.24± 1.01
T_{DC}	2.09	± 0.01	± 1	2.09 ± 1.01
T_{EF}	9.60	± 0.02	± 1	9.60 ± 1.02
T_{CJ}	-1.67	± 0.05	± 1	-1.67 ± 1.05
T_{EG}	10.01	± 0.01	± 1	10.01 ± 1.01
T_{MH}	-10.17	± 0.13	± 1	-10.17± 1.13
T_{IH}	-0.75	± 0.10	± 1	-0.75 ± 1.10
T_{HL}	-0.12	± 0.03	± 1	-0.12 ± 1.03
T_{LM}	-0.12	± 0.04	± 1	-0.12 ± 1.04

DIAGONAL MEMBERS (CASE II)

The diagonal members measured for Case II are the same as measured in Case I and were chosen to

demonstrate the impact of a lateral force at Joint H. Graphs of the measured tension forces for Members IH, HL, and LM are shown below in **Figure 5.13**, **Figure 5.14**, and **Figure 5.15**.

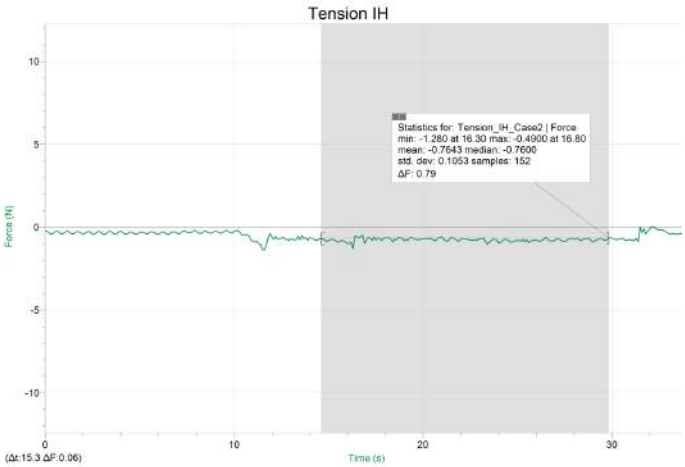

FIGURE 5.13: FORCE VS. TIME FOR MEMBER IH (CASE II)

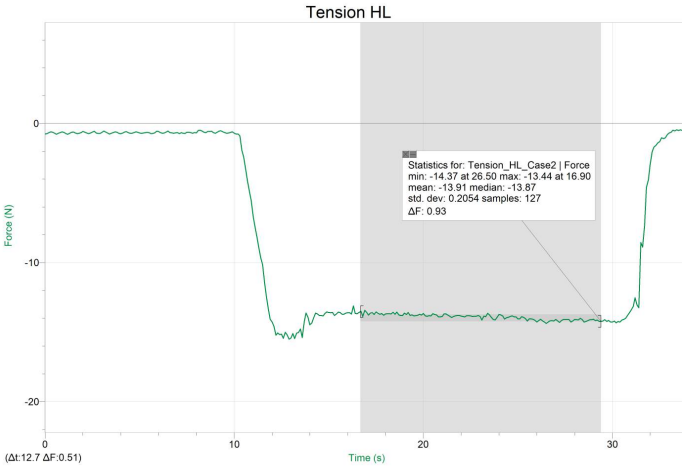

FIGURE 5.14: FORCE VS. TIME FOR MEMBER HL (CASE II)

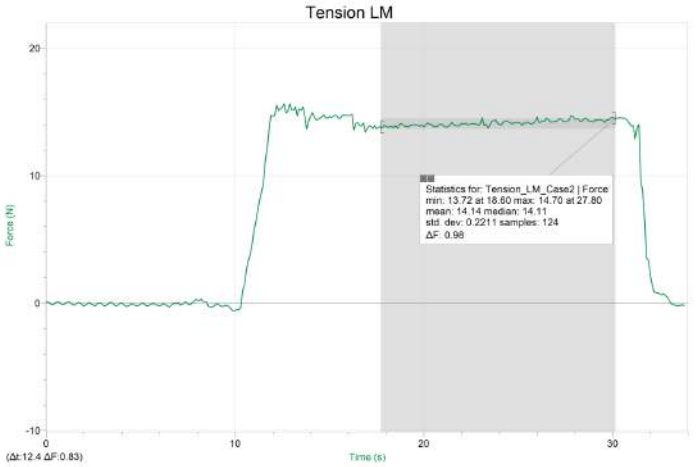

FIGURE 5.15: FORCE VS. TIME FOR MEMBER LM (CASE II)

The mean values found for T_{IH}, T_{HL}, and T_{LM} in Case II are -0.76 ± 0.10 N, -13.91 ± 0.21 N, and 14.14 ± 0.22 N, respectively.

A summary of the data analysis for Case II is shown in **Table 5.2**.

TABLE 0.2: ANALYSIS RESULTS FROM CASE II

Force	Avg. Force Value (N)	Data Uncertainty (N)	Load Cell Accuracy (N)[2]	Experimental Value (N)
T_{IH}	-0.76	± 0.10	± 1	-0.73± 1.10
T_{HL}	-13.91	± 0.21	± 1	-13.91± 1.21
T_{LM}	14.14	± 0.22	± 1	14.14± 1.22

A summary and comparison of the experimental and theoretical results are shown in **Table 5.3**.

TABLE 5.3: COMPARISON OF THEORETICAL AND EXPERIMENTAL ANALYSIS RESULTS

	Force	Theoretical Value (N)	Experimental Value (N)	Percent Difference (%)
CASE I	F_A	3.96 ± 0.28	4.14 ± 1.02	4.5%
	F_B	20.54 ± 0.28	20.95 ± 1.04	4.5%
	T_{AC}	-2.80 ± 0.19	-2.96 ± 1.01	5.8%
	T_{BF}	-14.53 ± 0.19	-14.24 ± 1.01	2.0%

	T_{DC}	1.98 ± 0.14	2.09 ± 1.01	5.7%
	T_{EF}	10.27 ± 0.14	9.60 ± 1.02	6.5%
	T_{CJ}	-2.38 ± 0.16	-1.67 ± 1.05	29.8%
	T_{EG}	-12.36 ± 0.16	-10.01 ± 1.01	19%
	T_{MH}	-12.36 ± 0.16	-10.17 ± 1.13	17.7%
	T_{IH}	0.00 ± 0.00	-0.75 ± 1.10	-
	T_{HL}	0.00 ± 0.00	-0.12 ± 1.03	-
	T_{LM}	0.00 ± 0.00	-0.12 ± 1.04	-
CASE II	T_{IH}	0.00 ± 0.00	-0.73 ± 1.10	-
	T_{HL}	-13.86 ± 27.72	-13.91 ± 1.21	0.4%
	T_{LM}	13.86 ± 27.72	14.14 ± 1.22	2.0%

DISCUSSION

All experimental findings were congruent with theoretical expectations within the measure of uncertainty. For example, in both cases where T_{AC} was calculated to be -2.80 ± 0.19 N, experimental data from Case I showed the actual force to be -2.96 ± 1.01 N. This would indicate that the theoretical tower was accurately analyzed as a truss and frame system and accurately modeled using the structure constructed. It also shows that analysis by method of joints was an effective and accurate theoretical approach.

Case I found support forces in only the vertical members, due to the downward force of the weight of the nacelle and rotor due to gravity. The joints located toward the front of the nacelle showed greater support reactions than members located toward the back. T_{EG} (a vertical member located towards the rotor) supported a force of -12.36 ± 0.16 N (theoretical) and -10.01 ± 1.01 N (experimental), larger than T_{CJ} (a vertical member located away from the rotor), which experienced compression forces of -2.38 ± 0.16 N (theoretical) and -1.67 ± 1.05 N (experimental).

In Case I, all diagonal members were zero force members, for example T_{HL} = 0 N (theoretical) and -0.12 ± 1.03 N (experimental). Although these members did not support any of the load, they are still critical in the design. The diagonal members act as reinforcements if any structural failure were to occur.

Case II, which incorporated a horizontal force idealized as a single force on a single joint, showed significant impact on the diagonal joints below the joint where the force was applied, such as at T_{HL} (-13.86 N, (theoretical) and -13.91 ± 1.21 N (experimental)). Intuitively, it is surprising to see that the diagonal member extending upward (T_{HI}) from this joint did not share the load distribution from the force. Experimental data in Case I shows the member experiencing essentially zero force (-0.76 ± 1.11 N); however, Case II (with horizontal force) also showed this member to be a zero force member (-0.75 ± 1.10 N). The similarity between these numbers indicates that the horizontal force had no effect on the loading of this member. The only diagonal member extending from this joint supporting the force was the diagonal member extending downward (T_{HL}). Theoretically, this is expected when utilizing a top-down analysis such as method of joints. Being that the top of the structure contained no support forces in the $x\chi$ plane, analysis at Joint I supports the finding that T_{HI} would be zero.

Loads on vertical members did not differ based on their relative height in the tower. A member located towards the bottom of the tower, T_{MH}, and a member located towards the top of the tower T_{EG} supported nearly identical forces. This indicates that the tower, in theory, could be built at extreme heights with little deviation in the maximum force load, however, greater heights would increase wind loading and weight of the members themselves.

The greatest obstacle during experimentation was creating a way to apply both vertical and horizontal forces. The pulley system described in the method section was a successful tool in completing this task. No other obstacles were faced and the data were sufficiently precise and accurate through meticulous and constant calibration of load cells. Although results showed no significant difference between theoretical and experimental data, there are still possible sources of error. One source of error is that members are not perfectly rigid although analyzed to be. This increases the potential for member flex and internal forces that were not incorporated into theoretical analysis.

Findings indicate that several considerations should be taken into account during maximum load analysis. Being that the vertical members support the most force, they are most susceptible to buckling. They are also typically the longest, which decreases their strength and therefore the maximum load they can bear. This is yet another reason why diagonal members are crucial to the design. Although they are zero-members during non-

wind conditions, they aid in increasing the buckling limit of the vertical members, allowing for a larger load to be supported. Secondly, the load is more concentrated in the members located underneath the front of the nacelle, and so due to the changing orientation of the nacelle all members must be optimized to support the changing load. Uneven distribution of weight on the tower also creates possible over-turning moments experienced at base supports, requiring special foundation considerations. Wind conditions increase the load experienced by vertical members and changes diagonal members from zero-force members to load-bearing members. It is crucial to take into account the maximum wind conditions expected given the location of the turbine.

Further analysis could include the internal stress, shear, and torsion of members. It is predicted that internal force analysis would show more deviation due to the large size of each member. It would also be fruitful to complete a sustainability analysis incorporating cost and strength of material. A dynamics approach to analysis is also a worthwhile investigation, being that most significant wind turbine tower loading occurs during dynamic conditions such as high variable wind (i.e., extreme gusts), as well vibrations caused from internal mechanisms of the system itself.

REFERENCES

1. "100N Load Cell - PS-2200 : PASCO," Accessed September 2013, http://www.pasco.com/prodCatalog/PS/PS-2200_100-n-load-cell/#specificationsTab.

2. Michael Plesha, Gary Gray, and Francesco Costanzao, *Engineering Machanics: Statics* (New York: McGraw-Hill, 2013).

SCHOLARS' DAY
REVIEW
VOLUME 2

Determining the Effectiveness of Container Lids on Heat Absorption: Measuring Heat of Reaction for NaOH(aq) and HCl(aq)

Christine L. Burton

Faculty Sponsor: Prof. Amy E. Irwin (Chemistry)

ABSTRACT

In the General Chemistry I laboratory at Monroe Community College, students combine a strong base, 1.0M $NaOH_{(aq)}$, with a strong acid, 1.0M $HCl_{(aq)}$, to assess the temperature change of the solution as a result of the chemical reaction. The temperature change of the solution is used to calculate the heat of solution. The reaction is carried out in a Styrofoam cup with a wooden lid to retain heat as per experimental protocol. We assessed whether different lid composites would influence the heat of solution generated in the vessel during an experiment. There were four conditions to the experiment: (1) Control - no lid, (2) wood lid, (3) wood lined with Styrofoam lid and (4) Plexiglas lid. Thirty trials were run for each condition of the experiment. The mean heat of solution was significantly higher ($p < 0.05$) for Condition 1 (no lid) than Condition 2 (wood lid) or Condition 4 (Plexiglas lid). There was not a significant difference ($p > 0.05$) in the mean heat of reaction between Condition 1 and Condition 3 (wood with Styrofoam lined lid). Our results suggest that a lid is no better at retaining the heat of solution than no lid which supports the removal of the lid from the experiment.

Editor's note: Christine Burton won a 1st place scholarship award at the 2014 Scholars' Day for her presentation on this topic.

MLA Citation
Burton, Christine L. "Determining the Effectiveness of Container Lids on Heat Absorption: Measuring Heat of Reaction for NaOH(aq) and HCl(aq)." *Scholars' Day Review* 2 (2014): 27-31. Web. Date of access

Determining the Effectiveness of Container Lids on Heat Absorption: Measuring Heat of Reaction for NaOH(aq) and HCl(aq)

One experiment performed by Monroe Community College (MCC) students in General Chemistry I is experiment 8A "Chemical Change and Energy: What Fuel Makes the Best Energy Source? – Part I: reaction of aqueous sodium hydroxide and aqueous hydrochloric acid" (Monroe Community College Department of Chemistry and Geosciences, 2014.). In the lab procedure, students combine hydrochloric acid and sodium hydroxide in a 250 mL Styrofoam coffee cup to form sodium chloride and water. The neutralization reaction releases heat, which causes a temperature change. The temperature change is calculated and used to determine heat of solution.

Balanced equation:

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + heat$

The laboratory protocol calls for a lid on the cup. It is thought that placing a lid on the reaction vessel would retain heat – an intuitive assumption. Our experimental question is whether covering the reaction vessel during the experiment actually retains a significant amount of heat, and therefore has an impact on the calculation of heat of solution.

PURPOSE

The purpose of our experiment was to assess the efficacy of a lid on a reaction vessel in retaining heat during a chemical reaction between $HCl_{(aq)}$ and $NaOH_{(aq)}$. Three different lid composites were tested and the results of those tests were compared to the results of tests on vessels without a lid. Data from this experiment will be used to recommend elimination or retention of a lid in the laboratory experiment.

METHODS

Solutions and equipment

Solutions used for this experiment included 25mL of 1 molar aqueous sodium hydroxide (NaOH) and 20 mL of 1 molar aqueous hydrochloric acid (HCl). The volumes used were based on the protocol from the original laboratory experiment performed by students. The $HCl_{(aq)}$ acts as the limiting reactant. Equipment included a 250 mL Styrofoam cup as our reaction vessel, magnetic stir bar, magnetic stirring platform, temperature probe, and three types of lids. This set-up is typically referred to as a "coffee cup calorimeter," as shown in Figure 1.

Figure 1: Coffee cup calorimeter setup

Design

There were four conditions (variations) to this experiment. Condition 1: no lid (control), Condition 2: wood lid, Condition 3: wood lined with Styrofoam lid, and Condition 4: Plexiglas lid. These lids were chosen because they are commonly used at MCC in calorimeter experiments. Thirty trials of the experiment were performed for each condition.

Procedure

For each trial of the experiment, 25 mL of the $NaOH_{(aq)}$ was measured using a graduated cylinder and added to the Styrofoam cup containing a magnetic stir bar. The magnetic stirrer was turned on low. A lid was selected, placed on the cup, and a temperature probe

inserted into the cup through a hole in the lid. Using Logger *Pro* software (Vernier Software & Technology, 2013), the temperature of the $NaOH_{(aq)}$ was recorded with the temperature probe until it stabilized. Then the 20mL of $HCl_{(aq)}$ was added and the temperature was recorded until it again stabilized. The lid and temperature probe had to be removed to add the $HCl_{(aq)}$. During the Condition 1 experiment, $HCl_{(aq)}$ was simply poured into the cup. After the reaction was complete, the software calculated initial and final temperatures of the reaction.

Figure 2 shows a Logger *Pro* display used to record the temperature and calculate the initial and final temperatures of the reaction. The first part of the line (A) indicates the temperature of $NaOH_{(aq)}$ before adding the $HCl_{(aq)}$. Point B is where the $HCl_{(aq)}$ was added. The temperature rises sharply upwards, indicating the reaction is taking place. The flat line at the top (C) indicates the reaction is complete and the temperature is again stabilized. Equations of the top and bottom lines were calculated by the software and used to determine the initial and final temperatures of the solution. This information is displayed in box D. Additionally, temperature information can be read from the data chart on the left (E).

Calculations

During this experiment, the change in temperature of the reaction was used to calculate the heat of solution using the following equation: $q_{solution} = mc\Delta T$. Because the acid and base are aqueous solutions, meaning the ions of the acid and base are surrounded by water, the properties of the solutions are similar to water. Considering the significant figures and concentrations of solutions used in this study, the difference in densities between water and the $HCl_{(aq)}$ and $NaOH_{(aq)}$ solutions are not significant. Since there are 45 milliliters of solution, the density of water (1.0 g/mL) was used to determine that the mass (m) of the solution is 45 grams. Additionally, the specific heat of the solution (a measure of how much energy is needed to raise the temperature of a substance) is the same as pure water. The specific heat of water and the solution is 4.184 Joules per gram degree Celsius. The change in temperature (ΔT) was determined from the Logger *Pro* software as described above. When mass, specific heat, and change in temperature are multiplied together, the result is the heat of solution in Joules.

Subsequent calculations and analysis for this experiment are based on the heats of solution as determined by this formula. During the lab experiment, students use the heat of solution to determine the heat of reaction. Since the energy absorbed by the solution (the surroundings) is equal to the heat given off by the reaction (the system), the heat of solution is equal to negative heat of reaction ($q_{solution} = -q_{reaction}$). Students then use the heat of reaction to estimate the enthalpy of reaction: heat of reaction divided by moles of product (water) as demonstrated in the following equation: $\Delta H \cong q_{reaction}/\text{moles of product}$.

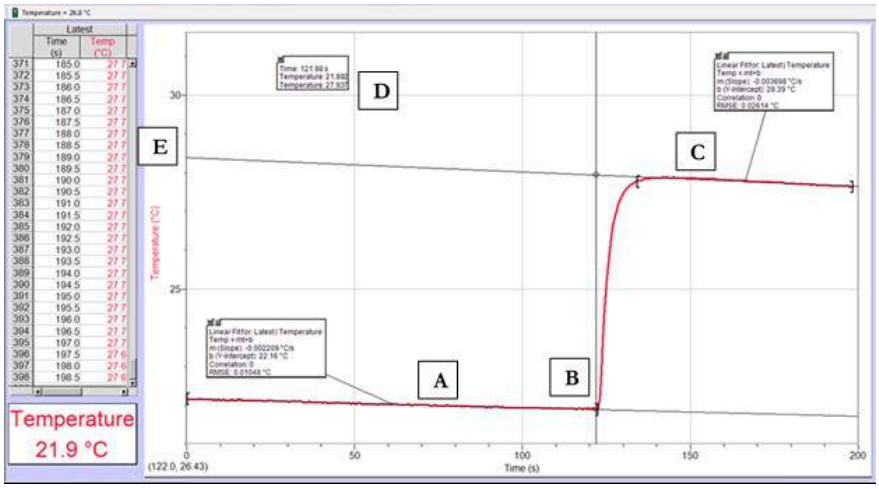

Figure 2: Logger Pro display

A hypothesis test was created and the Student's t-distribution was used to determine if the mean heats of solution for the three different lids were significantly different from the heat of solution when using no lid. A two-sample t-test was performed using Minitab 16 (Minitab Inc., 2013) with an alpha (level of significance) of 0.05.

DATA AND RESULTS

Figure 3 shows the mean heat of solution by lid type, as well as the standard deviations. Using no lid resulted in the highest heat of solution, followed by the Styrofoam wood lid, then the wood lid, and finally the Plexiglas lid. Figure 3 also illustrates that the variability in the results were similar for no lid and the wood lid, slightly higher for the Styrofoam wood lid, and even higher for the Plexiglas lid.

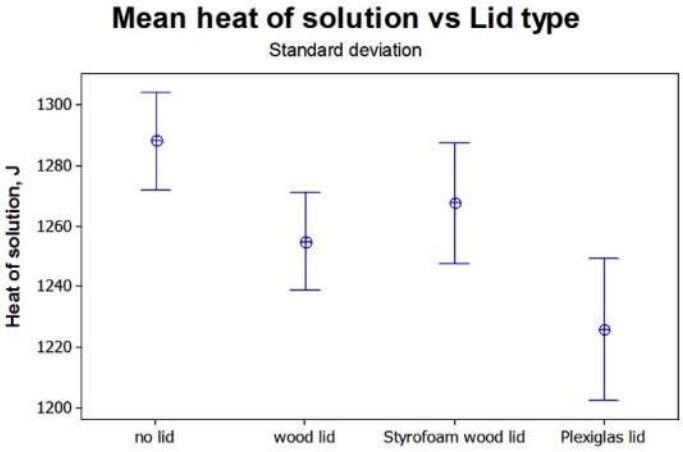

Figure 3: Heats of solution and standard deviations

The data and results are summarized in Table 1. In addition to the mean heats of solution and standard deviations as shown in Figure 3, the percent deviation shows that using no lid produced the least variability in heats of solution. The variability may be due to the difficulty in removing the lids to add the $HCl_{(aq)}$. The lid is not on the calorimeter for the same amount of time for each trial of the experiment, which introduces another variable.

There was no significant difference in the mean heat of solution generate by Condition 1 (no lid) and Condition 3 (wood Styrofoam lid; $p > 0.05$). The mean heat of solution generated by Condition 1 (no lid) was significantly higher than for Condition 2 (wood lid) and Condition 4 (Plexiglas lid; $p < 0.05$).

CONCLUSION

The highest mean temperatures of solution, and most consistent results, were attained when performing the experiment without a lid. Experiments performed with the wood lid (Condition 2) and Plexiglas lid (Condition 4) showed higher variability in results and statistically significant lower mean heat of solution values than the results of experiments without a lid. Although there was no significant difference in the mean heat of solution between a wood lid lined with Styrofoam (Condition 3) and no lid, the results using a wood lid lined with Styrofoam showed a higher degree of variability. These results support a proposal to eliminate the lid from the experiment.

The results of our experiment were not expected. We assumed, through personal experiences, that placing a lid on a vessel containing a heat-generating chemical reaction would retain the heat of reaction and may elevate temperature. We do not know why this happened. It is possible that the wood and Plexiglas lids absorbed heat from the reaction, causing the heats of solutions to be falsely low. It could be the lids somehow suppressed the reaction. Future experiments could investigate these possibilities and additional sources of heat loss such as conduction, convection, radiation, or evaporative cooling, and their effects on the heat of solution.

The wide deviations of results within conditions of tests using lids could have been due to the variability in the fit of the lids on the vessels from one experimental trial to the next. We found that the wood lid was most difficult to fit tight on the vessel, followed by the wood lid lined by Styrofoam, and then the Plexiglas lid.

Based on the results of our study, there is no benefit for heat generation to using a lid in the experiment. The results are most efficient and reliable when running the experiment without a lid. We suggest that the General Chemistry I laboratory procedure can be modified to eliminate the lid.

	$q_{solution}$, J			correlation to control	
	mean	standard deviation	percent deviation	Hypothesis test, α = .05 2.05 rejection	
no lid	1288.1	43.4	3.37		
wood lid	1255.0	43.3	3.45	2.96	different
Styrofoam wood lid	1267.6	53.1	4.19	1.64	same
Plexiglas	1225.8	62.9	5.13	4.46	different

Table 1: Mean heats and deviations of conditions

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SCHOLARS' DAY
REVIEW
VOLUME 2

In the Land of Nod: A Failure of Justice for the Mentally Disabled

Nia Mugnolo

Faculty Sponsor: Prof. Scott Rudd (English)

ABSTRACT

In *Brother's Keeper,* and the *Paradise Lost* trilogy, documentary filmmakers Bruce Sinofsky and Joe Berlinger explore the influence of bias in two different murder trials: The West Memphis Three and the case of an elderly farmer named Delbert Ward in upstate NY. Jesse Misskelley, a defendant from West Memphis, and Delbert Ward both have IQs below 70, yet they were interrogated without counsel for over six hours in both cases. Community support for Ward and community condemnation for Misskelley separates the two cases most clearly, which were both weak from an evidentiary standpoint. The current prison population in the United States is 50-55% mentally ill, five times the percentage found in the general population. The presence of this many mentally ill citizens in prison suggests even more are going through the court system. What is allowing these individuals to slip through the cracks and end up on trial and in prison instead of receiving rehabilitation or medical attention? Berlinger and Sinofksy explore why innocent people, who do not operate at the sufficient level of mental competence legally required, can have such vastly differing experiences on trial.

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In the Land of Nod: A Failure of Justice for the Mentally Disabled

In the early 1990s, filmmakers Joe Berlinger and Bruce Sinofsky made two documentaries exploring the influence of community, fear, and prejudice in the cases of two different murder trials. *Brother's Keeper* follows the case of an elderly farmer named Delbert Ward, accused of killing his brother, and the *Paradise Lost* trilogy chronicles the two-decade-long ordeal of The West Memphis Three, a group of teenagers convicted of killing three eight-year-old boys. Community support for Ward and community condemnation for The West Memphis Three separates the two cases most clearly, although these cases have many other factors in common. Both lacked substantial physical evidence, included false confessions, and dealt with suspects who had below average IQs. Jessie Misskelley Jr., who confessed in West Memphis and implicated the other two men, and Delbert Ward, have IQs at or below seventy. Misskelley has an IQ between seventy and seventy-three, making him borderline intellectually disabled (Wilkins 3), while Ward's IQ ranges from sixty-three to sixty-eight making him legally intellectually disabled (Bogdan 303). Both men (Misskelley a teenager at the time) were subjected to over nine hours of questioning by the police without an attorney present, and both confessed to something they had not done.

In both films, the issues of prejudice against the poor, "outcasts" (*Brother's Keeper*), and outsiders (*Paradise Lost*), are openly addressed, but another kind of prejudice that is not directly dealt with sits in plain view throughout both films. According to the most recent study from The Bureau of Justice Statistics (BJS), 55-60% of The United States prison population suffers from a mental disorder (Glaze and James 1). That proportion is five times the rate of mental disability that exists in the general population (11%). If so many people with disabilities are ending up in jail instead of receiving medical attention or counseling, how many are being put through the court system without being convicted, and is the legal system failing them? The cases presented in the aforementioned documentaries serve as examples of the gross miscarriages of justice that can and do occur when those with mental illness are abused by the courts, and used by the police.

The United States has a long history of misunderstanding and mistreatment towards those with mental disabilities. In 1876, prominent socialite and philanthropist Josephine Lowell Shaw began a eugenics campaign through a series of popular charities to eliminate the population of what were then called "feeble minded people." The definition of mental illness was quite different, and included destitute women: "inmates were weak minded women with numerous children. They depicted these women as doubly deviant: defective (mentally retarded), and dependent (unable to support themselves)" (Noll and Trent 233). Lowell helped to create a link in popular opinion between those who were poor, and propagandized the criminalized caricature of the "feeble minded" individual. It was believed, and even integrated into legal proceedings by policy makers, that "all mentally retarded people are by nature potential criminals" (Noll and Trent 238). "Feeble minded" people became a threat to themselves and others simply by nature, being "born" criminals; frequently, being poor, homeless, and having too many children became a characterization that thrived and made Lowell's ideas of population control even more popular. Noll and Trent explain that "Lowell's first major accomplishment to the charity board was to 'define feeble minded women as a biological threat to society'" (Noll and Trent 233). Another idea, circulating and engrained into society with the help of this propaganda machine, was that a disabled person's ability to make decisions was inhibited by their mental deficiency, unless they were to harm or affect others, circumstances under which these same people were considered responsible for their actions and in need of punishment or isolation from the rest of the population. This idea has permeated throughout American history and has still survived, shedding light on the recent and current treatment of the mentally disabled.

Both cases from the films went to trial, meaning that both defendants were considered to have the level of mental competency required to legally undergo a

trial, which also assumes that Misskelley and Ward were competent enough to experience the hours of solitary interrogation by the police. Considering that the questioning led to a false confession in both cases, there might have been a mistake in judgment about what kind of questioning would be effective, or even understood by the defendants. This is where legal details would play a major role in letting people slip into a trial they may not be able to mentally withstand. When a defendant's competency to stand trial is called into question, an appointed psychologist may administer a competency screening. A screening consists of a series of questions designed to gauge if the defendant understands the charges being brought against them, as well as the roles that the judge, jury, prosecutor, and lawyer play, and whether they can articulate these concepts themselves. It may also, but is not required to include an Intelligence Quotient (IQ) test. In order for the screening to be given at all, someone on either side of the case must make a request for one to be granted by the trial judge. A problem is presented, in that a defendant may be incompetent to stand trial, but if there is not an obvious need for a test one might never be asked for or given. The defense team is most commonly the side that asks for the screening, and until Pate vs. Robinson in 1966 defendants could even request a competency screening for themselves. In Pate vs. Robinson, the Supreme Court ruled, "it is contradictory to argue that a defendant may be incompetent and yet knowingly and intelligently 'waive' his right to have the court determine his capacity to stand trial" (Melton, Petrilla, Poythress, and Slobogin 132). If Delbert Ward were given a competency test, which he never was, he almost certainly would have failed, and the case may never have gone to trial.

In the following case study example of a failed competency test taken from Melton et al.'s *Psychological Evaluations for the Courts: A Handbook for Mental Health Professionals*, a perfect example of an incompetent defendant is given. He misses all the key points of understanding required to be found competent, and he is not able to articulate any of the ideas about court proceedings in his own words.

> CASE STUDY 6.1 Donald is charged with six counts of arson. Each count charges him with intentionally setting fire to a church. He has an IQ of 58. You are asked to evaluate whether he is competent to stand trial. During the evaluation, the following dialogue takes place:
>
> Q: Do you know what you are charged with?
>
> A: I dunno. What's "charged" mean?
>
> Q: Do you know why you're here in this jail?
>
> A: Yeah. Burnin' down stuff.
>
> Q: What stuff?
>
> A: Goddamn churches
>
> Q: Have you talked to your attorney about this?
>
> A: Those churches was wrong. They get in the way. I got them out of the way.
>
> Q: Is that what you told your attorney?
>
> A: Yeah.
>
> Q: Do you like your attorney?
>
> A: He doan like me.
>
> Q: Why do you say that?
>
> A: He doan talk to me or nothin'. He doan try to get me off.
>
> Q: Do you want to get off?
>
> A: Yeah.
>
> Q: Is that because you think you're innocent?
>
> A: I got good reasons for doing what I done. (Melton, Petrilla, Poythress, and Slobogin 125-126)

While they are not exactly the same, with Donald having less of a grasp on reality and a lower IQ than Delbert by about five to ten points, the following excerpt from Ward's trial demonstrates a similar line of questioning resulting in similar answers. The P indicates when the prosecuting attorney is speaking and W indicates Ward's response.

> P: And do you remember them telling you that it was a crime-
>
> W: Yes
>
> P: In the state of New York to give a false statement?
>
> W: Yes
>
> P: And you understood that?
>
> W: No I didn't understood it.
>
> P: You didn't understand that it's a crime to lie?

W: No, 'cause I knew I didn't kill him
P: And then they said to you Delbert if this is the truth, sign this statement, remember him telling you that?
W: Yes, I remember him telling me that.
P: And you signed the statement
W: Yes I signed it
P: They say they read this to you about four or five times?
W: 'bout that
P: and each time, you told them that was the truth and those were your answers
W: Yes I thought that if I didn't cooperate with 'em I'd get out of there but I didn't. (*Brother's Keeper*)

In this exchange on the stand with the prosecutor, Delbert misses the same key points as Donald, not understanding what the job of the court is, and not understanding why it is illegal to lie about committing a crime. Delbert Ward characteristically speaks by parroting exactly what is said to him, usually without understanding or stopping to think about what was actually asked. He does this here on the stand, often repeating a question instead of answering it himself. He does not understand the gravity of legal repercussions of a false confession or the idea that saying what the police want him to would put him in jail instead of letting him go home. Ward believed that if he gave a pleasing answer, he would get to go home to his brothers, and even asserts that the police told him that if he signed the confession, he would be allowed to do so.

Jessie Misskelley Jr. would mirror this kind of childlike misunderstanding and motivation for a false confession. Unlike Delbert Ward, Misskelley did have a psychological evaluation as well as a competency screening, which found him fit to stand trial. Misskelley's evaluation was nine pages long and consisted of several kinds of tests, IQ results, a psychological history, and old school records. It found that Jessie had severe past physical abuse by his family, a history of violent outbursts, a history of failure in school, and had previously been given an IQ of 63 in a test given ten years previously (Wilkins 3). The final paragraph from the evaluation finds that Jessie is fit to stand trial, but comes with a serious warning about what actually putting him on the stand will mean.

> In the strictest interpretation of the legal statute, Jessie appears to be able to distinguish between right and wrong. He also appears to be able to aid in his defense. Jessie also appears to have been in control of his faculties at the time of the alleged crime. However, it should be noted, there is important qualitative concern that needs to be raised at this point. While Jessie has an IQ in the low borderline range, he clearly demonstrates a significant deficit in his ability to do abstract reasoning and to comprehend a wide variety of information. Jessie consistently shows clear developmental deficits and impairments which occurred well before the age of 18. That is, we see Jessie is still doing problem solving and making moral decisions on a level comparable to a 5 to 8 year old. While it is true Jessie is able to differentiate between right and wrong, it is equally clear the criteria by which Jessie decides right and wrong and markedly different than what we would expect of an adult his age. For Jessie, decisions about right and wrong are made on the basis of the consequence of the action not in terms of any kind of intent. (Wilkins 9)

Dr. Wilkins warned the judge that while Misskelley legally can be found to know the difference between right and wrong, he is making those choices the way that a "five to eight year old" would. He is functioning on an entirely different moral and decision-making plane due to the mental age that he has reached. Putting seventeen-year-old Misskelley through a murder trial is equivalent to putting an average seven year old through a murder trial. If Jessie is functioning mentally like a child, it is reasonable to say that his interrogation without a parent or lawyer present was not something he could make a real decision to enter into, and the subsequent confession made under clear duress should have been thrown out. Since there are no rules regarding the age level of mental functioning when it comes to questioning or the court, Jessie and others like him can be charged, even if the questioning that got them there was irresponsible.

Misskelley and Ward both gave false confessions, a phenomenon that was very little understood at the time their trials where taking place, and is still

misunderstood by some. In the film Misskelley contends that "the police questioned me for eleven or twelve hours and finally I just got tired, you know. I wanted to go home and be with my dad. I was saying what the police wanted me to say" (*Paradise Lost*). Misskelley confessed and gave a time line, as well as a description of the scene that did not match up with any of the evidence presented, and was called in court "a false story" (*Paradise Lost*). Similarly, Ward was questioned alone for hours, and he asserts that the police told him the story of how he killed his brother and he said that he had done it so that he could go home. In Ward's case, a murder never took place (*Brother's Keeper*). Ward and Misskelley were not mentally ready for the stress of that kind of questioning and did not understand the consequences of just saying what they believed the police wanted them to say.

One important characteristic that sets Misskelley and Ward apart from people with more severe disabilities like Autism or Downs Syndrome is that their minor intellectual disability is far less visible and not socially debilitating or even that noticeable. Most people in the village of Munnsville, NY, either denied that Delbert was disabled, or at least "wouldn't call him retarded" (Bogdan 305). Jessie Misskelley Jr. is on the cusp of being intellectually disabled, but is one or two crucial IQ points over the legal limit of 70, making him a more legally reliable source of information for the court. These disabilities are not obvious to the public, and are easier to misrepresent. In addition, people with lower IQs are often highly suggestible, making them prime targets for police coercion and more likely to give a false confession. A study described by Everington and Fulero found that people with intellectual disabilities were more likely to give a "socially desirable" answer than a truthful one (213). For example, Everington and Fulero summarize that, when asking questions like "Did you make your bed this morning?" one would receive a "yes" response, while asking, "Do you ever forget to brush your teeth?" would produce a "no," no matter what the truthful answer was (213). Bennett and Brodsky elaborate that "When leading questions are asked, and indeed, they are virtually *always* asked in interrogations, retarded persons frequently seek to conform to the perceived desires of the interrogator. They seek to please" (363), indicating that the suggestibility of those with mental disabilities is much higher than those without, leaving them more vulnerable to less ethical tactics in interrogation. In the courtroom, attorneys are prohibited from asking any question or making any statement to someone on the stand if it can be considered leading him or her to a specific conclusion, but in the questioning process this prohibition does not exist.

Another issue of competency is whether someone has the capacity to waive his or her rights. In Ward's case, he waived his right to council when he was initially being questioned, and there is an audio recording of it, but in later interviews with neighbors and even Ward himself it is clear that he did not understand what was happening. In an interview taken from *Brother's Keeper,* one of Delbert's neighbors explains:

> And Delbert, to this day don't know what the hell to waive his rights means. It's just some words to him. I said 'What did you waive Delbert?' I asked him straight out, 'I don't know' that's his answer . . . That might have been somebody walking down the street he was waving at . . . How can you charge somebody like that? How can you take a statement to begin with like that without having a lawyer present? (*Brother's Keeper*)

It is irrelevant if Ward waived his rights if he has no concept of what Miranda Rights are. An adult operating at the mental level of a seven-year-old can legally be questioned by the police the same way that any mentally healthy citizen can be. There are no legal rules or guidelines for police questioning of the mentally disabled that differ from regular procedure. In the case of Delbert Ward, he was also illiterate, could barely write, and was deemed competent to sign a confession statement alone. Ward did not understand the consequences of just doing what the police told him to do. At trial, however, Delbert Ward was acquitted.

So why are these men, and thousands like them, being arrested, and in cases like Jessie Misskelley, serving serious sentences in prison instead of getting help? Prisons have been referred to as "the new asylums" (*Frontline*). With a disproportionate number of inmates suffering from mental issues that should qualify them for medical treatment, it is hard to argue

with the label. The United States imprisons more of their citizens than any country in the world. According to The International Centre for Prison Studies, the US imprisons 716 people for every 100,000, with the runner-up being St. Kitts and Nevis at 649 for every 100,000. Of those in prison, the BJS report indicates "56% of inmates in state prison suffer from 'any mental health problem,' 44% in federal prison, and 64% in local jail" (Glaze and James 3). While there are clearly other factors causing the United States' rank, including race (for every 100,000 African Americans in the US 2,207 are in prison compared to only 380 for every 100,000 Caucasians) and drug laws, evidence points to jailing the mentally ill as a large source of the problem. If an alternative to prison for mentally ill offenders were offered it would cut down on prison overcrowding, as well as cutting down on repeat crime. According to the BJS special report, 61% of violent offenders with three or more incarcerations are suffering from mental health problems (Glaze and James 1). If these people were able to return to a safer environment after they leave prison, where they would be able to receive and afford to stay on their medications, the rate of repeat offenses would drop.

Misskelley's attorney Dan Stidham said in the first *Paradise Lost* film, "Jessie is mildly retarded; it's much easier to get a confession out of a seventeen-year-old who is functioning at the level of a six- or seven-year-old" (*Paradise Lost*). The key words in that statement are "get a confession out of." Misskelley and Ward were not chosen by accident to be questioned, but were targeted for that exact purpose. An officer of the West Memphis police force interviewed in the film explains that Damien Echols (one of the other West Memphis Three men implicated, who would later be sentenced to death) was the first person he thought of for the crime when he first heard about the murders. Echols was not, however, the first person questioned. Misskelley, who had no substantial connection to Echols besides living in the same trailer park as him for a time, was picked up to be questioned because they thought he would be a good source of information. The intention by the police was not to accuse Misskelley of anything at first; it was to get him to implicate Echols (*Paradise Lost*). Why was Misskelley such a good source of information? After all, people were aware that he was slightly intellectually disabled, highly suggestible, easily confused, and did not come across as a highly reliable witness in the interview process. They did not need Jessie Misskelley because he saw something; they needed him because they knew they could shape his interview into whatever they wanted it to be. He was easy to exploit.

Ward experienced a similar kind of coercion, but it was met with outrage from his community rather than the complacency and even celebration that took place in West Memphis. While Delbert Ward's disabilities were not acknowledged for what they were in Munnsville, the citizens thought Ward and his brothers should be treated differently because they were different and uneducated. This was not mistreatment, for the people interviewed who helped raise money for Ward's defense team were either certain of his innocence, or thought that if Delbert had killed his brother, he shouldn't go to jail because he did not know any better. All of the townspeople interviewed in the film, and by Robert Bogdan, who covered the case and wrote about it while it was happening, had a bias favoring the Ward's (who had lived in the town their whole lives), and a bias against the prosecutors, who were from a larger city. There is a protective atmosphere in the interviews in the film, and one DA is interviewed saying, "They were outcasts but they were *their* outcasts" (*Brother's Keeper*). Even though there is acceptance in Munnsville, there is still misunderstanding, equating a psychological problem with being stupid or dim-witted.

Prison in the United States cannot be considered a successful system if it is populated by those with mental disabilities. Punishing the mentally disabled does nothing but create a cycle of misunderstanding and allows more innocent men like Misskelley to spend years in prison. Even those with mental illnesses who *have* committed crimes rarely belong in prison. There are, of course, other issues like funding and research that need to be concentrated on before the mental health and prison systems in the United States can be reformed, but they should not become one in the same while those issues are being explored. The root of the problem lies in the misunderstanding and ignorance of what having a mental disability actually means for the individual and those around them. There is a drive to make them alien, something "other," much like the townspeople of Munnsville behave towards the city

folk and how West Memphis viewed the three. Misskelley's community, his family, and finally the criminal justice system abandoned him. Ward, luckily, had support from his community despite being wholly mishandled by the police. Those who have difficulty functioning normally in society due to a mental illness need help from society itself to learn how to comply with society's laws, and when society sweeps them under the rug and into prison it creates a two-fold problem of abandonment of dependent people and misuse of our prisons.

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SCHOLARS' DAY
REVIEW
VOLUME 2

From Narcissism to Empathy: Ibsen's Plays in the Digital Age

Jeffrey Curtin

Faculty Sponsor: Prof. Thomas Blake (English)

ABSTRACT

The digital revolution has produced many new forms of communication that present us with the risk of losing touch with one another. As our society increasingly relies on technology as a substitute for face-to-face interaction, there is a tendency among people to form online social groups that reinforce their existing biases and exclude alternative points of view. As a result, social networks—though designed perhaps to cultivate connections—may in fact be producing a more narcissistic society. Empathy, in contradistinction to narcissism, allows us to understand the thoughts and feelings of someone else. Literature (including film and drama), by allowing readers and/or viewers to imaginatively identify with characters different from themselves, fosters empathy and offsets narcissism. This could be precisely why the Humanities have played such a significant role in cultural reform throughout history. In this context, by exploring Henrik Ibsen's drama, we confront our own selfishness, narcissism, desire for control over others, and fear that they may gain control over us. *A Doll's House* and *Hedda Gabler* examine individual freedom from a female perspective, and show us how narcissism—especially in conjunction with intolerance—acts as a corrosive agent to human empathy and compassion.

Editor's note: Jeffrey Curtin won a 2nd-place scholarship award at the 2014 Scholars' Day for his presentation on this topic.

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From Narcissism to Empathy: Ibsen's Plays in the Digital Age

The digital revolution has produced new forms of communication that present us with the risk of losing touch with otherness. As people increasingly rely on technology as a substitute for face-to-face interaction, there is a tendency among them to form online social groups that reinforce their existing biases and exclude alternative points of view. As a result, social networks—though designed perhaps to cultivate connections—may in fact be promoting a more narcissistic society. In his essay, "Empathy in the Time of Technology: How Storytelling is the Key to Empathy," P.J. Manney stresses that if "accelerating technology means our own species and its interactions continue to gain in complexity, then by necessity, we must increase our levels of empathy to follow suit. If we don't, we may become unfit to continue as a species and bring about our own demise" (Manney 52). Manney points to fiction as a practical and valuable method of counteracting this potential consequence, contending that if "you regularly place yourself in the shoes of different characters and experience empathy for them, this recurring behavior cannot but help open up your view of the world and create a more empathetic personality" (Manney 53). Facebook, Myspace, and Twitter are all conducive to self-aggrandizement and exclusion of otherness. While these social networks are potential tools for democracy, they tend more often to rally like-minded individuals around social interests and political causes they already support. As Craig Condella writes in his article, "Democracy, Narcisissm, and the World Wide Web," the Web is a "double-edged sword that enhances the possibilities of both political change and narcissistic self-absorption" and social networks "more often than not reinforce what we already believe, often in ways hitherto unseen…if a hundred, a thousand, or even a million people are of a like mind, how can they—or I—be wrong?" (Condella 270). By limiting exposure to otherness and creating a virtual existence in which each user is the center of his or her own universe, social networks encourage a narcissistic, less empathetic society.

Seeing another person behave in a way that I have behaved allows me to empathize even with inconsiderate, immoral, or destructive behavior. Ideally, if I recognize in another person selfish, morally irresponsible behavior that I myself have engaged in, the identification acts as a sort of mirror in which I might see at least some elements of myself clearly and then alter my behavior accordingly. In his essay, "See the Play, Read the Book," Howard Mancing argues that, while we experience novels and other written works only through "mediated" perception, theatre and film are art forms that we experience through direct perception (Mancing 192). That is, our perception of theatre and film is akin to our perception of events in everyday life. In film, however, cinematography manipulates our perception; the camera determines a viewer's focal point. Theatre, generally speaking, involves the verbal and physical interaction of actual people; each actor is a 'body among bodies.' Given its three-dimensional quality, its lack of a fixed visual focal point, and the element of humans in live performance, theatre can, more closely than film, approximate life. Assuming, then, that theatre is unique in its ability to present us with perceptive experiences very similar to those of our everyday interactions with others, it is also unique in its ability to show us our own behavior and foster empathy through the recognition of ourselves in characters on stage. Works within the aesthetic realm of realism and naturalism further enhance this recognition by attempting to render artistically our lived experience in all its nuanced complexity. According to Norwegian playwright Henrik Ibsen, his own plays "make people uncomfortable because when they see them they have to think, and most people want to be effortlessly entertained, not to be told unpleasant truths.… But I find that people's eyes can be opened as well from the stage as from a pulpit. Especially as so many people no longer go to church" (qtd. in Meyer 471). In his often bleak works of realism, Ibsen brings us face to face with our own selfishness, narcissism, desire for control over others, and fear that others may gain control over us. *A Doll's House* and *Hedda Gabler* examine individual freedom from a female perspective, and show us how narcissism—especially in conjunction with intolerance—acts as a corrosive agent to human empathy and compassion.

While narcissistic personality is a specific clinical diagnosis that describes a very particular condition, it is helpful to understand how narcissism more broadly applies to people who privilege the self and dismiss, to varying degrees, the needs of the other. It is unsurprising, therefore, that narcissism impairs one's capacity for empathy. A narcissistic dismissal of "the other" can manifest on a cultural level. Rejection of a collective "other"—be it an ethnic group, gender, or sexual-orientation group—can stem from what Paul Babiak and Robert D. Hare regard as "entitlement" and "a sense of superiority over others" (Babiak & Hare 124). Societies that legislate and enforce institutionalized racism or misogyny are clearly motivated by revulsion toward—and a desire to marginalize—otherness, and a culture that organizes itself with such socio-political asymmetry exhibits an intolerant worldview that privileges sameness (whiteness, maleness, heterosexuality, for example) and actively oppresses otherness.

For the purposes of this paper, I will not confine my use of the word "narcissism" to the parameters of its definition as a psychological disorder. And, since "narcissism" functions as a blanket term used to mean everything from self-admiration to sexual attraction to oneself, establishing a working definition here is crucial. To this end, I look to Jean M. Twenge and W. Keith Campbell, co-authors of the 2009 book *The Narcissism Epidemic*, for whom the "myth of Narcissus captures the tragedy of self-admiration, because Narcissus becomes frozen by his self-admiration and unable to connect with anyone outside himself—and his narcissism harms other people.… The legend reflects real life, with the most serious consequences of narcissism falling upon others in society" (Twenge & Campbell 19). This points to narcissism as a socially destructive force; much larger than a few inflated egos. The positive feelings and high regard a narcissist has for himself do not extend outward to others, as narcissists "lack emotionally warm, caring, and loving relationships" (Twenge & Campbell 19). While there are certainly other relevant views on narcissism, the ideas provided by Twenge and Campbell highlight a clear link between narcissism and Patrick Hogan's "ethics of disgust."

According to Hogan, one of the most influential voices in the field of cognitive cultural studies, while an "ethics of attachment" emphasizes "such virtues as nurturance, kindness, corporal works of mercy, and so forth," an "ethics of disgust" leads to intolerance and exclusion (Hogan 240). "Some of us," writes Hogan, "are much more likely to respond to disgust-provoking components of situations or actions; others are more likely to respond to attachment-based needs" (Hogan 241). Racism, homophobia, and sexism can all be linked to feelings of revulsion toward otherness. Narcissism can, and often does, act as a catalyst for feelings of disgust and hatred toward people who do not conform to the worldview—or cater to the aggrandizement—of oneself. Since narcissists "don't value warm or caring relationships," it follows that they have little use for genuine compassion and tend to view others as "tools to make themselves look and feel good" (Twenge & Campbell 19). Hogan asserts that, "as a moral emotion, disgust leads us to emphasize cleanliness and shame" and, in "the case of cleanliness, the physical virtue is extended to a moral virtue…chastity in both deed and thought is a prime case of moral 'cleanliness'" (Hogan 240). The notion of moral cleanliness is so pervasive it may go unnoticed by many people. From relatively harmless linguistic metaphors like 'dirty' jokes to fundamentally destructive ones like racial 'purity,' we associate words like 'impure' and 'unclean' with moral inferiority. For the narcissist who is perpetually concerned about maintaining an appearance of superiority to others, association with those who fall outside the narcissist's standards of 'moral virtue' or 'moral cleanliness' would be disadvantageous. It is important here to say the narcissist's standards, grounded in desire for self-aggrandizement, do not necessarily include preoccupation with societal norms of moral cleanliness. A narcissist could just as easily revel in debauchery and maintain an inflated sense of self according to almost any standard. Anyone deviant from the narcissist's moral standards (whatever they may be), or anyone who challenges or contradicts said standards, is almost necessarily undesirable; an object of disgust.

The problem of narcissism extends well beyond the self-centered individual. In patriarchal societies, for instance, the limited worldview of the individual male becomes the reigning cultural attitude. As it manifests in both Ibsen's plays and the 'real world,' patriarchy is fundamentally narcissistic in that it essentially

establishes a positive feedback loop among men that reinforces intolerance of otherness and the reduction of women to servants of various kinds. In a sense, women in patriarchal societies—or just marriages based on patriarchy—are subservient to their husbands' narcissism. They serve their husbands' various egocentric needs, sexual and otherwise.

In *The Second Sex,* Simone De Beauvoir presents us with the notion that, due to the existence of a number of pervasive myths surrounding femininity, the actual personalities of women have long been muted in the eyes of society and, in particular, men. The woman who wants to exist, be known by those around her, and ultimately respected as a flawed, idiosyncratic, utterly human self, is trapped behind a wall of clichés regarding the 'true nature' of women. As the "contrary facts of experience are impotent against the myth," a woman is likely to experience great difficulty in, for example, a heterosexual relationship; her individuality will constantly fail to fit within the conceptual framework of the myth, to the frustration and confusion of her husband or lover (not to mention herself) (Beauvoir 253). "If the definition provided for [the Eternal Feminine] is contradicted by the behavior of flesh-and-blood women, it is the latter who are wrong: we are told not that Femininity is a false entity, but that the women concerned are not feminine" (Beauvoir 253). The women who are 'not feminine,' then, potentially become undesirable others to their husbands or lovers. They fall outside societal standards of moral virtue and may become objects of disgust to their narcissistic mates. The inadequacy of any myth or ideal to accurately depict an actual human being is overlooked in favor of a focus on the inadequacy of a human being to actually embody an ideal. The 'mysteriousness' of women is a catch-all for characteristics of actual women that fly in the face of the ideal because "the categories in which men think of the world are established *from their point of view, as absolute*…a mystery for man, woman is considered to be mysterious in essence" (Beauvoir 257).

In Ibsen's *A Doll's House,* Torvald Helmer not only believes in an ideal of femininity, his entire married life with Nora absolutely depends upon the appearance of false conceptual notions as 'the truth.' Nora is Beauvoir's "slave" who "deliberately dissembles her objective actuality" (Beauvoir 259). She depends upon "the caprices of a master" and so has "learned to turn toward him a changeless smile or an enigmatic impassivity" while carefully hiding her real sentiments, her actual being (Beauvoir 259). Torvald has developed all sorts of habits and rituals that feed his idealized conception of Nora (not to mention his ego). When, toward the end of the play, he reveals to her that this conception includes viewing her as stupid and inferior, she sees the situation for what it is, and not only breaks free from the marriage, but also disabuses him of at least some of his delusions about their relationship. *A Doll's House* allows us to see the workings of a relationship that is based on ideals rather than concrete experience, and in doing so, cultivate empathy for women in situations similar to Nora's. As Ibsen biographer and translator Michael Meyer describes the play's impact on society, "No play had ever before contributed so momentously to the social debate, or been so widely and furiously discussed among people who were not normally interested in theatrical or even artistic matters" (Meyer 454).

When Torvald calls Nora "my most treasured possession," adding "all this wonderful beauty that's mine, mine alone, all mine," we get the sense that he does not care at all for Nora as an individual, only as something he owns that pleases him and increases his self-admiration and feelings of superiority to others (Ibsen 87). This is but one of many instances throughout the play in which Torvald embodies the sort of narcissism described by Twenge and Campbell. Perhaps the most significant and certainly one of the most memorable of these instances occurs during the climactic scene, in which, after cursing Nora for having forged her father's signature in order to take a loan from Krogstad, he then offers her forgiveness. After displaying disgust toward his wife: "Wretched woman…a hypocrite, a liar—worse, worse—a criminal…no religion, no morals, no sense of duties…," he then insists that their marriage continue only in appearance as he no longer wishes for her companionship and dares "no longer entrust" the children to her care (Ibsen 93-94). After receiving word that Krogstad is returning the I.O.U. and the threat of blackmail is extinguished, it doesn't occur to Torvald to ask his wife's forgiveness for verbally abusing her and demanding that she remain in the house as, essentially, a prisoner. The threat to his ego is gone, and the only

possibility he even considers is that Nora is afraid he won't forgive her. This scene makes a strong case for Torvald as a man nearly devoid of empathy, concerned only with controlling and arranging people in ways that best serve his needs. When we consider this scene alongside the tarantella scene toward the end of Act Two, in which Nora begins to dance passionately, exclaiming, "Oh Christine, we're having such fun," Torvald grows frantic and tells Rank to stop playing the piano immediately; a clear picture emerges of the Helmers' marriage as one dominated by the controlling impulses of a pathological narcissist (Ibsen 77).

Since, for much of the play, Nora—as far as Torvald knows—is, indeed, subservient to his narcissism, his disgust with her only occasionally surfaces, as in the two moments described above. Torvald's relation to an ethics of disgust is most readily apparent in his attitude toward the two other major male characters in the play, Krogstad and Rank. When Torvald tells Nora that Krogstad has "forged someone else's name," he goes on to say, "Just think how a man with that load on his conscience must always be lying and cheating and dissembling—how he must wear a mask even in the presence of those who are dearest to him, even his own wife and children" (Ibsen 53). Torvald's self-righteous condemnation of Krogstad here is ironic in one sense because Torvald essentially owes his life to a forged signature, and in another sense because Torvald disguises his true intentions and manipulates his own wife and children. He's expressing moral outrage toward someone for engaging in behavior he himself has engaged in; this hypocrisy on Torvald's part also functions as part of an ethics of disgust. As he goes on, his disgust with Krogstad becomes more apparent: "every breath that children draw in such a house [as Krogstad's] contains the germs of evil…I literally feel physically ill in the presence of a man like that" (Ibsen 54).

Torvald allows Rank to visit with Nora because he views the sickly man as a non-entity who poses no sexual threat to his marriage. Torvald likely enjoys feeling superior to him and inspiring jealousy in him. In Act Two, an interesting exchange takes place between Nora and Rank in which Rank informs her that he's going to die soon, and shortly after insists that Torvald not come to visit him in the hospital. At first, he pretends this is out of respect for Torvald, whom he calls a "sensitive chap," adding, "I know how he hates anything ugly" (Ibsen 65). This indicates awareness of Torvald's potential aversion to seeing him on his sickbed, but then Rank seems to express *fear*, refusing to allow Torvald into his hospital room should he attempt to visit. The precise nature of his fear is unclear, but it seems that Rank is horrified at the thought of Torvald being near him when he's dying, feeling superior and perhaps enjoying a feeling of power as he observes Rank's own weakness and powerlessness. A chilling aura of sadism pervades this moment of the play. Torvald's remark that Rank's "suffering and loneliness seemed to provide a kind of dark background to the happy sunlight of our marriage" reveals part of the way in which he used the man to serve his narcissistic desires (Ibsen 91). He expresses no wish to see Rank in the hospital; it is consistent with an ethics of disgust that he should want to keep terminal illness, and the bodily decay associated with it, at arm's length.

At the end of the play, as Nora stares at the possibility of self-discovery and individual freedom, she is also breaking away from Torvald's narcissistic control. Her parting words are not bitter, and her eagerness to experience life outside of her home, whatever that may entail, points toward an ethics of attachment. Arguably, the only other significant moment in the play filled with genuine compassion occurs in the beginning of Act Three, when Krogstad and Mrs. Linde meet. What has all the makings of a loveless partnership resulting from a desperate act on the part of Mrs. Linde begins to transform when she asks, "Nils, suppose we two shipwrecked souls could join hands?" (Ibsen 82). As Mrs. Linde exclaims, "What a change! Oh, what a change! Someone to work for—to live for! A home to bring joy into!" we sense that the connection that takes place between Mrs. Linde and Krogstad has converted a potentially bleak situation into an embodiment of Hogan's ethics of attachment (Ibsen 84).

In *Hedda Gabler*, the lines between just and unjust, freedom and oppression, control and dominance, narcissism and self-actualization, are much more blurry, much closer to the gnarled intricacy of their real-world counterparts than in *A Doll's House*. Hedda herself is a more nuanced, complex, unstable, and unpredictable character than Nora. The plot is somewhat predictable;

for instance, we can easily guess, based on the conspicuous introduction of General Gabler's pistols early in the play, that things will take a violent turn for Hedda. Hedda's moment-to-moment behavior, though, is such that she won't yield to interpretation as readily as Nora. In *The Actor, Image, and Action: Acting and Cognitive Neuroscience*, Rhonda Blair writes, "To box Hedda and her cohort up in a tidily psychologized, overly determined package diminishes the power of the work. We must strive for an experience of the *felt* meaning of the play, even if we cannot name it, using language to reach beyond language and toward experience" (Blair 12). If Nora is a slave who takes the first step toward freedom at the end of the play, Hedda is Nora years down the road, when the idealism and hope for a better life, the dream of self-actualization, have long since deteriorated into empty self-obsession. Hedda embodies the concept of narcissistic disgust as a corrosive agent, eating into anyone with whom she comes in contact. In sharp contrast to Nora, who, at the end of *A Doll's House*, freely admits to not understanding how society works, Hedda understands almost *exactly* how society works and despises it almost entirely. She sees that to obtain the fulfillment she craves would require scandal, and so retreats into marriage with a man for whom she can barely muster contempt, a sort of disinterested dismissal of him as a person. She is neither intellectually nor emotionally tethered to the societal notion that she ought to have a husband and bear his children, and does not believe that submission to the will of a man will bring her happiness; but she can see no path that offers her the freedom and control she so desperately wants without the threat of 'falling from grace' in the eyes of her peers. She has, in a sense, freedom of mind, but there's nothing for her to *do* with it, no way for her to embody the ideals that she has. As a result, she has, by the start of the play, long since grown bitter and developed disgust toward herself and those around her.

If not for the same reasons as Torvald, then certainly to at least the same extent, Hedda tries to control the lives of those around her. Like Torvald, she seems to feel completely entitled to do so where possible. It seems to be largely because of Hedda's lack of power over her own life that she seeks to control the lives of those around her. In the end, she is able to exercise a great deal of control over her husband's rival, Eilert, and her old friend, Thea, only to realize that, in doing so, she has put herself at the mercy of Judge Brack and her husband. When she kills herself, she is exercising what she views as the only form of control still available to her. Despite her intense dissatisfaction with life and eventual suicide, it would be inaccurate to say Hedda suffers from a low self-opinion. She is preoccupied with selfish interests; and her concern with her own appearance in the eyes of others ultimately prevents her from pursuing the freedom that Thea has obtained. When, in Act Two, she responds to Brack's suggestion that she find something to occupy her time and help counteract her boredom with "I was thinking, if I could persuade Tesman to go into politics…," as though it's something she has genuinely considered and has some amount of enthusiasm for, this reveals that even a *tiny* amount of control over a person is infinitely more interesting to her than an actual relationship (Ibsen 281). Hedda tells Brack that she is married to Tesman because, essentially, she "felt sorry for the great scholar" when he was awkwardly trying to find something to talk about as he walked Hedda home from a party (Ibsen 280). She told him "quite frivolously" that she'd love to live in the house they were walking past (Ibsen 281). In consequence, she and Tesman got engaged, got married, went on their honeymoon, and moved into the house in question. According to this description at least, there never was any honeymoon period during which Hedda and George Tesman were deeply enamored of one another. There has only ever been boredom and, on Hedda's part, disgust.

An ethics of disgust characterizes Hedda's attitude toward Tesman, herself, and the circumstances of her life. Her disgust with each of these is evident in comments she makes to Brack regarding childbirth: "I've no leanings in that direction, Judge. I don't want any—responsibilities…I often think there's only one thing for which I have any natural talent…For boring myself to death…Talking of boring, here comes [Tesman]" (Ibsen 282). A case could be made that these comments have more to do with withdrawal from and utter indifference toward life than any particular attitude, but Hedda's subsequent vicious actions and eventual suicide strongly support the argument for narcissistic disgust. Regarding Tesman, she seems—somewhat understandably—repulsed by his childish

relationship with his aunts. His seeming indifference and/or obliviousness to her actual feelings and his utterly unappealing personality contribute to Hedda's view of Tesman as the 'other' and her disgust with his otherness.

Aside from Tesman's relationship to his aunts, the only relationship in *Hedda Gabler* that seems rooted in an ethics of attachment is the one between Eilert Loevborg and Thea. The conversation between Hedda, Loevborg, and Thea toward the end of Act Two is a pivotal point in the play. When Loevborg tells Hedda that Thea has "the courage of her convictions," we begin to see how deeply Hedda envies their relationship (Ibsen 294). Hedda's reply, "Yes. Courage. Yes. If only one had that…One might be able to live. In spite of everything," reveals that, on some level, she views herself as cowardly for failing to take the sort of chance that Thea has by running away with Loevborg (Ibsen 294). This conversation sets in motion a streak of cruelty on Hedda's part that ultimately results in both Loevborg's death and her own. Hedda's suicide is a reaction to the horror of knowing someone else has power over her for the foreseeable future. As she says to Brack just before shooting herself, "From now on, you've got your hold over me...I'm in your power. Dependent on your will, and your demands. Not free. Still not free! No. I couldn't bear that. No" (Ibsen 332).

While Ibsen's plays are the work of a man writing within European culture in the late nineteenth century, the truths they lay bare remain powerful tools for change. Both *A Doll's House* and *Hedda Gabler* manage to generate empathy for their main characters, allowing audiences to imaginatively identify with characters who are mainly narcissistic and operate from within an ethics of disgust, and ones who are compassionate and empathetic and embody an ethics of attachment. In doing so, these plays challenge us to look beyond our own narcissism and self-centered behaviors as they present us with new ways of seeing and understanding the world. In this sense, rather than act as a barrier, the antiquated language and cultural situations found in the two works may—*because* of their unfamiliarity to twenty-first century Americans—further encourage empathy by asking audiences to look beyond their received notions of these elements as well. Ibsen's plays encourage us to reject narcissism and expose the ethical problems embedded in prevailing ideology. As empathy for those unlike oneself becomes important in new ways, *A Doll's House* and *Hedda Gabler* are as relevant as they have ever been.

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SCHOLARS' DAY
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William Shakespeare's "United" Kingdom: Henry V's Captains and the Dawn of Empire

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ABSTRACT

Primary historical accounts contain no indication that Wales, Ireland and Scotland participated in the battle of Agincourt in the way that Shakespeare portrayed in *The Life of King Henry V*. The captains are strikingly similar to individuals and groups involved in England's past, present and future. Specifically, Fluellen seems to be a call-back to the Welsh troops at the battle of Poitiers in 1356, MacMorris a representation of Earl Hugh O'Neill (whose military ferocity caused the English to flee Ireland in 1599), and Jamy a reference to the transference of the English crown to the Scottish king, James VI four years after the play was performed. This essay explores the development of the sense of unity that would envelope the British Isles through Shakespeare's representations of the nations that would make up the United Kingdom. The historical significance of the captains in the context of the rhetorically patriotic play sketches a timeline of British unification through cultural rather than violent imperialism. In reveling in and partaking in Henry's proto-nationalism, the captains became something that was unheard of in 1415, as well as 1599: British.

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William Shakespeare's "United" Kingdom: Henry V's Captains and the Dawn of Empire

Based on an Arthurian prophesy, Britons believed that the nations of the British Isles would be united under a virgin monarch, convincing many that Queen Elizabeth would consolidate England, Wales, Scotland and Ireland into an empire (Canny 116). The first monarch to title their domain the Empire of Great Britain was not the "virgin queen," Elizabeth I, but her successor, King James I, formerly James VI of Scotland. *The Life of King Henry the Fifth* is a fundamentally English play, celebrating the early modern imperialism of the monarchy through King Henry V's 1415 campaign in France. The play creates an overarching theme of unity in everything from the chorus unifying the audience and actors, to Henry's unification of his forces at Agincourt in his legendary "band of brothers" monologue.

The word "Britain" is rooted in the name "Brutus"; in English lore Brutus fled Rome prior to his death with his three sons, Locrine, Albanact, and Camber who went on to be the first rulers of England, Scotland and Wales respectively. Prominent in the myth is the reverence owed by the younger brothers of Scotland and Wales to the eldest king of England (Canny 113). The myth of Brutus began a precedent of familial connection between the British nations, as well as creating a precedent of reverence for England as the heir to Roman glory, and therefore head of the eventual empire. *Henry V*'s Chorus encourages an impression of mythological grandeur, calling back to epic poems like *The Aeneid* about the origins of empire. *The Life of King Henry the Fifth* features four captains from the countries that would eventually make up the British Empire: Gower of England, Fluellen of Wales, MacMorris of Ireland, and Jamy of Scotland. Gower makes very few contributions to the plot, allowing the characterization of the English to be left to Henry and his subjects. James L. Calderwood notes that the captains "though contentious enough with one another, are united in their desire, as Jamy puts it, to 'de gud service' against the French" (Calderwood 144), but in doing good service against the French, they are doing good service for the English, their mythological patriarch. Henry V is not inciting a war for the defense of the British Isles, nor to right any wrong the French have committed against his people, but rather to imperialistically seize the French throne.

Fluellen, captain of Wales, is a fundamentally anachronistic character; in nearly every one of his scenes he makes references to the history of warfare. Fluellen goes so far as to solidify the play's theme of mythical imperialism and warfare by referencing *The Iliad* and the Trojan War when he praises "The Duke of Exeter is as magnanimous as Agamemnon" (3.6.6-7), seeing a kind and forgiving nature in Agamemnon that most of Homer's readers have failed to sympathize with. Fluellen's words are riddled with archaic references, including a preoccupation with traditional warfare so persistent that his compulsion to adhere to it seems to outweigh his desire for victory. When called to the trenches dug around the walls of the besieged town in order to plant explosives, in the midst of battle, he argues "To the mines? Tell the Duke it is not so good to come to the mines; for look you, the mines is not according to the disciplines of war" (3.2.56-58). He goes on to describe that the mines have not been dug to traditional depth and that the mistake must be rectified before he will participate in that front, despite the fact that it will all be blown up anyway.

Fluellen's behavior can be explained by the service of the Welsh forces in the battle of Poitiers in 1356 under Edward the Black Prince. The Welsh did not participate in the battle of Agincourt in the numbers that Shakespeare would have his audience believe; it is estimated that only about 400 Welshmen participated in the battle, many of them former rebels whose only goal was receiving legal pardon as reward for their service (Chapman 312). The history of the battle of Poitiers, however, paints a much more complimentary picture of Welsh forces and their allegiance to the reigning Prince of Wales, the son of Edward III. Medieval French historian Jean Froissart described the English forces as "in number a four thousand men of arms and ten thousand archers, beside Irishmen and Welshmen that followed the host afoot" (5), emphasizing the loyalty of Prince Edward's fellow Britons. Unlike Shakespeare, a French historian would have no motivation to sensationalize or glorify the English forces, nor is his account presented as a

dramatic piece. By invoking the harmony of the Welsh and the English in 1356, in a play celebrating British unity and patriotism in 1415, Shakespeare emphasizes, much like Fluellen himself would, tradition; citing history as justification for contemporary comradery much like the English would reference the mythical history of Brutus as reason for dominion over the sovereign nations of the British Isles.

MacMorris, captain of Ireland, has significantly less dialogue than Fluellen but does not waste a single line on small talk, ferociously erupting into celebrations of the act about being a soldier or lamenting the state of his people at the hands of the crown he serves. MacMorris in his Irishness and conflicting Englishness, seems to be a reference to the contemporary Elizabethan Irishman Hugh O'Neill Earl of Tyrone. The relationship between the Irish and the English is one of cultural blending, antagonism, and resistance. The first mention of the Irish in the *Henriad* takes place in *Richard II*, when the solipsistic king over whom Henry V's father would triumph orders "pet wars" in Ireland for the sole purpose of attaining military glory. The juxtaposition between relations with the Irish in *Richard II* and *Henry V* illustrates the alternating periods of invasion and camaraderie present throughout history. Polarizing shifts in international politics are personified in MacMorris's character, as well as in the patriotic Irishman and assimilated Englishman Hugh O'Neill. MacMorris laments the imperialistic cultural forces ravaging his homeland and the anti-Irish sentiments of the English commonwealth, asking "Of my nation? What ish my nation? Ish a villain, and a bastard, and a knave, and a rascal? What ish my nation?" (3.2.118-120).

MacMorris is fundamentally separate from the other captains, just as Ireland is geographically separated from the nations of Great Britain. While Fluellen and Jamy only have slight tinges to their dialogue, MacMorris's thick accent can be seen clearly in the text. In 1599, as Shakespeare was writing *Henry V*, the English Earl of Essex took a large army to Ireland, but within a year, Hugh O'Neill Earl of Tyrone, an Irishman with a penchant for adopting English characteristics, embarrassed the invading army, sending them fleeing back to England (Carroll 13). Both the historical O'Neill and the fictional MacMorris simultaneously embody antagonism and assimilation into English life and behavior, highlighted by Brian Carroll with the fundamental statement that "O'Neill, like MacMorris, could have rightly asked 'what ish my nation?' toggling, as he did between his Irishness and his adopted Englishness, between otherness and sameness" (13). When a country is occupied by foreign invaders over the course of centuries, it is inevitable that the aggressor culture will begin to permeate that of the invaded. The English have had a strong influence on what it means to be Irish, complicating the nationalistic fervor of Irishmen like MacMorris or O'Neill, because as time goes on more and more of the native culture they sought to defend and preserve became that which they resisted. Irishmen like MacMorris and O'Neill were faced with the dilemma that the culture they defended from the English was in some part an English culture; that the invading English had already diluted Irishness to be inseparable from Englishness, begging the question "what ish my nation?"

The Life of King Henry V was written a short four years before the death of Elizabeth I and the reign of James I of Scotland. Captain Jamy is a dutiful soldier, praised by Fluellen as "a marvelous falorous gentleman, that is certain, and of the great expedition and knowledge in th'aunchent wars" (3.2.74-76). Jamy is distinct from his counterparts in that his motivation to fight on behalf of the English does not appear to have any root in a love for battle; Jamy fights with neither complaint nor bloodlust. There is little to no evidence of any Scots serving under Henry V or under Edward III in the original Anglo-French conflict. In fact, Scotland was a catalyst in inciting the Hundred Years War as they had been at war with the English on and off for years (Mortimer 28). Fluellen references Welshmen from the past; MacMorris alludes to the great contemporary Irishmen of Shakespeare's lifetime; and Jamy, with no parallels in pre-Elizabethan history seems to glorify the Scottish in a manner that would calm the English as their rule by a Scottish king drew near. It was crucial in the last years of the 16th century that the English people came to trust the Scots in order to ensure stability, and Shakespeare had a unique means of delivering ideas and influences to the common people through the theater. In Elizabethan England, theater was woefully out of style with the upper rings of society, inspiring most great writers of the time to

write sonnets for the aristocracy, while Shakespeare chose to remain the playwright of the people.

Cultural trends are molded and reflected by those who create and proliferate media. This circular relationship lays the foundation for speculating on the symbolic identity of captain Jamy. The priesthood and aristocracy of Shakespeare's England were enemies of the public theater, the very institution from which Shakespeare derived his livelihood. Elizabeth did not explicitly weigh in on either side of the issue, but James was not so silent on the matter. Leonard Tennenhouse points out that "In contrast to Elizabeth, James made it a matter of royal policy not only to seek control of the theatre but also to advocate the celebration of festivals" (116), and writer James Melville, often trusted as an authority on Scottish life at the time, penned in his *Diary and Autobiography* an account of James attending a play with the aristocracy in 1580 (62). As king of England and Scotland in 1603, James I united the crowns of the two nations, becoming the first to title his dominion The British Empire, and to call his people – in England and in Scotland – Britons.

Shakespeare's belief in and promotion of King James did not lack payoff. Shortly after James' coronation, Shakespeare put on seven of his plays, including *Henry V*, for the new king, and as a result his acting company, Lord Chamberlain's Men, was made the official acting company of the crown, rebranding them The King's Men (Greenblatt 329). While the Scottish captain is listed in the dramatis personae as Jamy and typically referred to as such, Fluellen greets him "Good e'en to Your Worship, good captain James" (3.2.81) both parts of which foreshadow King James; the latter obviously because they share the same name, but in referring to a fellow military captain as "Your Worship" as a proper noun, the monarchy as divinely chosen head of the church of England may be hinted at, a concept with which King James would define his reign.

Shakespeare presented the international captains as symbols of unity between the nations of the British Isles, as mythical representations of the past, present, and future. Despite the squabbles of the captains, they are eager to do battle in the name of the English crown. While a great many English characters in the play express doubt regarding the justifications for war, the captains are unflinchingly loyal: the personification of a diverse empire united harmoniously for a valiant cause. While it is Henry's speeches to his men which command the most attention, the captains subtly do more for the unity of the British Empire than rhetoric can accomplish. Henry can speak of a band of brothers, but those brothers, mythically descended from Brutus and spread across the empire and spread throughout time itself, represent the true spirit of British union, not as Welshmen, Irishmen, or Scots, nor subjects of the king, but as Britons.

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Will The Real Paleo Diet Please Stand Up? Amylase Variation Between Human and Non-human Primates

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ABSTRACT

The degree to which humans can digest starch is a fundamental difference between humans and non-human primates. This adaptation in early man led to the ultimate colonization of the planet. The advent and control of fire occurred simultaneously with a drastic increase in brain size, a primary distinction in the genus homo. This makes sense in biological anthropology because starch must be cooked in order to access adequate amounts of nutrition. Amylase converts starch into glucose. By the same token, the brain runs on glucose. With a reliable energy source, irrelevant of location or season, early man was able to have a dependable fuel source that allowed for human migration out of Africa. With a focus on the salivary amylase gene and its specific function, this paper compares and contrasts salivary levels of amylase between the great apes. The results are useful for both human and non-human primate dietary guidelines.

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Will The Real Paleo Diet Please Stand Up? Amylase Variation Between Human and Non-human Primates

Taxonomy categorizes organisms into kingdoms, phyla, class, order, family, genus and finally species (Bailey). Now, as it were, we are all cousins by contiguity, we all evolved from a singular, biological twitch in some smorgasbord of hydrogen, carbon, and various other elements necessary for life to occur some three and a half billion years ago (Bryson). Once life began, it has never stopped doing what it does best: reproducing. In order to engage in reproduction, one (or two) must take in the necessary fuel, as in kilocalories. Engaging in the act of reproduction is not guaranteed by virtue of being. Rather, it is a competitive dance of the highest degree. Therefore, only those who eat enough, who are vital enough and healthy enough will see to it that their genes are passed on. Kilocalories, also known as food, are first and foremost the primary concern of all species. One evolutionary constraint that all animals face, with the exception of humans, is a species-specific diet. When an animal strays from its specific diet, by choice or otherwise, degenerative and sometimes fatal repercussions follow.

There is an epidemic of obesity, chronic disease, and premature death amongst three types of animals in this world: humans, cats, and dogs. I would like to add to this list captive animals, specifically some of our closest kin: orangutans, chimpanzees, and gorillas. Great apes in zoos across the nation are facing the same chronic ailments that humans are facing in the first world and other westernizing nations. Orangutans are suffering from diabetes, chimpanzees are dying from heart disease, and gorillas are undergoing anesthesia for cardiac ultrasounds (Great Ape Heart Project). Approximately 2% of orangutans in North America suffer from diabetes (Dierenfeld). "According to an article published in the SAGE journal, *Veterinary Pathology*, Arrhythmogenic Right Venticular Cardiomyopathy [ARVC], a human heart disease that causes sudden cardiac death in teenagers and young adults, particularly healthy athletes, has now been identified in chimpanzees" (Human Heart Disease). A gorilla's heart is structurally similar to a human heart, and the implications are relevant (Bressanin). "Primates held in captivity are at increased risk of death from heart-related disease, they can get high blood pressure, high cholesterol, and heart failure" (Great Ape Heart Project). The Great Ape Heart project highlights this theme in the 2012 White Paper, "A Collaboration to Understand Heart Disease, Reduce Mortality, and Improve Cardiac Health in all Four Great Ape Taxa"; "Obesity is not uncommon in captive apes, and there is evidence they have metabolic abnormalities" (Great Ape Heart Project). It isn't all monkey business. Moreover, obesity and metabolic syndrome affect nearly one in three Americans and are the direct result of improper diet (PCRM). Obesity isn't only a risk factor for cardiovascular disease in humans but for non-human primates as well (Great Ape Heart Project). A nutritional focus reveals that amongst both human and non-human species, an improper diet can lead to insulin resistance, obesity, and hypertension that can increase the risk of cardiovascular disease (Great Ape Heart Project). The difference between the diets of wild and captive apes is the main precursor to the problem at hand.

Great apes are mainly herbivorous by nature, meaning they typically feed on plant matter when available. In contrast, zoo nutritionists are inclined to offer orangutans 14% of their diet as nutritionally complete primate biscuits and the remaining 86% as produce, with higher proportions of raw vegetables and leafy green vegetables than fruit (Dierenfeld). By dry weight the diet consists of 50% biscuits and 50% plant matter (Dierenfeld). However, as noted by Dierenfeld in his 1997 paper, "Orangutan Nutrition," published in *Nutrition Advisory Group to the Association of Zoos and Aquariums*, "the specific dietary requirements of vitamins, minerals, fat and protein for orangutans are not known" (Dierenfeld). All captive great apes are given nutritional supplementation in the form of processed foods with vitamins and minerals added ("Primate Diet Dry"). The primary ingredient in these supplemental food-like substances is starch. Starch is a semi-crystalline granule that is very difficult to digest ("Diet and the Evolution of Human"). Recently it has been discovered that humans

have abundant numbers of the gene known as salivary amylase, the enzyme responsible for breaking down starch into sugar ("Diet and the Evolution of Human"). Other great apes have the ability to hydrolyze starch as well, but to a much lesser degree ("Diet and the Evolution of Human"). Human and chimpanzee DNA is approximately 2% different, but that 2% difference, which includes the ability to digest starch more readily, was crucial for the evolution of humanity's earliest ancestors (Mcdougall).

Examination of the number of copies of the gene that is responsible for digesting starch has found an average of six copies in humans, compared to only two copies found in other primates (Mcdougall). This genetic difference results in the production of six to eight times higher levels of starch-digesting enzymes in human saliva. Therefore, the limited ability of chimpanzees and other great apes to utilize starch tied their species to the tropical jungles where fruits and foliage were abundant all year long (Mercader). Biological anthropologist Nathaniel Dominy of Dartmouth College theorizes that humans probably gained this adaptation as opposed to great apes losing it ("Diet and the Evolution of Human"). These particular mutations, which led to the gene that produces salivary amylase, allowed for a distinct advantage in our ancestors who ventured out of Africa.

The unique traits that humans have, like the ability to think abstractly and to communicate with language, as well as a large brain, and the ability to walk upright are no doubt characteristics of an awesome animal. According to a paper published in *Nature Genetics*, "hominine evolution is characterized by dietary shifts, facilitated in part by the development of stone technology, the control of fire, and most recently, the domestication of plants and animals" ("Diet and the Evolution of Human"). Chiefly, starch has become an increasingly prominent component of the human diet.

Examining the amount of amylase in humans and our closest primate relatives may provide insight into our own evolutionary history (Diet and the Evolution of Human). To better explain human evolution, there must have been something extraordinary, and that something is starch. Humans were remarkable animals long before engaging in agriculture and the domestication of animals. The factors that caused humans "to exploit what anthropologist John Tooby and evolutionary psychologist Leda Cosmides have jointly described as the cognitive niche" (Lisle & Goldhammer), can be explained by shedding a little light on the matter. Fire didn't come under modern hominids' control until about 1.8 million years ago (Wrangham). Interestingly enough, Harvard primatologist Richard Wrangham suggests that starchy plants were important sources of food for humans as early as 1.8 million years ago (Anthony). Cooking is the next logical step in this equation. Cooking allowed for greater digestion, allowing greater access to calories. Starches wouldn't have been important foods until we learned to control fire because starch granules are not efficiently digested in their raw state. We know that we ate meat but not as much as popular media suggests. Anatomically speaking, we aren't designed for meat eating. In fact, the enamel on our teeth is too thick, the cusps of our teeth are too short, and our canines are too blunt (Berthaume). We simply don't have the adaptations that tigers and bears have to eat meat. Instead, we developed a face and mouth that is excellent for eating plants.

Current mainstream thought links starch directly to the epidemic of obesity and type II diabetes (PCRM). Starch, however, was vital to human evolution. The reports that starch is somehow unnatural to humans or that starch was the downfall of human health and that we should eat more like our "paleolithic ancestors who consumed a diet of only meat, supplemented by fruits, vegetables, nuts, and seeds" is a façade (Cordain 71). Starch granules from plant food trapped in the dental calculus on 40-thousand-year-old Neanderthal teeth, revealed that the once-thought savagely primitive man actually shared a sophisticated diet with their contemporaries ("Starch Grains Found on Neanderthal").

> Research presented in a 2011 issue of *Proceedings of the National Academy of Science* shows that even the Neanderthals ate a variety of plant foods; starch grains have been found on the teeth of their skeletons everywhere from the warm eastern Mediterranean to chilly northwestern Europe. It appears they even cooked, and otherwise prepared, plant foods to make them more digestible-44,00 years ago (Mcdougall).

We know that an early pre-human, Australopithecus, was eating starch almost two million years ago (Mercader). Traces in their teeth of what they had eaten then, as well as over a lifetime of foraging

revealed they were grass eaters (Mercader). This information is important because it heeds way for a new way of thinking. No longer can we perpetuate schools of thought that hold on to the primitive understanding of man and his emphasis on hunting when the latest science clearly states otherwise. Fortunately, it's turning out that our brains are more plastic than ever thought before.

The brain requires only twenty watts of energy to function normally, similar to a conventional light bulb (Magistretti). However, as far as the body's energetic budget goes, the brain is a glutton (Magistretti). "The brain takes up less than 2% of body weight but may burn up to 50% of the body's fuel (Greger). This value means that the brain uses, per unit mass, twenty-five times more energy than the rest of the organism (Magistrettti). "What is news, however, is the role glycogen plays in the acquisition of long-term memory" (Anthony).

> A 2011 article published in the journal *Cell* titled *Astrocyte-Neuron Lactate Transport is Required for Long-Term Memory Formations* shows that glycogen in brain cells called astrocytes is necessary for the consolidation of short-term, transient memory into long-term memory. The effect of glycogen cannot be imitated by glucose, regardless of quantity (Anthony).

In other words, it is the direct storage of glucose in the liver and muscle tissue that literally feeds the brain. The formation of glycogen is the direct result of glucose intake in the form of carbohydrates. The most dense source of carbohydrates in the plant kingdom are found in the storage organs of plants, in the form of starch, and this includes rice, potatoes, yams, corn, beans, barley, etc. The glycogen that allows our brain to consolidate short-term memory into long-term memory is allowing humans to engage in such practices as recalling the past and planning for the future. Professor of Bioethics at Princeton, Peter Singer, has argued that this is the quintessential difference between humans and non-human animals (Bengtsson). The ability to look to the future and learn from the past defines the human experience.

As we look to the future, a grave prospect is at hand. Predictions have been made that the great apes will be extinct by the twenty-second century (News). Unregulated jungles in West Africa and the popularization of "bushmeat" can be partly to blame (Primatologist). Simultaneously, palm trees are being cut down at an alarming rate in Indonesia, the primary habitat of the orangutan (Orangutans and Oil Palm Plantations). Strikingly, more than two million human children die each year due to hunger-related issues (Global Hunger) while 141 trillion calories are discarded each year in the United States (Barclay). By adopting lessons learned from the fossil record and the human genome, we can mitigate these dire realties and predictions. The insights provided by the analysis of the salivary amylase gene must play a domineering role in the application of dietary appropriations for all of the great apes. "The future of nutrition is now inseparable from the future of humanity" and the great apes (Humanity Past and Future).

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