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Letter from the Editors

We are always indebted to the professors at the University of Rochester who take time out of their own research to review and support the research of undergraduates. This semester we had overwhelmingly positive feedback from these professors, which we were delighted to read but which made our decision more difficult than usual. After discussions with our editorial staff, we decided to publish a longer edition of JUR to stand by our mission of providing representation for undergraduate research. We are immensely proud to present this edition of JUR with all of the research that it holds.

We are grateful not only for the number of papers we are publishing this semester but also the breadth of research represented in the Spring 2019 issue. From optics to religion, this issue represents the range of the university's liberal arts curriculum. We are fortunate that our institution encourages research in all disciplines and that students are finding opportunities to explore their own projects within these subject areas.

With the large number of papers in this issue, we hope that more students will be inspired to start their own research projects or publish their existing ones. Each student at the University of Rochester is uniquely involved in a wide variety of extracurricular activities, many of them often getting more publicity than their research. JUR offers the opportunity to make this aspect of students' lives heard, and as we receive higher volumes of submissions we feel proud that we are fulfilling this mission.

Despite the objective nature of the submissions, we still find the unique qualities of student researchers in each paper we read. The topic, style, and presentation of the research offers insight into the author's creative and personal flair. This creativity is especially prevalent in the Spring 2019 issue of JUR where it's made clear that having more articles in no way reduces their distinctiveness.

As always, we offer a huge thanks to our entire editorial board, our advisors, and the professor reviewers. We would not have been able to publish the extraordinary work of our fellow students without them. We hope you enjoy this tour through the worshiping of Guanyin, Drosophila lipid droplets, job opportunities in Zimbabwe, and more. Please join us in celebrating the wonderful Spring 2019 of JUR!

Sincerely,

Michelle Klein and Victor Zhang

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Mid-Wave Infrared Photodetectors

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Introduction

Infrared detectors, specifically in the mid-wave region (3-8μm), have far-reaching military and civilian applications. From medical research to missile defense to atmospheric sensing, devices designed to operate in this region impact lives in numerous ways. However, such detectors remain difficult and expensive to produce [1]. In order for these devices to become more prevalent in daily use, understanding their limitations and how to improve their design is absolutely essential.

Initially, the simple photoconductor was used as an infrared detector. Advancements in material fabrication techniques later produced the p-n photodiode, which was a significant improvement over the photoconductor. Current research is now focused on compound semiconductors that can be designed in unique ways to further improve detector performance and will be the topic of discussion for this paper [2].

The Photoconductor and P-N Junction-Based Diode

To appreciate the advantages and benefits of compound semiconductor devices, it is worthwhile to discuss earlier types of detectors and their limitations. The photoconductor consists of a single material (typically n-type) with metal contacts. Incident light is absorbed by the n-type material, thereby generating an electron-hole pair. When the device is operated at a reverse bias, the current flowing
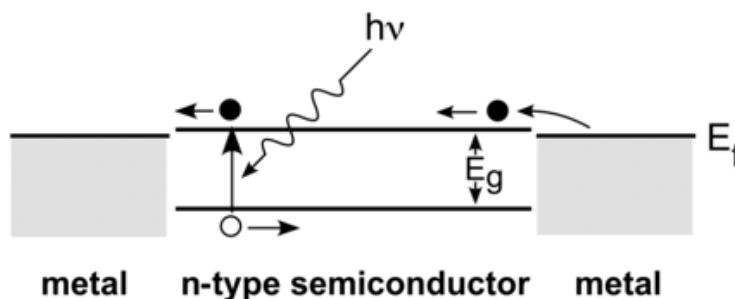
Figure 1. Band diagram and operation of a simple photoconductive device. The incident photon is depicted by hv. The metal contacts for flow of current are also shown [2].
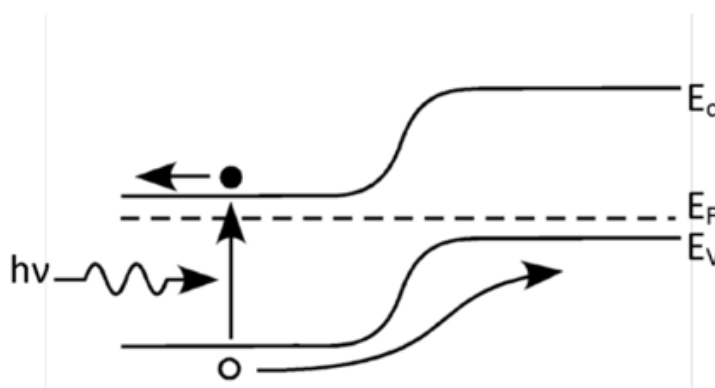
Figure 2. Band diagram and schematic of a p-n photodiode. The n-type is shown on the left and the p-type is shown on the right. The center region with the sloping energy bands is known as the depletion region [2].

ohmic, there is nothing preventing the flow of majority carrier electrons from contact to contact. This means that more current, other than that generated by the incident photon, is produced across the detector, giving the impression that more photons were incident on the detector than in actuality. This device is also extremely sensitive to spontaneous electron-hole pair generation due to thermal fluctuations and must be operated under temperature controlled conditions [4]. As with most of the detectors discussed in this paper, the simple photoconductor is

the position of the valence and conduction bands, the p-n photodiode has a built in barrier which blocks the flow of majority carriers [2]. This device is based on the standard p-n junction and does not need to be operated at a reverse bias. As with the simple photoconductor, incident light with energy equal to or greater than the bandgap energy (Eg) is detected. While this device design is an improvement, other sources of dark current (current not produced by incident light) now limit performance; tunneling is problematic and background noise must still

be addressed. Another phenomenon, known as Shockley-Read-Hall generation (SRHG), also produces unwanted current in the depletion

The nBn Photodetector

The nBn structure is shown in Fig. 3. This mid-wave infrared detector consists of an n-type semiconductor, an extremely large band gap undoped barrier layer, and a second thin n-type layer. The joining of the layers, known as heterojunctions, are unique in that there is no valence band offset, rather all of the bandgap differences appear in the conduction band [5].

With this new device structure, majority carrier current, tunneling, and SRHG are all effectively eliminated. The large barrier layer stops the flow of majority carrier current from the right contact to the left contact, just like the natural barrier did in our p-n photodetector. Next, the height of the energy barrier can be made sufficient enough such that the probability of tunneling is effectively zero. The probability of tunneling can be calculated by applying the time-independent Schrödinger equation to the n, B, and
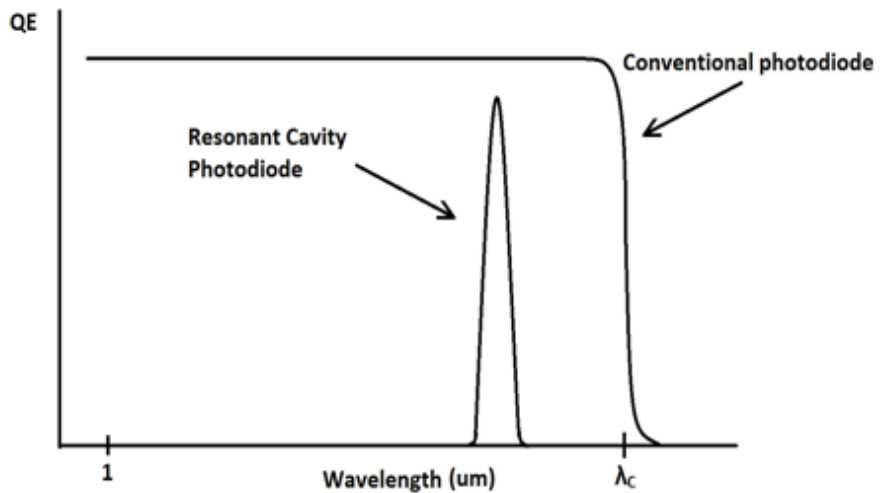
Figure 4. Quantum efficiency (QE) of a conventional photodiode and a resonant cavity photodiode (RCP). Notice the sharp increase and decrease in sensitivity of the RCP while the conventional photodiode has a broadband sensitivity [4].

n regions. Recall that tunneling was an issue with the p-n photodetector.

Lastly, SRHG can be made to be zero. SRHG is when an electron-hole pair is generated from a trap, or defect, state in the forbidden region of a semiconductor. This trap state is much more likely to exist when the Fermi level energy (Ef) is located at the midgap energy (Emid). In a p-n junction-based photodiode, Ef = Emid at the center of the depletion region, as can be seen in Fig. 2. It is thus unsurprising that the high-

est levels of SRHG are found in the depletion region of p-n photodetectors [6]. If we look at Fig. 3., we can see that nowhere in the device is the Fermi level near the middle of the bandgap. This effectively suppresses the SRHG current that typically limits cooled p-n junction-based photodetectors. Of course, background noise is still an issue, and a stop and filter must be used to suppress the unwanted signal.

Future Work

If one is able to successfully suppress all major forms of dark current (majority carrier, tunneling, and SRHG), the detector is then limited by either Auger recombination or background noise. While Auger recombination is out of the scope of this paper, it is worth discussing the impacts of background noise. If the source of interest is surrounded by other 'bright' sources, it may be difficult to resolve the desired source, even with an otherwise perfect detector

For most infrared detectors, the solution is to use a field stop to limit the
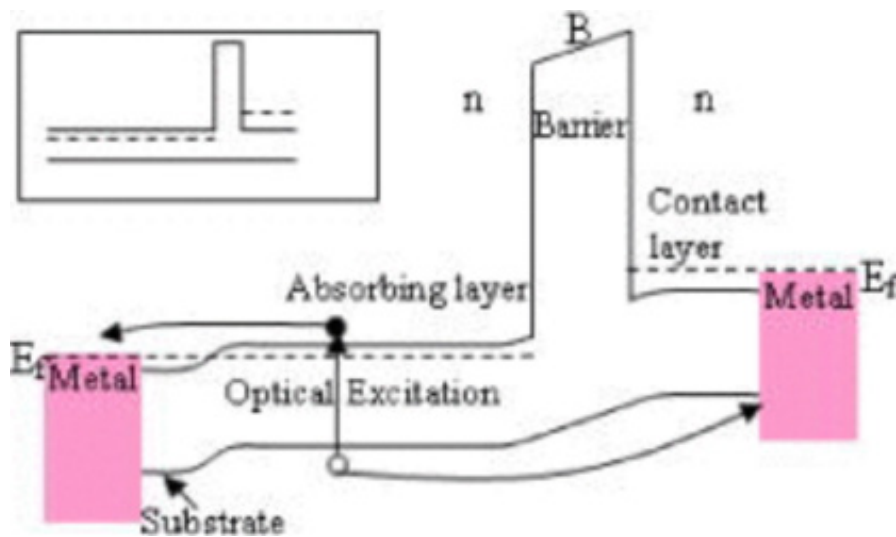
Figure 3. Band diagram and schematic of a biased nBn photodector. The n-type absorbing region is shown on the left, the barrier in the center, and the thin n-type contact layer on the right. Inset: unbiased nBn photodetector [2].

field of view of the detector and to use a filter. Current research looks to combine the filter and detector into a single device known as a resonant cavity detector (RCD). This device leverages the resonance behavior of a Fabry-Perot cavity. Two mirrors are formed to create a cavity whose thickness is tuned to accept the wavelength of interest and reject other wavelengths; this behavior can be seen in Fig. 4.

Techniques currently being investigated for fabrication of these devices are via molecular-beam epitaxy or physical vapor deposition such as sputter deposition. Typically, a mirror layer is deposited, then the detector itself is deposited, followed by the final mirror layer. Since the resonance of the cavity is very sensitive to the layer thicknesses, extreme precision is required: any error will result in the peak QE occurring at the wrong wavelength.

Conclusion

nBn photodetectors are significant improvements over their previously developed counterparts. Majority carrier current, tunneling, and SRHG current can all effectively be made to zero. With new research on RCDs underway, we can expect effects produced by unwanted background noise to also be made to zero. Although undiscussed, Auger recombination is then the limiter for detector performance and will need to be investigated for additional gains to be made.

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Balancing Facilitation and Friendship as a Workshop Leader

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Of all of the college courses that appear in a large number of degree curricula, organic chemistry is perhaps the most notorious. It has a prolific reputation for presenting great difficulty and discouraging students from pursuing their original choices for major programs due to negative outcomes. This stigma has a significant effect on those who enroll in organic chemistry, not only inspiring fear but also hindering the transition from memorization-based learning to higher cognition levels necessary for conceptual mastery[1]. Incorporating the Workshop model of peer-led team learning (PLTL) as a supplement for student engagement has a demonstrably ameliorative effect on these damaging, stigmatic preconceptions [2,3]. When students can share the trepidations they feel and decentralize the notion of an insurmountable challenge while working together to assimilate the content into their own mental models, their attitudes about the course *and their performance* both markedly improve[2]. It is possible, then, that students' cognitive and emotional experiences in Workshop are appreciably distinct from those in lecture or during office hours. In addition to their interactions with each other, reformulating and processing knowledge according to their nascent levels of understanding, students also depend on a constructive relationship with their Workshop leaders.

It is well-established that the relationship between instructors and their students directly influences those students' educational and sociological outcomes within the course and within the subject field altogether[4,5,6]. In kindergarten students, a bond between teachers and students characterized by trust and friendliness has been shown to positively affect not only academic performance but also transitions into new classroom environments[4], the latter being particularly critical for psychological safety in a college class or Workshop given typical unfamiliarity. Friendliness, as used here, is a multidimensional dynamic including warmth, affection, receptivity to praise, low frequency of anger, and engaged conversation on students' life events[7]. In mathematics, the level of support that junior high students perceive on the part of their teachers has been directly correlated with their attitudes on the intrinsic value and usefulness of the entire subject[5]. It is thus unsurprising that conflicts between students and teachers measurably increase students' anxiety levels in the third and fourth grades, particularly among high-achieving girls[6]. To prevent such consequences, and to maintain a high standard for psychological safety in Workshops, leaders must take an active role in cultivating a trustworthy and supportive rapport with their students.

But what kind of relationship best fulfills students' needs, both social and educational, at the college level? The aforementioned research confirms the conceptual importance of the student-instructor bond, but even the oldest subjects in these studies had only just entered high school. Comparatively few investigations have been conducted on this dynamic for university students, but the Workshop PLTL paradigm may provide a starting point. The peer leaders are much closer in age to their students than instructors and, therefore, from a cultural and professional standpoint, have an inherently greater chance to present themselves as someone with whom their students can identify. This notion that students' instructors are "someone like them," or someone who can understand the stress and considerations of their lives has been shown to breed positive outcomes for academic achievement[8]. More specifically, this increased personal familiarity presumably begets better communication, which leaves more time for identifying and addressing individual educational needs[8]. Furthermore, stemming from this communication, open and honest dialogue about course material between students and instructors has been shown to support more critical thinking and deeper cognitive engagement with the material[9].

At present, the *relative* merit of students sharing personal information or educational concerns and preferences on a friendly basis is unclear. That is, in the construction of a productive relationship between Workshop leaders and their students, what sort of

dynamic yields the best student outcomes? The importance of personal engagement has already been outlined, but regarding input on instructive practices, leaders must be judicious as to which exchanges are actually informative. For instance, as of 2014, a survey of teachers showed that about 76 percent still apply the concept of learning styles to their instructional techniques and lesson plans based on their interactions with students, but this theory has been resoundingly refuted by the pedagogical community at large[10,11]. And even if students volunteer this information themselves, the research shows that they are seldom correct in pinpointing their strongest sensory learning skills and lack concrete rationales for their choices[12]. With respect to the field of organic chemistry, however, the progression of theories and problem-solving methods over the last century depend heavily on visuo-spatial reasoning, and the benefits of both physical and virtual modeling kits for students' 3-D cognitive abilities are unequivocal[13,14,15,16]. Consequently, it may be difficult for Workshop leaders to discern which thoughts and preferences that students bring to the Workshop should inform their pedagogical approach to facilitation. This example is part of a larger challenge to discover the axes along which they relate to their students that best support a productive, psychologically safe environment and, ultimately, performance and self-fulfillment in the course. The goal of the present study is to investigate the components of productive relationships between college-level students and their Workshop leaders (WSLs) and connect these to specific strategies that WSLs may further develop. Students' perception of Workshop quality, their comfort in the environment, their trust in their respective leaders, and their content-

ment with the course altogether will be assessed following the administration of controlled surveys, designed to either cultivate friendship or to clarify educational needs, and following the collection of data through student interviews. More broadly, this will provide Workshop leaders with a more concrete understanding of how to constructively relate to their students and of the merits of different engagement strategies with respect to maximizing the students' sense of satisfaction in their learning process.

Methods

In this study, the subjects were comprised of students enrolled in the first of a two-course sequence in introductory organic chemistry for both first-year students (N = 53) and upperclassmen (N = 372). The experiment was conducted in two main phases. In Phase I, the 42 Workshop leaders employed for the Fall 2018 semester were randomly divided into three groups. Each of these groups was then assigned an experimental group: educational survey administration (Group 1), personal survey administration (Group 2), and no survey administration (Group 3, negative control). During the seventh week of the 14-week semester, the links to the surveys were distributed to the WSLs for administration to their students in the Workshop session. Both surveys anonymously solicited participants' class year, current gender identity, and the name of their WSL. Following the collection of all of the responses, these were distributed to the respective WSLs.

The educational survey (49.4% response rate) asked students about "learning preferences" and how to "optimize Workshop." In the former section, to provide the WSLs and

students with some common ground of pedagogical understanding, two questions allowed students to select from any one or more of options aligned with typical visual, auditory, and kinesthetic categories, while the second two questions asked students to describe their study strategies for general chemistry and their anticipated strategies for organic chemistry. Finally, the participants were encouraged to recall the experiences that they believe contribute to their present learning preferences. For "optimizing Workshop," students were given free-response opportunities to make specific recommendations to their WSLs for Workshop activities and to share with their WSLs something about "[their] learning process."

In the case of the personal survey (34.6% response rate), the questions were more arbitrary, seeking to provide the WSLs with a general sense of familiarity with their students, their campus life, and their overarching goals. Some selected questions include "What made you choose the University of Rochester?", "How would you describe your favorite genre(s) of music?", and "Where do you see yourself 10 years from now?" At the end of this survey, as well as with the educational survey, participants were asked if they would be willing to have a further conversation (interview) about their experiences in Workshop and how they inform their perspectives on the most productive relationship with a WSL.

Over next three weeks, five agreeing students were interviewed and posed the following questions:

"How big of a part does your Workshop experience play in your educational experience and level of personal fulfillment in a class?"

"(For upperclassmen) What was your relationship like with your general chemistry WSL? How do you think this impacts your relationship with your WSL for organic chemistry?"

"(For first-years) What was your relationship like with your teachers in high school or secondary school chemistry? How do you think this impacts your relationship with your WSL for organic chemistry?"

"Do you think that a WSL should be only an educational guide or a friend? Or both? Or neither?"

"What is one thing that could be better about your relationship with your WSL or his/her/their leadership of the Workshop environment?"

Six weeks after the administration of the Phase I surveys, during the thirteenth week of the semester, Phase II was carried out. A survey (17.4% response rate) was distributed to all WSLs, regardless of Phase I experimental group, for administration to their students during Workshop session. Apart from two free-response questions allowing students to provide direct feedback to their WSLs, both regarding the Workshop environment and their relationship with the WSL, this survey was quantitatively oriented. Nine aspects of the educational experience were assessed: the usefulness of Workshop discussions with respect to understanding organic chemistry (1), the friendliness or familiarity of the interactions between Workshop members (2), the perceived benefit of Workshop attendance with respect to course performance (3), the level of psychological safety (freedom to participate, respect, comfort in engaging with leader or peers)(4), the level of trust with the WSL (5), how well the WSL understands the students' educational needs (6), the perceived

level of support from WSL to succeed in organic chemistry (7), the level of personal satisfaction with the students' learning experience in organic chemistry (8), and the quality of the students' feeling about the decision to take the course (9). Each was measured on a four-point Likert scale, with each most positive attribute being 4. Wilcoxon's sum-of-ranks tests were completed for each covariate group pairing (1-2, 2-3, 1-3) with Phase I experimental group, self-reported gender identity, and class year as covariates.

Results & Discussion

Phase I: Surveys

The results obtained from the educational Phase I survey confirm the validity of the practices in which WSLs are trained within the University of Rochester's Workshop program. Students generally assented to the importance of pacing, such that all Workshop members comprehend a problem before progressing, as well as the benefits of the WSL giving a summary of the session's core material either before or after the completion of the problems. Additionally, the respondents pointed to the need for judicious use of either small groups or group-wide discussions on the part of WSLs for certain problems. In some situations, students indicated that the faster-paced, better-contained small-group discussion best balanced efficiency and detail, while in others, typically concept-heavy problems, this could leave some students behind. The latter, thus, would be better managed with a group-wide approach, with all members of the Workshop simultaneously part of the same discussion. Regarding study strategies, it seemed that students are most comfortable with the methods that they have already tried and honed in previous

courses. The most popular responses included the use of a textbook for lecture preparations, learning terminology, and practice problems; repeatedly attempting Workshop problems; and working through practice exams. Very few students (<5% of respondents) indicated an intention to formulate an entirely new study pattern distinct from their previous methods. Just as students typically assimilate technical content into existing mental models rather than constructing new models , it appears that their study techniques develop similarly. In the personally-oriented Phase I survey, when given the chance to tell their WSLs "anything" about themselves (without any prompt or guidance as to the topic), 62.5% of students spoke to some aspect of work-ethic, educational attitudes, interest in organic chemistry, or learning difficulties. Most of these responses appeared to honestly treat concerns about performance in the course while giving a statement of resolve or effort. Selected examples follow:

I have a sequencing disorder similar to dyslexia so stereochemistry is proving to be challenging. Anything that involves flipping the orders of things is hard for me to distinguish. If I work hard enough to figure it out I can usually compensate but it might take me a while to get it. (Female student, class of 2021)

I actually do want to understand all the concepts we go over but I'm kind of a slow learner. (Female student, class of 2021)

I'm always overwhelmed with school work and I'm always going through the day with very little sleep. So if I seem out of it, don't take it personally. Being a STEM student in the school is really hard and drains a lot out of you. (Male student, class of 2020)

I tend to be very shy so it takes time to break that shell and be comfortable around a group. (Male student, class of 2021)

When presented with an opportunity to develop their relationship with their WSLs, students seemingly anticipate that their WSLs' opinions of their performance in Workshop will play an influential part in that relationship. Here, specifically, students make statements that clarify the source of potential issues or difficulties, presumably out of a belief that if these are left without explanation, their rapport with their WSLs will suffer. Chong et al. have contextualized this pattern, demonstrating that perceived support from instructors is significantly related to academic performance, resilience, and self-efficacy[17]. Therefore, as students set out to establish a supportive relationship with their WSLs, it is reasonable to suspect that they believe that exhibiting these attributes in Workshop is a necessary stage in that process.

Phase I: Interviews

The five interviewees each uniquely expressed that Workshop is an essential supplement to the experience of organic chemistry. It provides an opportunity for dialogue and discussion of thought processes, rather than discussions of only the material itself. This "validates everything that [they] have learned independently," offering students a chance to lay bare their mental models and receive feedback with relative immediacy, contrary to the one-way information flow of lectures (first-year, Chinese male student - Respondent 3). Much like learning a language, to which the study of organic chemistry is often compared, students can safely "translate [what they have learned] into their own words" and

not consequently wonder about the accuracy of their statements or tentative, novel connections (second-year, white male student - Respondent 1). One student also highlighted Workshop's utility as a consultation for organization, saying that "Workshop is incredibly helpful…[for] keep[ing] on track and [choosing from] so many paths to take for studying" (third-year, Asian-American male student - Respondent 5). The dialogue that students have with their WSL and each other helps to reveal weaknesses in comprehension and guides students to discover shortcomings in their understanding that may have gone undetected otherwise. These responses thus suggest that a large part of the unique benefit that Workshop provides lies in the meta-cognitive aspects of the discussion. It purposefully does not solely revisit the lecture material, but rather encourages students to achieve, or at the least routinely emulate, the self-assessment and analysis characteristic of Bloom's "evaluation," an essential milestone toward mastery[18].

Upperclassmen, having had previous experiences with WSLs for general chemistry, called upon these experiences to clearly delineate between effective and ineffective leadership styles. Most crucially, a WSL should be well-versed in the subject material and approachable with questions and concerns. Leaders who have taken the class the year or semester prior, the students indicate, are typically those with whom they can most closely relate, both in terms of mental model similarity and commonality of collegiate experience. This, in turn, supports conversations about organic chemistry and "time-management [and]…other courses" (second-year, white female student - Respondent 4), ultimately building trust between stu-

dents and WSLs, with students feeling able to place confidence in "someone who's been through it before…[and now] doing bigger and better things" (Respondent 4). The resultant degree of trust and respect likely has a strong influence over students' willingness to engage with the Workshop environment: "…how willing they are to help me has an impact on how much I'm willing to give back to them" (Respondent 5). To this point, leaders who seem more distant as a result of reinforced "power dynamic[s]" and "[not] understand[ing]as much as they should" presumably disadvantage themselves from completely open communication with their students (Respondents 1,5). Thus, both a solid grounding in logical and ethical authority and a clear motivation to give students a positive experience are of paramount importance. The first-year interviewees, who called upon previous experiences with chemistry teachers, echoed that these traits are crucial for the function of Workshop as a resource that provides "a different thing than a teacher…not [simply] replacing bad answers with good ones" (first-year, white female student - Respondent 2); "Workshop leaders know the material that they need to teach even better than teachers in high school, and we can trust them more as a result" (Respondent 3). Therefore, the appropriately narrowed scope of WSLs' knowledge and presentation of the material, with respect to that of instructors, factors into the degree of trust enjoyed with their students. This emphasizes the importance of effective WSL training in management of discussion and curation of level-appropriate Workshop content. If WSLs do not challenge students' potential for comprehension or leave them confused with appeals to higher-level analyses, this will be to the detriment

of their relationship.

The central question of the study, on whether students feel WSLs should take the role of educational guide, friend, neither, or both, was met with a diversity of answers. While all of the interviewees agreed that a WSL must be partly both an authority on the material and a friendly figure, they had different opinions about the relative merit of each of these roles. Some students reflected that the position cannot be fulfilled without an aspect of friendliness:

"*…leaning toward friend…the point of Workshop is that students can ask you what they couldn't ask a professor…can open up about the multifactorial nature of class performance…can ask for [help] in life…can't have that without friendship.*" (second-year, white male student - Respondent 1)

"*…friendliness is important for students not being afraid to say what they think, as they probably would be with a teacher or professor.*" (first-year, white female student - Respondent 2)

"*…it is important to have some further relationship…this is the key to students looking forward to going to Workshop and not having it be like pulling teeth.*" (second-year, white female student - Respondent 4)

To the contrary, some students decisively ranked facility with the material over any degree of familiarity or friendliness:

"*…most important is that the WSL knows the material. If they don't know anything then nothing else matters, and developing relationships comes after that in terms of making things effective.*" (first-year, Chinese male student - Respondent 3)

"*It's a very fine balance…maybe 60/40*

or 75/25 educator to friend…important to know what you're doing because it's very impeding to the flow of Workshop to have the WSL not be able to answer simple questions." (second-year, white female student - Respondent 4)

"*Definitely both, but the most important thing is knowledge…[I] can tell when the WSL is describing things from their own perspective or memory, but if this is hidden in friendly talk, [I] feel less confident in what I'm learning.*" (third-year, Asian-American male student - Respondent 5)

From these responses alone, it is difficult to draw conclusions about the relative merit of WSLs cultivating pedagogical and friendly relationships with their students. It is clear, however, that effective WSLs project a personable and authoritative identity to students, answering questions within the boundaries of students' course material, focusing the scope of the discussion to match, and interacting with students openly and empathetically with respect to their own course experiences. The interviewees' input informs a scrutiny of some of the potential problems within Workshop, suggesting that they may arise by virtue of this relationship skewing to one extreme or the other. For instance, if students do not seem receptive to the WSL's guidance or direction, the discourse in which their relationship has been grounded may be too informal or too familiar. Aultman et al. present anecdotal evidence for this danger at the elementary educational level, with students disobeying teachers or refusing to participate in lessons because they speak of the teachers as friends[19]. While the dynamic is considerably mature at the college level, it is still reasonable to suppose that due to the lack of an educational dynamic among students and their friends outside of

class, the friendlier a WSL becomes, the less students will respond to the maintenance of an academic relationship while in Workshop. On the other hand, if WSLs observe that the flow of information among group members is inefficient or irregular during problem-solving, it may be due to the way relevant aspects of the material were framed and highlighted. This may require a course-correction to reassert the common ground of concepts necessary for the Workshop problems and should indicate to WSLs that they may benefit from revisiting the material to enrich their discussions and promote better organization of content.

Finally, the interviewees were asked for their recommendations to improve both their relationship with their current WSLs and their WSLs' approach to leading and organizing Workshop. Three main themes emerged here: pacing, pre-Workshop review, and group divisions. One student pointed out the issues arising from a WSL too eager to provide clarity: "[The] biggest thing is encouraging the struggle of trying to figure problems out…doesn't encourage the group struggle enough and all participation…those [questions] make the Workshop worthwhile and productive" (Respondent 1). Another complained of the opposite, reporting that " [t]he pace is a little too slow…[I] don't want [the WSL] to give the answer right away, but it can lead to sitting in silence…no smooth facilitation, no one knows, and no learning…cueing in more quickly would be better" (Respondent 4). This confirms the importance of monitoring the flow of conversation, which the Workshop program already heavily emphasizes for its leaders, and adjusting the type of discourse to meet students' needs given their levels of comprehension. The class itself, whether for first-

years or upperclassmen, may have an independent impact, however. Students with different levels of intrinsic motivation to study and comprehend organic chemistry likely had different expectations for the pace of Workshop discussion and distinct needs to be fulfilled through the WSL's input. In the first-year course, for instance, students might be more inclined to "struggle" with the material for longer than in the upperclassmen course, changing the optimal level of WSL input to the problem-solving process. As part of a second theme, two students focused on the substantial benefit of WSLs taking the time to review the relevant material to prime the discussion before approaching the problems:

"[I] like him going over the material in the beginning as a proactive review of stuff that might be confusing", and Workshop "…generally works better if WSL goes over general concepts before breaking off into small groups because we don't know where everyone stands before the problems, and going around to individual groups is really slow…" (Respondents 3,4). As a consequence of this, as Respondent 5 reflected, divisions into small groups may be "intimidating" for students who "don't fully understand the material". This underscores the importance of WSLs' ability to take stock of their students' understanding of the material rather than executing a formulaic Workshop format. To establish a bedrock of rel-

evant concepts, it appears that a brief review at the beginning of Workshop can refresh students' cognitive toolkit, and depending on the collective facility with these concepts, a large-group discussion may be more appropriate for optimizing consistency and efficiency.

Phase II: Survey

As shown in Table 1, the experimental group treatments through the Phase I surveys had no significant effect on students' reported ratings of the nine aspects examined. One limitation of this study was the non-compulsory nature of the surveys, meaning response rates were limited (see Methods) and data could not be matched by WSL for

Figure 1. Box-and-whisker plots of statistically significant Phase II survey results across gender identitiy. Note: N(female) = 47, N(male) = 37, N(other/non-binary) = 2; **$p < 0.050$, "×" denotes mean

Figure 2. Box-and-whisker plots of statistically significant Phase II survey results across class year. Note: N(2020) = 9, N(2021) = 39, N(2022) = 38; **$p < 0.050$, ††$p < 0.050$, "×" denotes mean

Table 1: Wilcoxon sum-of-ranks p-values for Phase II survey covariates. Cells give p-values for tests among groups 1-2, 2-3, and 1-3 (descending). For experimental group, 1 = educational survey, 2 = personal survey, 3 = no survey. For gender identity, 1 = female, 2 = male, 3 = other/non-binary. For class year, 1 = 2020, 2 = 2021, 3 = 2022. Note: **$p < 0.050$

Aspects	Comparison by group		
	Phase I Experimental Group	Gender identity	Class year
Usefulness (1)	0.774 0.656 0.928	0.826 0.118 0.130	0.275 0.916 0.257
Friendliness (2)	0.265 0.618 0.578	0.722 0.374 0.397	0.930 0.767 0.764
Benefit (3)	0.903 0.755 0.864	0.111 0.670 0.333	0.532 0.603 0.351
Psychological safety (4)	0.480 0.859 0.599	0.950 0.356 0.397	0.930 0.659 0.751
Trust (5)	0.930 0.796 0.739	0.897 0.887 0.856	0.600 0.572 0.881
Understanding (6)	0.766 0.769 0.538	0.301 0.060 0.109	0.570 0.875 0.527
Support (7)	0.825 0.880 0.944	0.795 0.414 0.486	0.146 0.727 0.237
Satisfaction (8)	0.427 0.449 0.920	0.017** 0.127 0.333	0.580 0.006** 0.040**
Feeling on enrollment (9)	0.903 0.412 0.544	0.093 0.047** 0.079	0.513 0.022** 0.067

more rigorous non-parametric testing. The fact that the treatment did not reach all the intended recipients may have contributed to the lack of significance of the results. However, whilst stating this, a single survey administered by a WSL is unlikely to be the primary determinant of the dynamic between the WSL and the students. These relationships are built through months of trial-and-error, frustration, accomplishment, and growth, and in order to have the best opportunity to make a significant, positive impact on their students' lives, WSLs must continually take an interest in both the types of information solicited in the Phase I surveys. As evidenced in the interview responses, a smooth and efficient Workshop paradigm can only be achieved when a WSL has cultivated a thorough understanding of the students' educational needs and enough familiarity to cushion the intense hours of teamwork that meet those needs. However, when examining the results by the covariates of gender identity and class year, five significant differences emerged, all within the two aspects of educational satisfaction (8) and quality of feeling about the decision to enroll (9). A graph of these results can be seen below.

The significant differences displayed above appear to be functions of demographic information, or perhaps, what occurs as part of these students' experience in Workshop as a result

of this information. In the case of the analysis shown in Figure 1, women and gender-variant students face an enormous range of negative biases, treatment, and stereotyping, especially in STEM curricula[20,21,22,23,24]. It is beyond the scope of this investigation to elucidate the particular experiences that contribute to these groups' consistently less positive sentiments on the experience of organic chemistry education. Any of the results from the Spring 2018 semester could be at play, including a WSL's failure to ease transitional in the early weeks, when anticipatory gendered behaviors play their largest part, or ongoing reflections of bias that inhibit psychological safety[25]. However, these results call attention to the crucial goal of creating a safe, inclusive learning environment, both in lecture and Workshop, to mitigate the biases that have discouraged women, gender-variant people, and other minorities from achieving their highest academic potential. In Figure 2, based on course descriptions and prerequisites, the data show a predictable pattern. At the University of Rochester, any student enrolling in the first-year course makes a deliberate choice and must have required AP or IB scores in chemistry to do so. These students decide to challenge themselves during their first semester of study, presumably out of a high level of intrinsic interest. It is logical to suspect that they experience more fulfillment in acquiring and applying this knowledge than otherwise suspected. However, given the limitations of this study, it is unclear whether this trend arises from the students' interest or from discrete events occurring within the course, but the choice of course may not be independent from aspects 8 and 9.

Conclusions

The relationship between WSLs and their students is evidently complex and holds distinct nuances for each learning approach that students bring to the course. Whereas the research on these connections has been limited to students up to high school age, this study aimed to examine them at the collegiate level and clarify the social and behavioral components that productively ally students with their WSLs. The results suggest that WSLs meet the students' needs as an educational guide, and depending on the degree of friendship or familiarity between them, smooth interactions and catalyze group development among all Workshop members. While this is fairly intuitive, this study expressed the importance of establishing restrictions on each of these identities.

Students report the perception that the unique benefit of Workshops stems from the psychological safety in talking freely about both problems and thought processes in problem-solving techniques, which can be hindered through WSLs' over-management of discussions or inflexibility to varied approaches. On the other hand, though with a similarly negative impact, a lack of control by the WSL leading to unstructured dialogic discourse can leave students feeling isolated or unheard. Furthermore, impediments to the flow of discussion due to unanswered questions can perturb students' trust in their WSLs or the value of their efforts in Workshop. Assuming that WSLs come to the role with an adequate mastery of the subject material, it is incumbent upon them to organize Workshop around key concepts in such a way as to not constrain the students to a limited number of problem-solving methods.

One excellent technique for achieving this paradigm appears to be a brief review of relevant content at the beginning of Workshop. They must also establish level-appropriate standards for the scope and pace of Workshop discussions in order to maintain focus and motivation on the routes to solutions, adjusting as necessary to meet students at their present depth of comprehension.

The similarity in age and experience among students and WSLs allows for communication that, as students reflect, is appreciably less comfortable to share with professors. It gives students a resource who can closely identify and empathize with their plights (as first-time scholars of the subject matter) and undoubtedly promotes their psychological safety throughout the course. Without a personal rapport and cordiality of interaction, such a relationship cannot be achieved; yet over-familiarity therein may have diminishing returns at a certain threshold. For some students, for example, containing technical information within informal conversation may be distracting and may actually lessen the perception of WSLs' expertise among the Workshop members. At the same time, it is evident that students typically desire to have a friendly, working relationship with their WSLs - as opposed to an unfamiliar dynamic - and believe that their performance in Workshop may impact their ability to cultivate it. Most often, this seems to manifest in students' preemptive concern that struggling will damage their rapport with leaders, which could inhibit their intellectual comfort while in Workshop and in turn reduce the educational benefit. It is thus essential that WSLs remain vigilant to the potential for distraction in informal discourse while also emphasizing to

students that their support is intrinsically motivated, not conditionally dependent on students' facility with the material.

Workshop provides several important services to students in the program, but not all are as accurately measured through quantitative methods as course performance. The direct correlation between Workshop attendance and course performance has been thoroughly evidenced for more than a decade[26,2]. However, this is not the only benefit that students may extract from the Workshop environment. Having more thorough and engaging discussions of the material alongside peers, rather than simply with the professor, promotes interest and satisfaction in learning, which supports material retention in STEM education[27]. The limitation of this study's quantitative approach in Phase II is that students likely do not reflect on their encounters and emotions in a mathematical manner. Anecdotes, however, demonstrably give richer information and more thoroughly clarify students' agency in reacting to and dealing with issues that arise during the course. An interview-based approach to data collection in future investigations may elucidate the experiential motifs among different gender identities and class cohorts that contribute to students' feelings about their education. Beyond these, there are undoubtedly other significant trends not resolvable through statistical testing that underlie students' perceptions of Workshop and that may emerge from such conversations. These data will add to the existing range of considerations that WSLs take in their efforts to rigorously and cordially supplement their students' instruction through guidance, patience, and appeals to their highest intellectual potential.

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Seismic Reinforcement Analysis of the Triumphal Arch of the Church of Andahuaylillas, Peru

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Introduction

Perched in the Andean village of Andahuaylillas, Peru, the Church of Andahuaylillas (official name: San Pedro Apóstol de Andahuaylillas Church) is one of the most important monuments of early colonial religious architecture from the late 16th or early 17th century (Figure 1). It is an important artistic and historical resource for the region today, and a key tourist attraction in the local area.[1] However, the repeated seismic activity in that area and the brittle nature of the construction material (adobe) have led to the structural instability of the church.[1] Given the significant role of the church, it is urgent to keep the church structurally intact.

The church is composed of a main nave and a presbytery, separated by a triumphal arch (Figure 2a).[2] This research specifically focuses on analyzing the Triumphal Arch section of the church (Figure 2b), which contains a tympanum in the middle and two side

Figure 1. St. Peter Apostle Church of Andahuaylillas: (a) location on the Andean baroque route and (b) the church façade.

walls connected to it. Specifically, this work focuses on evaluating the effect of steel bars and steel frames inserted in the arch in order to increase its resistance to seismic loading. By numerically analyzing different ways of strengthening the Triumphal Arch, using non-linear 2D Finite Element models in Abaqus CAE/Explicit[3], a solution for stabilizing the church while maintaining its original architectural design and aesthetic may be found.

Objectives and Methods

Research Objectives

One factor that quantifies the effect of an earthquake is the peak ground acceleration (PGA), an estimation based on actual recordings of the maximum ground acceleration that can be expected in a particular area, usually given with the probability of occurring over a certain period of time. For the village of Andahuaylillas, the estimated maximum PGA is 3.2 m/s^2 (32.6% g), with a 10% probability of occurring in the next 50 years.[4] The goal of this research is to ensure that the church
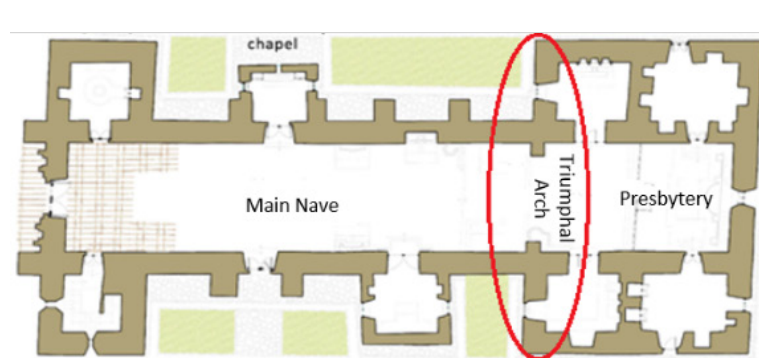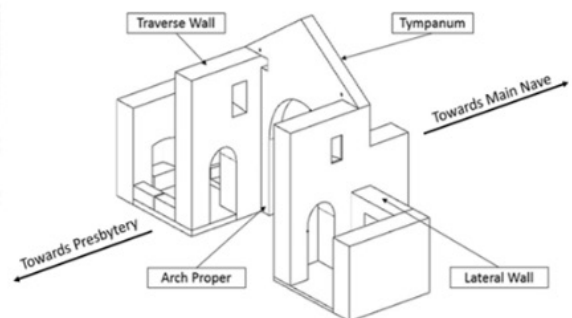
Figure 2. Architectural representation: (a) plan view of the church, and (b) 3D model of the triumphal arch.[2]
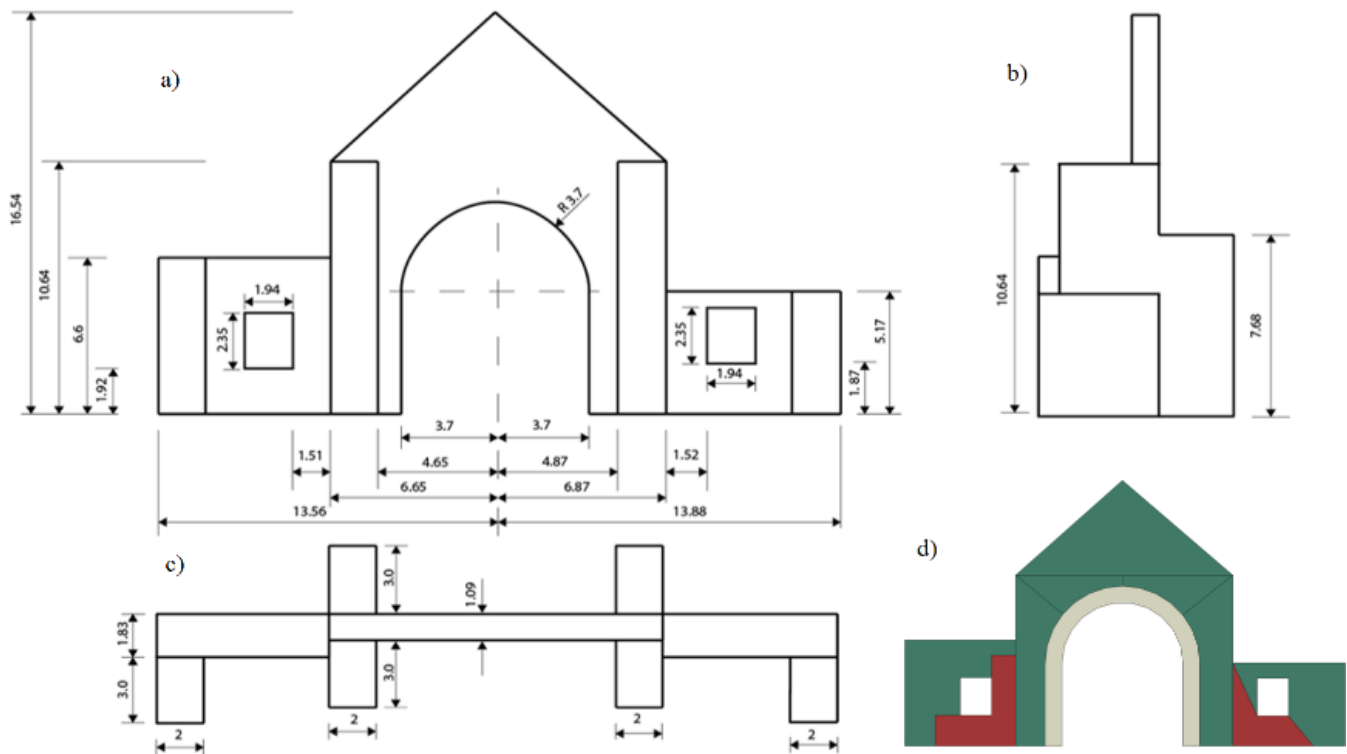
Figure 3. The triumphal arch and connected structures: a) front elevation, b) side elevation, c) plan, and d) material distribution (green, white, and red colors represent adobe, fired brick, and stone masonry, respectively).[2]

is able to maintain its structural integrity during times of peak ground acceleration. The structural integrity can be measured in terms of lateral capacity, which is the maximum lateral acceleration that the structure can support before failing. This is the horizontal force applied to the structure at the time of failure and expressed in percent of g (gravity) by dividing the force by the mass of the structure. The civil engineering code of Peru also requires that the PGA be multiplied by a factor that reflects the specific geology of the Andahuaylillas region and the social function of the building. The Triumphal Arch's current lateral capacity, as determined in previous research, is 33.6% g, which does not ensure the safety of this structure in case of an earthquake.[1] Therefore, this research aims to design a practical way of reinforcing the structure to increase its lateral capacity, without affecting the architectural aesthetics. Different designs of reinforcements are evalu-

ated numerically using non-linear Finite Element (FE) models. This research identifies the reinforcement configuration with the highest lateral capacity and suggests possible ways of reinforcement so that the Triumphal Arch may survive future earthquakes.

Analysis Specification

Pushover analysis is a well established approach for analyzing a masonry structure's response to seismic behavior.[5,6] It is commonly used in assessing damage sequences and resistance to lateral displacement, acceleration, or force. We apply monotonical, horizontal acceleration to the entire structure until it collapses using the Explicit FE formulation built in Abaqus. Once each model is constructed in Abaqus/CAE Explicit using actual dimensions and materials (Figure 3), a boundary condition is applied to the base of the structure. Each node on the base of the model is fully constrained. To prevent any dynamic effect during the process,

the research uses quasi-static analysis. The desired quasi-static condition is enforced by adopting long time intervals for the application of both gravitation and lateral accelerations. Gravity is applied to the entire model as a linear ramp that reaches its full value of 1g at three seconds, followed by linear lateral acceleration of 0.6g to the entire model over seven seconds.

For each test, the time development of strain energy, kinetic energy, plastic dissipation, and viscous dissipation are recorded to create time-dependent energy plots. The strain energy is the elastic energy stored by the Triumphal Arch during deformation caused by gravity and lateral acceleration. The kinetic energy is the energy generated due to the dynamic motion of structural elements moving apart due to fractures. The plastic dissipation is the dissipative energy due to plastic deformations, simulating internal fractures. The viscous dissipation is the dissipative energy produced by the fictitious
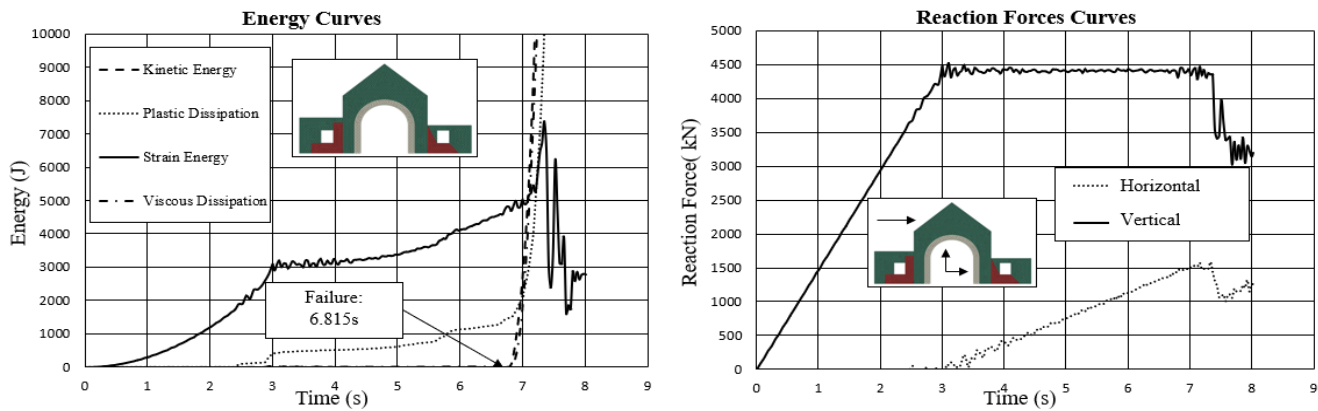
Figure 4. Time-evolution of energy curves (a) and forces reaction (b) due to gravitation followed by uniform lateral acceleration.

viscosity parameter used in Abaqus/ CAE Explicit to dampen possible oscillatory behavior. The energy plot is used to determine when structural failure occurs. When the structural integrity is maintained under lateral acceleration, the process is quasi-static, and the kinetic energy should remain negligible. As soon as the process turns from quasi-static to dynamic, the kinetic energy rises asymptotically (Figure 4a) and the strain energy suddenly drops. Furthermore, the dissipative energy remains negligible during static conditions and then becomes asymptotic at failure.[2] Figure 4b shows the time-evolution of the reaction forces. In the first three seconds, only gravitational load is applied, thus no horizontal force is developed. Thereafter, the linear application of lateral acceleration causes an relatively linear increase in the horizontal force. The horizontal forces and vertical forces show a sudden drop at the time of failure due to structural collapse.

Explicit nonlinear FE formulation is required for this analysis to model large deformations and local material failures, and therefore, capture collapse conditions at the time of failure.[2] However, the drawback of using dynamic explicit formulation is that the computational calculation is very

time-consuming because it involves very small time steps (10^{-6} s).

Model Layout

Two approaches are used to attempt to increase the lateral capacity of the structure: a pre-tensioned steel bar or a reinforcing steel frame inserted into the arch. Both approaches are based on the dimensions and the distributions of materials in the Triumphal Arch, as shown in Figure 3. A full list of different design layouts can be seen in Figure 5. Model 0.0 is the original model. Model 1.0 is the model with a steel bar being inserted inside the tympanum and anchored to the outside walls of the arch. Models 2.0-2.4 show different reinforcing steel frames. Finally, Models 3.0-3.2 include window openings on the side walls being reinforced.

As mentioned earlier, the steel bar in Model 1.0 is pre-tensioned to increase tension to help with the restoration of the structure. To simulate the pre-tension effect with the numerical model, a thermal compression coefficient is applied. Because the bar is temperature sensitive and its length is reduced when temperature drops, applying a temperature coefficient in the model can create tension on the bar. The temperature change is applied in between the gravity and the lateral acceleration as a linear ramp for three seconds. The amount of force being applied in the bar is then calculated based on the following equation[7]:

where Δt is the change in the temperature, F is the force applied, A is

$$F = A\Delta tE\alpha$$
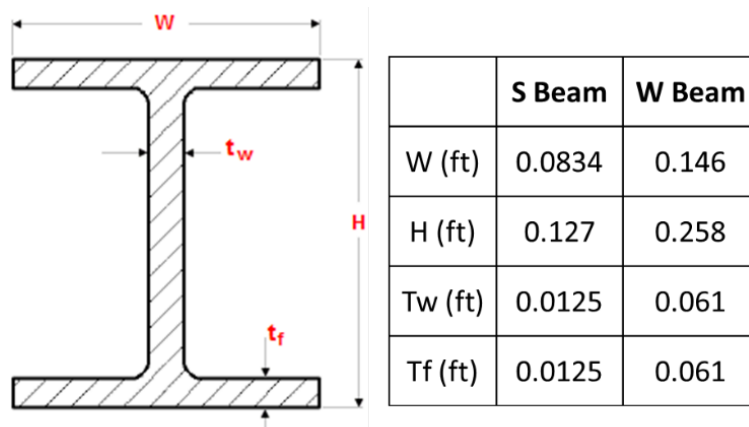
Figure 6. Inserted I Beam Dimensions

	S Beam	W Beam
W (ft)	0.0834	0.146
H (ft)	0.127	0.258
Tw (ft)	0.0125	0.061
Tf (ft)	0.0125	0.061

Materials	Density [kg/m³]	Young's Modulus, E [MPa]	Poisson ratio, ν
Adobe	1539	350	0.25
Brick	1800	1200	0.25
Stone masonry	2200	2350	0.25
A36 Steel	7800	2E+5	0.26

Table 2. Plasticity properties of adobe, brick and stone masonry[4]

Dilation Angle	Eccentricity	f_b0/f_c0	K	Viscosity Parameter
1	0.1	1.16	0.67	1E-8

Table 3. Post critical properties of adobe, fired brick and stone masonry[2]

Materials	σ_c [MPa]	σ_f [MPa]	G_{IC} [N/m]	G_{IF} [N/m]	h [mm]
Adobe	0.875	0.0875	1400	4	212
Brick	2.4	0.12	3840	2.16	202
Stone masonry	5.3	0.176	8480	5.104	205
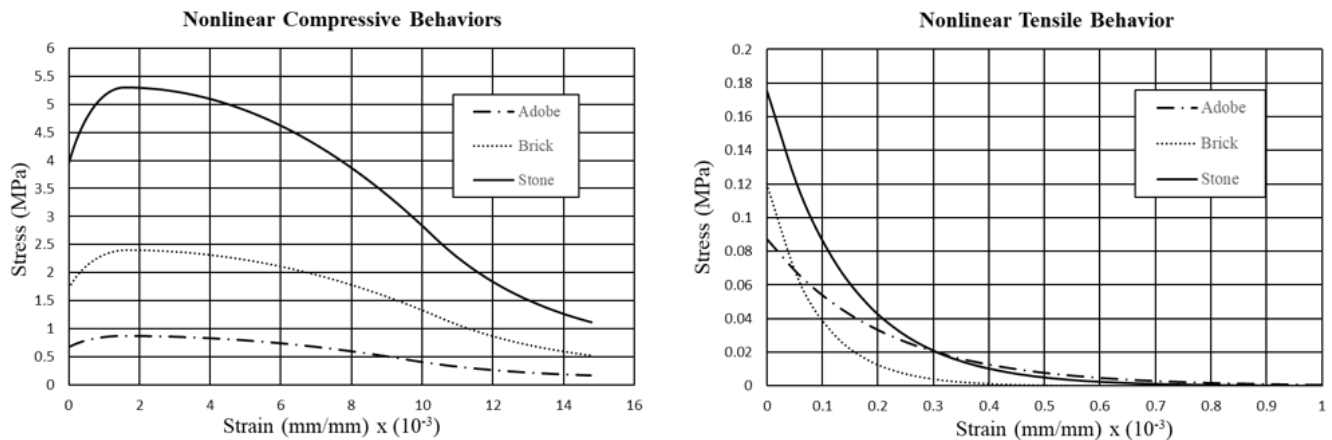
Figure 7. Nonlinear material uniaxial stress-strain curves: compressive (a), tensile (b).

the cross-sectional area, E is Young's Modulus of steel, and α is the coefficient of thermal expansion for steel. By setting the temperature changes to 12°C, 18°C, and 24°C, the steel bar is respectively pretensioned by 14.6 kN, 21.9 kN, and 29.2 kN. From Model 2.0-Model 2.4 and Model 3.2, two I-beams with different dimensions as shown in Figure 6 are used to construct the frame. Using two different types of I-beams allows us to test the effect of beam stiffness on the lateral capacity.

Material Characterization

Adobe bricks, fired bricks, and stone masonry are quasi-brittle materials with an initial elastic behavior (Table 1) followed by a softening curve associated with fracture energies both in tension and compression.[8] Elastic properties of A36 steel are also shown in Table 1. Lourenço's continuum formulation for the quasi-brittle materials is used to determine the stress-strain curves for each of the three materials.[9] The stress-strain curves are created by using the tensile and compressive strengths of the materials and the fracture energies in Table 3. To ensure that the results are objective with regard to mesh sizes, h is taken to correspond to a representative dimension of the element size (Table 3).[10] The resultant stress-strain curves for all three materials are shown in Figure 7. Only elastic properties of steel are used since steel never reached its yield strength during the entire experiment.

Results

For each test case, the capacity curve
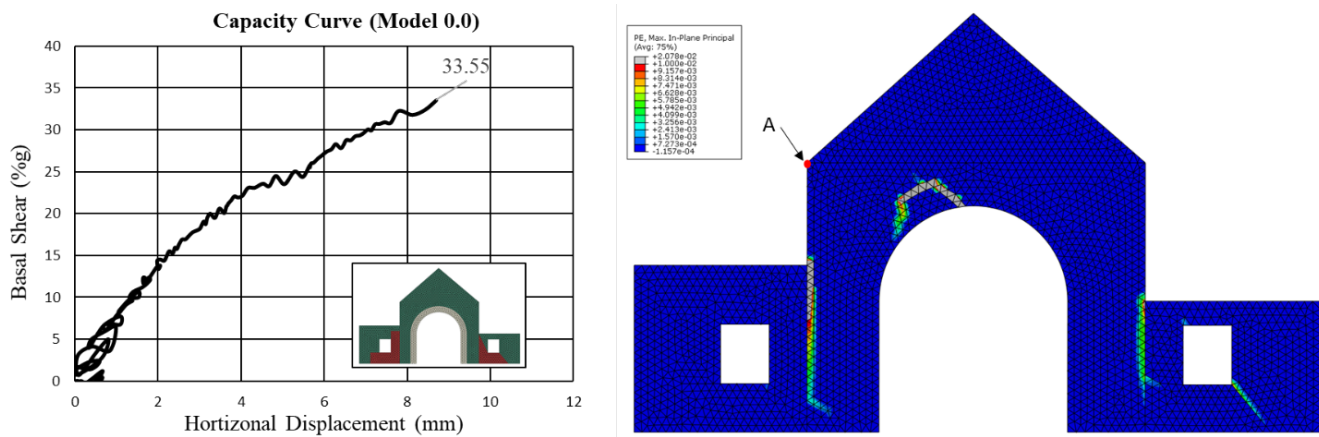
Figure 8. Lateral capacity curve and damage configuration at failure for Model 0.0

Table 4. Linear capacity for different axial loads in the bar for Model 1.0

Axial Force in the Bar (kN)	Basal Shear (%g)
0	32.21
1406	35.25
21.9	35.89
29.2	36.79

(basal shear vs. the displacement of a reference point) and the corresponding image of structural damage distribution at failure conditions are shown (Figure 8 for Model 0.0). All capacity curves refer to the deformation of the same structural point (the left corner at the base of the tympanum, see point A in Figure 8.). The damaged status is shown in terms of maximum principal plastic strains distributions. The gray bands represent areas where these strains exceed 10^{-2} in intensity. Since plastic strains simulate actual fractures in the concrete damaged plasticity formulation, the evolution of the gray bands can be interpreted as the propagation of fractures in quasi-brittle materials.[2]

In Model 0.0, the separations start at the left upper portion of the arch intrados and between the left lateral wall and the arch intrados, which cause the total failure. To reinforce the stone masonry arch, a pre-tensioned bar is added in Model 1.0. As the axial loads in the bar increases, the lateral capacity of the model also increases. When the axial load is 33.5 kN, the lateral capacity increases to from 33.6g% to 36.8%g (Table 4).

To further increase the lateral capacity, different beam configurations are inserted into the tympanum, as shown in Model 2.0 – Model 2.4 (Figure 5).
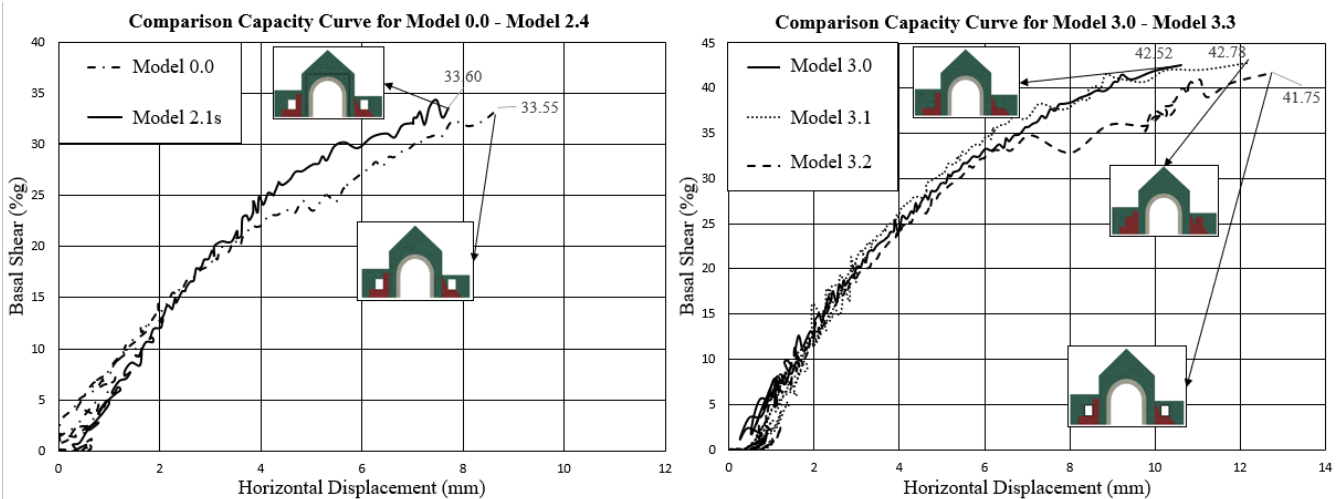
Figure 9. Capacity curve for (a) Model 2.0 – Model 2.4 (b) Model 3.0 – Model 3.2

However, this plan doesn't effectively increase the lateral capacity. Only Model 2.1 has similar lateral capacity as the original model (as Figure 9a shows). Figure 10 shows the failure mechanisms of Model 2.0 to Model 2.4. In general, there are two explanations for the reduction in capacity. First, the S beam is not stiff enough so it deforms under lateral acceleration and creates extra forces on the arch section. Second, the W beam is over-stiff and does not move as much as the adobe under acceleration. Therefore, separations between the beams and the adobe tympanum occurs after a while. For instance, in Model 2.3s (Figure 10), since the inserted S beam is less stiff than the W beam and is heavier than the adobe, the lateral acceleration on the beam creates deformation and transmits extra forces on the brick arch, causing failure. On the other hand, because the W beam is relatively stiffer, it deforms less and therefore prevents the failure of the brick arch from happening. However, because of its stiffness under lateral acceleration, the beam doesn't move significantly compared to the adobe material on the right of the tympanum. Therefore, in this case, separations occur between the adobe tympanum and the W beam, as shown in Figure 10 Model 2.3w. The mechanism of Model 2.3s immediately after failure is shown in Figure 11. The beam deformation directly creates forces on the brick arch and causes partial collapse of the arch.

Model 2.0s

Model 2.0w

Model 2.1s

Model 2.1w

Model 2.2s

Model 2.2w

Model 2.3s

Model 2.3w

Model 2.4s

Model 2.4w

Figure 10. Failure mechanism of Model 2.0 – Model 2.4
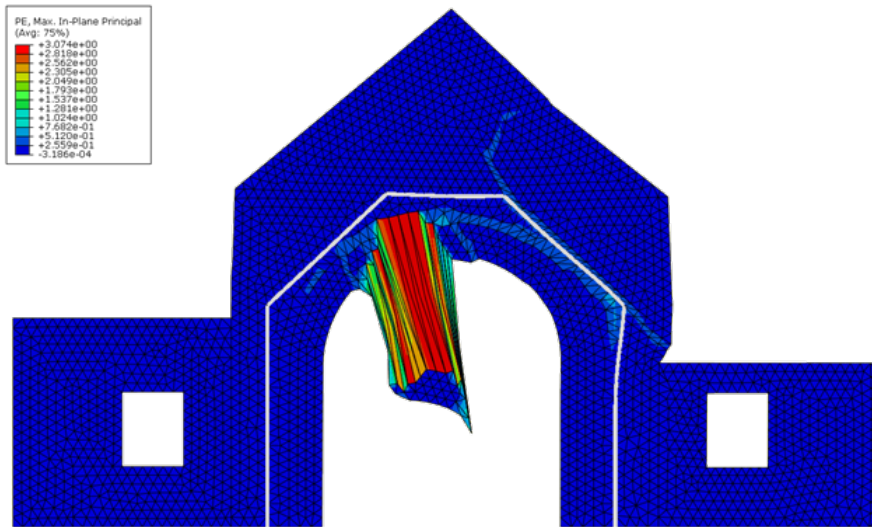
Figure 11. Mechanism of Model 2.3s at 6.75s (after failure)

Discussion

The results show that both the addition of the pre-tensioned bar and the beam configurations can increase the lateral capacity of the Triumphal Arch, therefore increasing its resistance to earthquakes. With the addition of a 33.5 kN pre-tensioned bar, the lateral capacity increases to 36.79% g. Therefore, adjusting the amount of pre-tensioning that takes place in the steel bar adjusts the structure's lateral capacity. The lateral capacity of the Triumphal Arch drops and varies unpredictably when the beam configuration is inserted into the middle of the structure. However, the lateral capacity increases up to 41.7% g when the beams are added around the window openings on the walls. These results indicate the significance of reinforcing the window openings of the lateral walls. The insertion of the window openings not only efficiently increases the lateral capacity, but also can be easily constructed without affecting the aesthetics of the Triumphal Arch.

At the same time, the right part of the adobe tympanum begins separating from the beam.

Because the reinforcement added to the arch does not significantly increase the lateral capacity of the model, another approach was tried. As shown in Figure 8, besides the separations at the arch intrados, cracks can be seen on the right lateral wall due to stress concentration caused by the lateral acceleration. Therefore, the window openings are reinforced from Model 3.0 to Model 3.2. The lateral capacity is shown in Figure 9b. When the window openings are filled with adobes and bricks, the lateral capacity suddenly increases to over 42% g. With the aim of preventing the architectural con-figuration of the windows, beams are used to reinforce the window openings as shown in Figure 5 Model 3.2. The lateral capacity remains high when the high stiffness beams are inserted around the window openings, but it drops when the high stiffness beam is replaced with the low stiffness one. Figure 12 shows the failure mechanism comparison between Model 0.0 and Model 3.2w. The reinforcement of the window openings first prevents the fractures, and simultaneously delays the occurrence of the separations at the arch intrados. Eventually, due to the heavy mass of the tympanum and the right lateral walls, the separation occurs between the left lateral walls and the tympanum.

The Church of Andahuaylillas' survival in a region of high seismic hazard for over 300 years has shown the prowess of its builders in the 17th century. However, with partial damages existing on the structures and the high risk of being destroyed from severe earthquakes, it is a priority to reinforce
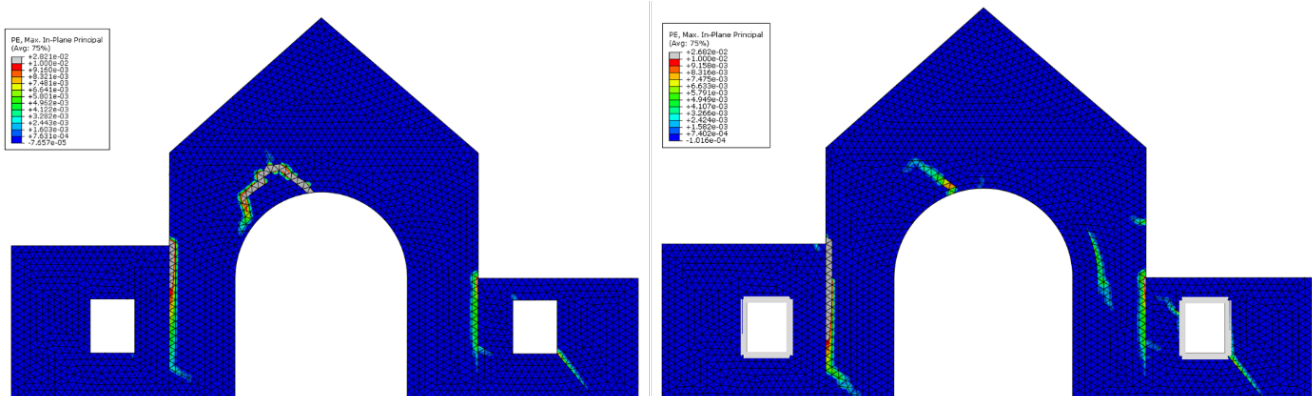

Figure 12. Failure mechanism of Model 0.0 and Model 3.3w

the structure. Based on the research results, the threat can be lessened by reinforcing the window openings.

Future research will focus on 3D analysis of the Triumphal Arch's response to an earthquake. The walls that connect the Triumphal Arch and the nave will be added in the 3D model. Meanwhile, the beams are inserted into the wall with consideration of its thickness. This analysis is significant in analyzing the true response of the Triumphal Arch after beams are inserted.

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Coercion and Empire in a Thucydidean Slavery

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Man's triumph over arthropod, as hailed by Marx, is in his unique faculty to architect. The exquisite constructions of the spider and the bee, however it may pretend their mastery over spinneret and mandible, is not mastered by them at all, who are not so much acting as doing. While humans cannot speak to erecting such natural splendors, for that which we erect, we can always claim to having "raised in the mind." Our prestige lies in our affinity for design, to Marx so intolerably sundered by the capitalist mode of production. Yet, be that as it may, human architecture prevails over biology in regimes far other than the aesthetic. *Exempli gratia*, we need not even leave the aforesaid phylum. Familiar to the amateur entomologist are those species of ant, collectively called *Polyergus*, which engage in a behavior known as *dulosis*, the regular enslavement of other colonies. Familiar to the classicist is the provenance of this term, which comes by way of the Greek for slave, *doulos*, and the lasting notoriety of the Hellenic slave apparatus. Not least is this notoriety owed to the "Greek intellect" so venerated by Weber. Greek slavery vitiates any excuse as a crime of passion. Xenophon made a banal science out of his human chattel. Euripides set the yoking of war captives to iambic trimeter. Plato maintained slavery in his utopia; his pupil Aristotle predicated a new jingoism on Persians being natural slaves. Each in their indelible way, the Athenian *cognoscenti* compounded the inventiveness of human dulosis,

all save seemingly for the historian Thucydides.

It is a deafening silence, especially coming from an otherwise grand narrator of *to anthropinon*, the human condition., However, *grand* being the operative word, perhaps this was to be expected. The soldier who wrote the definitive history of the Peloponnesian War did not write a people's history, much less one of slaves. Thucydides has no care for domestic vignettes. His accounts are of great men, his set pieces, *poliorkiai*, the besiegements of entire cities. Neither his subject nor setting would have sprouted grass roots, even had he stooped to look. Both Bosworth and Morrison point out that his famous Melian Dialogue, the conference at which was negotiated the *anschluss* of Melos, was closed to the very civilians whose lives were at stake. The works of Thucydides are not canonically *specula principum*, mirrors for princes, but they sit on the same mahogany shelf. In his introduction to Strassler's *Landmark Thucydides*, perhaps the widest circulation of the *Historiai* today, Hanson laments, "Yet again, both the unfree and the women remain virtually unknown, as Thucydides' history deals almost exclusively with the free male citizenry of the Greek city-states, a group that constituted perhaps no more than a quarter of the adult resident-population." Hanson's complaint is nigh incontestable. When Thucydides so exerts himself as to mention slaves, he largely treats them as a locomotive force, as engines of

the Athenian triremes or of the peninsular war machines—this drossiness coming from one of only two Greeks praised by name in *The Protestant Ethic*. The other, of course, is Aristotle, whose imagination did not stop short of reformulating Greek slavery into ethnic terms, thus inventing a new class of genocide. The difference in interest is clear: a crude, lemmatic search for *doulos* across the *Thesaurus Linguae Graecae* lists Aristotle among its highest users. The same is true of *soma*, literally, body. Thucydides makes neither list. The only curiosity, and hence any resolve towards a theory of Thucydidean slavery, resides in his pre-eminent usage of two lemmata in the Greek slave-lexicon: *andrapodizesthai*, literally, to render into a man-footed-thing, and *aichmalotos*, literally, one taken at spear-point. Neither are particularly exotic, appearing in any frequency list of modest size. Both, however, are martial terms, and would suggest only a staff-officer's clinicality—not an outright indifference—to Thucydides' outlook on slavery.

We behold a simple hypothesis for this blasé detachment. It is that enslavement, being an exercise of force, is a *vernacular* of the meta-language of coercive diplomacy in which Thucydides was fluent. For him, the verbs and nouns of slavery, and likewise its actions and ideas, are a parochial grammar. The wide-sweeping *Historiai*, collectively his *magnum opus*, are an effort to chronicle a Hellas embroiled in cataclysmic inter-political conflict.

Thucydides' guiding *historia*, or examination, is of the colliding ambitions of the Athenian Empire and Peloponnesian League, and the resultant displacement of human life on a colossal scale. The transient effects of the war included, but were not in the least limited to, the wholesale neutralization of combatants and non-combatants alike via enslavement. The dispassion of *neutralize* is here entirely apt—it approximates both in morphology and tone the Thucydidean usage of *andrapodizesthai*, to enslave an entire people, particularly when he nonchalantly juxtaposes the verb with other types of deprivation, as if to paint a landscape in different shades of pain:

πρῶτον μὲν Ἠιόνα τὴν ἐπὶ Στρυμόνι Μήδων ἐχόντων πολιορκίᾳ εἷλον καὶ ἠνδραπόδισαν, Κίμωνος τοῦ Μιλτιάδου στρατηγοῦντος. ἔπειτα Σκῦρον τὴν ἐν τῷ Αἰγαίῳ νῆσον, ἣν ᾤκουν Δόλοπες, ἠνδραπόδισαν καὶ ᾤκισαν αὐτοί. πρὸς δὲ Καρυστίους αὐτοῖς ἄνευ τῶν ἄλλων Εὐβοέων πόλεμος ἐγένετο, καὶ χρόνῳ ξυνέβησαν καθ᾽ ὁμολογίαν. Ναξίοις δὲ ἀποστᾶσι μετὰ ταῦτα ἐπολέμησαν καὶ πολιορκίᾳ παρεστήσαντο, πρώτη τε αὕτη πόλις ξυμμαχὶς παρὰ τὸ καθεστηκὸς ἐδουλώθη, ἔπειτα δὲ καὶ τῶν ἄλλων ὡς ἑκάστη ξυνέβη.

First, under the generalship of Cimon, son of Miltiades, the Athenians besieged and captured Eion in the mouth of the Strymon, then held by the Medes [the Persians], and enslaved her occupants. They next did the same to Scyros, an island in the Aegean inhabited by the Dolopes—they later colonized the island themselves. In addition, they waged war on the Carystians of Euboea (not the other Euboeans) who in time capitulated. After this they suppressed the Naxian rebels

and beleaguered their city, she being the first to be enslaved contrary to allied [Greek] custom. Others soon followed.

περὶ δὲ τοὺς αὐτοὺς χρόνους τοῦ θέρους τούτου Σκιωναίους μὲν Ἀθηναῖοι ἐκπολιορκήσαντες ἀπέκτειναν τοὺς ἡβῶντας, παῖδας δὲ καὶ γυναῖκας ἠνδραπόδισαν…

Around that time of that summer the Athenians forced the capitulation of Scione, killed her men of military age, and enslaved her women and children…

οἱ δὲ ἀπέκτειναν Μηλίων ὅσους ἡβῶντας ἔλαβον, παῖδας δὲ καὶ γυναῖκας ἠνδραπόδισαν: τὸ δὲ χωρίον αὐτοὶ ᾤκισαν, ἀποίκους ὕστερον πεντακοσίους πέμψαντες.

They [the Athenians] killed all the Melian men of military age, enslaved the women and children, and themselves later settled the place with five hundred colonists. When the victor in a fight among the cities executes the entire male citizenry in accordance with the laws of war, and sells all the women and children into slavery, we see in the sanction of such a law that the Greeks considered it an earnest necessity to let their hatred flow forth fully.

This blanket observation, however accurate of Homeric or Heroic slavery, does not characterize Thucydides, whose clinicality abstains not only from love, but hate as well. It is true that one will not find in Thucydides any eulogizing sympathy for the victims of empire, nothing so approaching Tacitus when he quotes the Celtic chieftain Calgacus:

Auferre, trucidare, rapere falsis nominibus imperium, atque ubi

solitudinem faciunt, pacem appellant.

To deprive, to massacre, to abduct, they [the Romans] call in lying names empire; they make a desolation and call it peace.

But neither will one find a domineering enthusiasm in Thucydides' descriptions of andrapodization or mass-internment. He does not consider the violent domination of master over slave as an end unto itself. Moreover, he does not even consider said domination as an end unto any one master, singular. Thucydides describes the enslavements of entire nations by entire nations *qua* nations. This is in contrast to slavery as presented by Xenophon, his fellow Athenian and soldier-historian, in whose *Anabasis* the individuality of the captor and his captive are preserved:

ἐπεὶ δὲ ἀριστήσαντες ἐπορεύοντο, ὑποστήσαντες ἐν τῷ στενῷ οἱ στρατηγοί, εἴ τι εὑρίσκοιεν τῶν εἰρημένων μὴ ἀφειμένον, ἀφῃροῦντο, οἱ δ᾽ ἐπείθοντο, πλὴν εἴ τις ἔκλεψεν, οἷον ἢ παιδὸς ἐπιθυμήσας ἢ γυναικὸς τῶν εὐπρεπῶν.

After breakfast the generals began the march, stationing men in the pass that they might confiscate, if they found any not to have been given up, the contraband [which would slow the march]; the soldiers complied, except the odd man who, smitten with some beautiful boy or woman, smuggled them across.

βασιλεὺς δὲ καὶ οἱ σὺν αὐτῷ τά τε ἄλλα πολλὰ διαρπάζουσι καὶ τὴν Φωκαΐδα τὴν Κύρου παλλακίδα τὴν σοφὴν καὶ καλὴν λεγομένην εἶναι λαμβάνει.

And the king [Artaxerxes II] and his men took many spoils, and he in

particular took the Phocaean woman, the concubine of Cyrus, who was said to be both intelligent and beautiful.

Although Mann recognizes in his genocide studies that slavery could be prosecuted on the scale of a *genos*, nation, by both Greeks and non-Greeks alike, sees this only as the aggregate of so many lusts or avarices on the part of individual personalities—not unlike those recorded by Xenophon. Thus, without really imagining any emergent *state* slavery, he relegates mass-enslavement to a distributed impulse, never a delegated intelligence: "Since civilization was all about avoiding labor (it still is), barbarians wanted people to rule over, do the work, and create the surplus." But Thucydides' views on slavery can be described as issuing from a *realpolitik* precisely that emerged from the celestial mechanics of superpowers. It is falling from the sheer height of this promontory, which observed the terminal pathology of the entire Hellenic conflict, that Thucydides' few pronouncements on slavery obtain their "sneer of cold command." Slavery, to Thucydides, is *an instrument* by which one state may hurt another to further its own security. As such, Thucydidean slavery frustrates the typologies used among sociologists and classicists, in which there is a literal *personality* to the arm which cracks the whip. Patterson's definition of slavery as a violent domination, although coinciding with Thucydides' coercive interests, is in a sense too insistent on an idiosyncratic, almost neurotic, domination, not the imperial hauteur that is ubiquitous in the *Historiai*. He writes, "[T]he slave was usually powerless in relation to another individual…. Nothing in Hegel or Friedrich Nietzsche more frighteningly captures the audacity of power and ego expansion than the

view of the Ahaggar Tuaregs of the Sahara that 'without the master the slave does not exist, and he is socializable only through his master.'" Finley's material slavery, on the other hand, captures the objectification of war captives that is latent in Thucydides, but not his supra-domestic currency—imperial interest. Thucydidean slavery, if it seems wholly unobservant of individuals' power or profit, is so because it operates toward *hegemonia*, state supremacy.

This primacy that Thucydides ascribed to *raison d'état* has always been acknowledged—and aggrandized—by the Realist. The fact of the former motivates our brief recourse to *international security studies* in which the more humanistic sciences have been deficient. The addendum motivates our sobriety as we do so. It is not without tongue in cheek that Bagby, a political scientist wise to the heritage that the likes of Thucydides, Machiavelli, or Hobbes bestow upon a modern claimant, writes that Thucydides can "guide us in our studies beyond Realism—and especially beyond Neorealism." The past century of human conflict, from *totaler Krieg* to the coalescence and contest of superpowers, has seen its students, who are usually Realists, locate Thucydides in their newfound theories because of his manifest correspondence: Morgenthau for his study of power, Waltz for his "Third Image," Kissinger by way of historical analogy, and for his protégé, Allison, as an immortal lesson in the ineluctability of war. Thucydides has doubtlessly been identified as the forefather of the Realist and Neorealist schools of thought, more so for his manifest *authority*. This paternity, however, has been increasingly challenged in recent years—it is not immediately evident that Thucydides presumed nation-

states to be suspended in anarchy or anomie, the vacua that inflate much of the Realist literature. Nor need this be evident for our tempered demands. We are not so much requesting a Realist Thucydides as we are a Thucydides mildly capable of subordinating mass-enslavement to the purview of statecraft. This, as it turns out, is a benign request; 5th century Greece readily supplies the political infrastructure.

To be sure, to pinpoint the maturation of the Hellenic peoples into discrete city-states, *poleis*, capable of self-representation or self-interest *qua* city-states, is necessarily a diachronic endeavor. As late as 480 BC, the Persian general Mardonius is recorded to have remarked:

τοὺς χρῆν ἐόντας ὁμογλώσσους κήρυξί τε διαχρεωμένους καὶ ἀγγέλοισι καταλαμβάνειν τὰς διαφορὰς καὶ παντὶ μᾶλλον ἢ μάχῃσι.

As they [the Greeks] share the same language, they ought resolve their differences by heralds and messengers, or in any way other than fighting.

But constitutional representation does not preclude constitutional hawkishness. From the formative survey of Greek diplomacy conducted by Adcock and Mosley, it would seem that by the 6th century, the *poleis* had produced the "personalities concerned in political activity" and a tradition of nominating *presbeis*, elders, into deliberative councils and representative delegations, so as not only to possess a statecraft *in spite of* which they still went to war, but one *for* which they often did. It is telling of the Greek pathology that *symmachia*, the word for a compact between city-states, is obtained from *symmachein*, to fight *together*. Certainly, by the Peloponnesian War, the Greek *poleis*, sophis-

ticated as they were, could make war upon one another as such, as a means to a political end.

The *Historiai* describe a discriminate deployment of state power which commonly would not always annihilate its mark. In fact, rare are the instances of unattenuated wrath, that Achillean rage immortalized in the opening lines of the *Iliad*. On the eve of the Peloponnesian War, in response to Megara's provocations, the nature of which remains disputed, Athens contented herself with merely the *economic* strangulation of the isthmian city. The consequent Megarian *psephisma*, decree, as described in passing by Thucydides, was an embargo that denied the usage of Athenian harbors to Megarian ships, and likewise, markets to citizens. The *isthmos* of Corinth is a veritable neck less than five miles wide—so easily could it have been otherwise snapped, as it were, with spear and shield. Three years later, in the opening of the grand game between Sparta and Athens, a Sparta-backed Mytilene, a city-state in the northern Aegean, attempted to remove herself from the Athenian sphere, only to be blockaded and laid low. This time, the *tigerartige Vernichtungslust* proved far more tempting. The hardline elements of the Athenian assembly, the *ekklesia*, actually resolved to andrapodize the city:

ὑπὸ ὀργῆς ἔδοξεν αὐτοῖς οὐ τοὺς παρόντας μόνον ἀποκτεῖναι, ἀλλὰ καὶ τοὺς ἅπαντας Μυτιληναίους ὅσοι ἡβῶσι, παῖδας δὲ καὶ γυναῖκας ἀνδραποδίσαι, ἐπικαλοῦντες τήν τε ἄλλην ἀπόστασιν ὅτι οὐκ ἀρχόμενοι ὥσπερ οἱ ἄλλοι ἐποιήσαντο, καὶ προσξυνελάβοντο οὐκ ἐλάχιστον τῆς ὁρμῆς αἱ Πελοποννησίων νῆες ἐς Ἰωνίαν ἐκείνοις βοηθοὶ τολμήσασαι παρακινδυνεῦσαι: οὐ γὰρ ἀπὸ

βραχείας διανοίας ἐδόκουν τὴν ἀπόστασιν ποιήσασθαι.

From their outrage they [the Athenians] decided not only to kill the [Mytilinean] men currently present in Athens, but to put to death all the Mytilinean men of military age, and to enslave all their women and children; they claimed that the Mytilineans had revolted despite not even being subjected as the others, and what did not ease their fury was that Peloponnesian ships should dare venture to Ionia to succor the rebels; from this the apostasy seemed to have been done with premeditation.

Even then, as put by Lebow and Kelly, "cooler heads prevailed the next day." The resolution was debated once more, where Diodotus, a moderate, questioned the proportionality of the Athenian reprisal, exemplary though necessary to keep the alliance system from imploding:

οὓς μὲν Πάχης ἀπέπεμψεν ὡς ἀδικοῦντας κρῖναι καθ᾽ ἡσυχίαν, τοὺς δ᾽ ἄλλους ἐᾶν οἰκεῖν. τάδε γὰρ ἔς τε τὸ μέλλον ἀγαθὰ καὶ τοῖς πολεμίοις ἤδη φοβερά: ὅστις γὰρ εὖ βουλεύεται πρὸς τοὺς ἐναντίους κρείσσων ἐστὶν ἢ μετ᾽ ἔργων ἰσχύος ἀνοίᾳ ἐπιών.

Sentence at leisure those whom Paches [the commander of the Athenian forces] has sent having deemed guilty; let the rest live in peace. This will be good for the future, and yet is already a terror to our enemies, for he who considers wisely is stronger against the adversary than are displays of irrational violence.

Diodotus won the day. In a sequence not entirely lacking in sardonicism, Thucydides describes the haste of the Athenians to outfit and dispatch a second Mytilene-bound trireme, hoping

it would overtake the kill-and-enslave order borne by the first. Thucydides thereby implicitly describes some ratiocination to Athens-sponsored slavery, that it could in practice be second-guessed.

We might also read in these examples a salient linkage, preserved even overseas, between the Athenian state and the field of war. This connection enabled mass-enslavement or *policide*, the wasting of cities, to be delegated from the state level, and hence become the political problematics that they are to Thucydides. The Athenian generalship, or *strategoi,* did not enjoy, at least compared to the Roman *imperatores*, as much the freedom to deprive their own captives of theirs. The writ of Roman *imperium* granted a frontline commander an ambassadorial apotheosis, and the codification of his military adventurism or megalomania into foreign policy. Caesar is described by both Appian and Plutarch to have sold one million Gauls into slavery over the course of his Transalpine and Gallic campaigns. This conduct was only a *res publica* insofar as Caesar had become the acting organ of the castrated Late Republic. The absence in "Roman" enslavement of any consideration other than the meanly acquisitive has long been conspicuous to commentators. Gibbon, writing in the 18th century, observed:

The perfect settlement of the Roman empire was preceded by ages of violence and rapine. The slaves consisted, for the most part, of barbarian captives, taken in thousands by the chance of war…. But when the principal nations of Europe, Asia, and Africa were united the laws of one sovereign, the source of foreign supplies flowed with much less abundance, and the Romans

were reduced to the milder but more tedious method of propagation.

Yet it says nothing of the existence of a statecraft if it should be effected, however extensively or enthusiastically, without consultation of the *political* apparatus and its manifesto. While Bismarck bypassed the Reichstag, he was at least in consort with his fellow Junkers who were the centroid of the Prussian state. By this count, when, as is recorded in Herodotus, Persian troops employed the *sagene* maneuver, linking hands to comb one end of a fallen city to the other, trawling for beautiful boys and girls, they were practicing by all means a *systematic* enslavement, but not one pertinent to the assurance of the Achaemenid will, unless the sexual appetite of the Persian elite was really a deliberate policy matter. Only in Thucydides do we see an enslaver hold fetters in one hand and a *psephos*, a voting stone, in the other, both arms being not so much attached to a body as a body-*politic*.

This conjoining of slavery to government renders it a weapon of the latter, or, if the reader will permit, an arm of the state. Governed thus, the power to enslave becomes a ramification of *military power*, as are the powers to kill or to maim. Granted, this title neither sanitizes nor decorates the pure obscenity of reducing a human being to an *andrapodon*, a man-footed-thing; the reason why andrapodization was usually preceded by the purging of the *hebontes*, the men of military age, is because few were men who would stand idly by as their wives and daughters were raped and their sons castrated. There is no question that it was always flesh that abused flesh. Patterson is not incorrect when, having introduced the "individualized condition" of slavery, he writes, "[w]e may conveniently neglect those cases where the slave formally belonged to a corporation such as a temple, since there was always an agent in the form of a specific individual who effectively exercised the power of a master" . Slavery cannot possibly be divested of the human element, in the same way that killing and torturing cannot. In its sanction by the state, however, we see the possibility of *doctrine*, in the same way that the firebombing of 67 Japanese cities was performed by human operators but was nonetheless a programmatic use of force by the United States. Take away slavery's ability to violate the most fundamental human charters and we are no longer left with slavery, much less something that can be coordinated to violate entire nations. It is having presupposed the constituent horrors described at length by the scholars of slavery, and not at all to supplant them, that we invoke the Realist literature on diplomatic violence, which was pioneered a mere half-century ago in Schelling's *Arms and Influence*, the seminal treatise on the game-theory of inflicting pain.

Let us be clear; there was very little *grand strategy* to Athenian mass-enslavement. As has been noted by Stahl and Hawthorn, for Thucydides, the tragic failings of *pronoia*, or human foresight, are just as much a motif as its successes. For reasons that are neither here nor there, the Athenian "empire of the spirit," as Joyce's Professor MacHugh calls it, did not nearly have the longevity of the Roman Empire and its artless "material domination." Centralized and mindful as her operations were, Athens had nothing approaching the requisite National Security Council or RAND Corporation to truly take the helm against her rival superpower, Sparta. So many of her kill-and-enslave orders were *ad hoc*, initiatives in small theaters to enforce a constellation that was scattered throughout the Aegean island system. One ought keep in mind that we are referencing *Arms and Influence*—and only its first few chapters at that—instead of Kahn's *On Thermonuclear War*. Although the Ancients were not incapable of theory, they effected what they did not out of global insight, but largely as common sense aspiring towards local design (but design nonetheless). This sense is common to us as well: the playground bully is aware of the importance of "sending a signal" and of guarding the pecking order, the difference between him and the Athenian *ekklesia* being the degree of atrocity.

Schelling is particularly germane to our subject because he deconstructs what are really timeless principles of coercive diplomacy. He would suggest that we examine not only the instances where the Athenians actually andrapodized a city, but how and why they threatened to do so. The cardinal moral of *Arms and Influence* remains this: "the power to hurt—the sheer unacquisitive, unproductive power to destroy things that somebody treasures, to inflict pain and grief—is a kind of bargaining power." As Schelling continues, "[Military] victory is often but a prerequisite to the exploitation of the power to hurt…. [It] is often the prelude to violence, not the end of it, and the fact that successful violence is usually held in reserve should not deceive us about the role it plays." Strategic enslavement, although never developed by Schelling, is remarkably specialized for *postbellum* hurting; one cannot enslave at a distance as one can loose an arrow or drop a bomb. In every instance where Athens brandished her *nuclear option*, she had disarmed her enemy before dragging them by the hair to the bargaining table—Myt-

ilene fell to naval blockade, the Melian Dialogue took place with an overwhelming retaliatory force already encamped on the island. Incidentally, as Schelling explains, what makes actual nuclear weapons so deleterious is *not* because of platitudes to the effect that such weapons, for the first time in history, give mankind the ability to annihilate itself. This has always been a question of enthusiasm. Rather, nuclear and thermonuclear weapons are deadly because they compress the timescale from military defeat to political capitulation into a singularity. In comparison, the Athenians were exceedingly committed to *conquering* the enemy before exacting, or threatening to exact, their punishment on soft targets. Bosworth is spot on when he argues that there is a "humanitarian aspect" to the Melian Dialogue. There is some decorum to the Athenian delegation which forgoes *kala onomata*, literally, fine names, to remind the Melian commissioners that they are at the mercy of the Empire, both sides knowing

ὅτι δίκαια μὲν ἐν τῷ ἀνθρωπείῳ λόγῳ ἀπὸ τῆς ἴσης ἀνάγκης κρίνεται, δυνατὰ δὲ οἱ προύχοντες πράσσουσι καὶ οἱ ἀσθενεῖς ξυγχωροῦσιν.

that in human discourse justice is discerned only from the equality of powers, and that the strong take what they can, and the weak suffer accordingly.

Virgil puts it in poetry in the *Aeneid*:

Una salus victis nullam sperare salutem

There is one salvation for the conquered—to expect none at all.

Part of our point is that this salvation is not even afforded when the conquered are *not aware*, are *not made aware*, or *refuse to be made aware*, of their status. By Seaman's chronology, which remains, two decades on, the most cogently defended from the Thucydidean and non-Thucydidean evidence, the Melian Dialogue occurred *twenty years* after the first Athenian mission to neutral Melos, which Melos had rebuffed. The islanders *knew* that their continued neutrality was an imbecility for Athens, for whom *arche tes thalattes*, control over the sea, was a matter of survival. According to Wassermann, on the eve of the Dialogue, Melos remained the only sector of the Aegean not allied with the Empire, which consequently revealed its high hand, just for it to be called as if it were a bluff. Thucydides is brisk in describing the aftermath—not only because he is unsympathetic, but because for him the episode bodes a troubling breakdown in Athenian *realpolitik*, which met in Melos an unmovable object: a state which would actually die for its pride. Diplomatic violence against a suicidal enemy is just violence. If Athens erred (other than by threatening what we would call crimes against humanity), it was not actually by lack of communication, but, as put by Schelling's contemporary George, by wrongly assuming "pure rationality on the part of the opponent—an ability to receive all relevant information, evaluate it correctly, make proper judgments as to the credibility and potency of the threat, and see that it is in his interest to accede to the demand made on him." Thucydides sees Melos as an experimental failure in diplomatic coercion.

"States" though they were, the Greek *poleis* were still fetal, deformed by the whole gamut of human affectations which, if they included nobility for Melians, included depravity for many others. There is a reason why we have described our slavery as a *Thucydidean* slavery, instead of giving its procedural disregard for both mercy and cruelty a popular label. It would seem that few Greeks, certainly very few non-Athenians, were capable of theorizing mass-enslavement as a means to a purely diplomatic end. We know this because Thucydides is quite outspoken in condemning what he believes to be abortive escalations to slaughter—situations where armies could have instead made demands loaded with the threat of enslavement or pain. The very man who so yawningly describes Athens' andrapodizations of city after city, at last expresses outrage at the Thracian sacking of Mycallesus in 413:

καὶ τότε ἄλλη τε ταραχὴ οὐκ ὀλίγη καὶ ἰδέα πᾶσα καθειστήκει ὀλέθρου, καὶ ἐπιπεσόντες διδασκαλείῳ παίδων, ὅπερ μέγιστον ἦν αὐτόθι καὶ ἄρτι ἔτυχον οἱ παῖδες ἐσεληλυθότες, κατέκοψαν πάντας: καὶ ξυμφορὰ τῇ πόλει πάσῃ οὐδεμιᾶς ἥσσων μᾶλλον ἑτέρας ἀδόκητός τε ἐπέπεσεν αὕτη καὶ δεινή.

There [in Mycalessus] the wildest panic ensued, and destruction in every form was rife. They [the Thracians] even fell upon a boys' school, the largest in the place, which the children had just entered, and massacred them every one. No calamity could be worse than this, touching as it did the whole city, none was ever so sudden or so terrible.

The contention is that Thucydides was *not* offended by the gross extermination of schoolboys (he had glossed over the enslavement of the Melian children two books earlier). For him, rather, the Thracians had committed a massive procedural infraction by descending upon their victims *adoketa*, unexpectedly. To wit, there was no

Mycallesian capitulation nor dialogue nor andrapodization, only a Mycallesian annihilation. Likewise, perverse though it may sound, Thucydides would not have so mournfully described the violent *stasis* at Corcyra, the powder-keg of 5th century Hellas, had it been more *governmental*:

πᾶσά τε ἰδέα κατέστη θανάτου,
καὶ οἷον φιλεῖ ἐν τῷ τοιούτῳ
γίγνεσθαι, οὐδὲν ὅτι οὐ ξυνέβη
καὶ ἔτι περαιτέρω. καὶ γὰρ
πατὴρ παῖδα ἀπέκτεινε καὶ ἀπὸ
τῶν ἱερῶν ἀπεσπῶντο καὶ πρὸς
αὐτοῖς ἐκτείνοντο, οἱ δέ τινες καὶ
περιοικοδομηθέντες ἐν τοῦ Διονύσου
τῷ ἱερῷ ἀπέθανον.

Death thus raged in every shape;
and, as usually happens at such times
[during revolutions], there was no
length to which violence did not go;
sons were killed by their fathers, and
suppliants dragged from the altar
or slain upon it; while some others
were even walled up in the temple of
Dionysus and died there.

Mass-enslavement, at least as it was conducted by Athens, never receives this sort of coverage in the *Historiai* because it obeyed what to Thucydides was protocol—people do not write about the more or less routine. Truly, it says more about the profundity of Thucydides than of his mundanity that he could even think of slavery as something mundane, as something *banausic*. Weber, who read Thucydides long before scholars of slavery ever did, appreciated what they did not: his unremitting and technical "method." The intellect of Thucydides regarding human dulosis was wholly different from the intellect of Euripides, to raise a canonical example, who responded to the sack of Melos by composing *Troades.* We today call it *Trojan Women*—it compares the Athenian actions at Melos to the epic atrocities of the *Iliad*. Yet, Thucydides would also have made it known had he thought Athens had acted out of line—his line being not a moral, but strategic, proprietary—there being in mindless atrocity not much of either. Thucydides, in his methodical presentation of an Athens acting as a hegemonic power, attests to an Athens that was capable of and willing to wield slavery for this architectural purpose, this *empire-building*. In this highly anomalous context which we should not overstate, even slavery became subordinate to statecraft, and therefore, to the abstract dictates of coercive diplomacy. Such a use of force, to put it glibly, is to a state never an end unto itself, which would contradict the notion of *use*. Slavery was leveled against those who would defy Athens, *not in order to enslave*, but to make intolerable the continuation of that defiance. This is an unexplored, although niche, aspect of Greek slavery. Perhaps it is better called an aspect of Athenian slavery during the Peloponnesian War, which in so many ways observed the tragedy of the human genius.

To have seen in Thucydidean slavery a certain intelligence is a hollow - almost distasteful - find. We put stock in the fact that he makes slavery ever more an abomination who practices it with creativity, because he deprives others of that same human potential. Thucydides boasts that his *Historiai* are a *ktema es aiei*, a possession for all time. What does it say of the permanence or ultimate justification of his slavery that such strategies are largely rejected by today's liberal order, that when detected they are cause for international tribunal? What does our modernity say of our capacity to be intelligent *and* moral? If, in their intelligence, the Athenians seem odd or impossible slavemasters, one might recall what Raskolnikov says of Pyotr Petrovich: "He's an intelligent man, but it takes more than intelligence to act intelligently."

Endnotes

1. Karl Marx, *Capital; a Critique of Political Economy*, ed. Frederic Engels (Chicago: C.H. Kerr & Co., 1909), 198.

2. P. D'Ettore and J. Heinze, "Sociobiology of Slave-Making Ants," *Acta Ethologica* 3, no. 2 (2001): 76-82.

3. Max Weber, *The Protestant Ethic and the Spirit of Capitalism* (New York: W.W. Norton & Co., 2009), 3.

4. For relevant selections from Xenophon's *Oikonomikos* as well as from Aristotle's *Politika*, see Thomas Wiedemann, *Greek and Roman Slavery* (London & New York: Routledge, 1981). Intensive commentary on Aristotelian, ethnic slavery can be found in Peter Garnsey, *Ideas of Slavery from Aristotle to Augustine* (Cambridge: Cambridge University Press, 1996). For the playwright, see Euripides, *Troades*. For slavery in Plato's *Politeia*, see Gregory Vlastos, "Does Slavery Exist in Plato's Republic?", *Classical Philology* 63, no. 4 (1968): 291-95. Vlastos did not settle the issue—the question remains debated today, but I agree with him that Plato preserves slavery as *status quo*.

5. See A.B. Bosworth, "The Humanitarian Aspect of the Melian Dialogue," *The Journal of Hellenic Studies* 113 (1993): 30-44, and James V. Morrison, "Historical Lessons in the Melian Episode," *Transactions of the American Philological Association* 130 (2000): 119-48.

6. Victor D. Hanson, [Introduction] in *The Landmark Thucydides*, ed. Robert B. Strassler (Free Press, 2008).

7. Thesaurus Linguae Graecae Digital Library, ed. Maria C. Pantelia, University of California: Irvine. Accessed on Dec. 12, 2018. http://www.tlg.uci.edu.

8. See Malcolm Campbell, *Classical Greek Prose: A Basic Vocabulary* (London: Bristol Classical Press, 1998).

9. Thucydides, *Historiai*, 1.98. All translations in this paper are mine unless otherwise stated.

10. Ibid., 5.32.1.

11. Ibid., 5.116.4.

12. Kathy L. Gaca, "The Andrapodizing of War Captives in Greek Historical Memory," *Transactions of the American Philological Association (1974-2014)*, no. 1 (2010): 117-61, 158. I will use the term "andrapodize" rather loosely in this paper to mean "mass-enslavement"; Gaca explicates the nuances in depth.

13. Friedrich Nietzsche, *Homer's Contest* (1872), as quoted in Eli Sagan, *The Lust to Annihilate: a Psychoanalytic Study of Violence in Ancient Greek Culture* (New York: The Psychohistory Press, 1979), vii. One does not need to be a Freudian to see the "lust."

14. Tacitus, *Agricola*, 30.6.

15. Xenophon, *Anabasis*, 4.1.14. For a description of how the Ten Thousand distributed their plunder as they made their way through Anatolia, see Andrew Dalby, "Greeks Abroad: Social Organization and Food among the Ten Thousand," *The Journal of Hellenic Studies* 112 (1992): 16-30.

16. Xen., *Anab.*, 1.10.2.

17. Michael Mann, *The Dark Side of Democracy: Explaining Ethnic Cleansing* (Cambridge: Cambridge University Press, 2005), 35. A discussion on wartime genocide is offered in Eric Markusen, "Genocide and Warfare" in *Genocide, War, and Human Survival*, eds. Charlies B. Strozier and Michael Flynn (Lanham, MD: Rowman & Littlefield Publishers, 1996).

18. Orlando Patterson, *Slavery and Social Death: a Comparative Study* (Cambridge, MA: Harvard University Press, 1982), 4.

19. See M.I. Finley, *Ancient Slavery and Modern Ideology* (New York: Penguin Books, 1980).

20. Laurie M. Johnson Bagby, "The Use and Abuse of Thucydides in International Relations," *International Organization* 48, no. 1 (1994): 131-53, 133, as quoted in Jonathan Monten, "Thucydides and Modern Realism," *International Studies Quarterly* 50, no. 1 (2006): 3-25.

21. See Hans J. Morgenthau and Kenneth W. Thompson, *Politics among Nations: the Struggle for Power and Peace*, 6th ed. (New York: Knopf, 1985). For the "Third Image"—war as a result of anarchy—see Kenneth N. Waltz, *Man, the State, and War: a Theoretical Analysis* (New York: Columbia University Press, 2001). For Kissinger's deep consultation of political history, see Niall Ferguson, *Kissinger: 1923-68: the Idealist* (New York: Penguin Books, 2015). For Allison's recent alarming reading of Thucydides, see Graham Allison, *Destined for War: Can American and China Escape Thucydides' Trap?* (Boston: Houghton Mifflin Harcourt, 2014).

22. . Herodotus, *Historiai*, 7.9b. As quoted and translated in Polly Low, *Interstate Relations in Classical Greece* (Cambridge: Cambridge University Press, 2007), 1 (trans. modified).

23. Frank Adcock and D.J. Mosley, *Diplomacy in Ancient Greece* (New York: St. Martin's Press, 1975), 12-13. The formalization of envoys would become the principal diplomatic contribution of the Hellenes to Alexander's satrapal empire—see John D. Grainger, *Great Power Diplomacy in the Hellenistic World* (New York: Routledge, 2017).

24. A summary of scholarship and debate on the Megarian Decree is provided in Brian R. MacDonald, "The Megarian Decree," *Historia: Zeitschrift für Alte Geschichte* 32, no. 4 (1983): 385-410.

25. Thuc., 1.139.1.

26. Ibid., 3.36.2.

27. Richard Ned Lebow and Robert Kelly, "Thucydides and Hegemony: Athens and the United States," *Review of International Studies* 27 (2001): 593-609, 599.

28. Thuc., 3.48.

29. Ibid., 3.49.

30. Appian, *Ek Tes Keltikes*, 1.2. Plutarch, *Bioi Paralleloi*, 17.15.

31. Edward Gibbon, *The History of the Decline and Fall of the Roman Empire*, vol. 2 (1827), 46.

32. Hdt., 6.31, as discussed in greater detail in Gaca, "The Andrapodizing of War Captives," 32.

33. See Gaca.

34. Patterson, *Social Death*, 4.

35. See the prefaces to Hans-Peter Stahl, *Thucydides: Man's Place in History* (Swansea: The Classical Press of Wales, 2003) and also Geoffrey Hawthorn, *Thucydides on Politics: Back to the Present* (Cambridge: Cambridge University Press, 2014).

36. James Joyce, *Ulysses* (Random House, 1986): 110.

37. See the preface to Thomas C. Schelling, *Arms and Influence* (New Haven: Yale University Press, 2008).

38. Ibid., 13.

39. Ibid, 18-19.

40. Thuc., 5.89.

41. Virgil, *Aeneid*, 2.354. Virgil is not making a political point, and I am reading liberally. Nevertheless, there is a difference between being conquered and being *annihilated*, and recognition of one's military defeat can make the difference between the two—hence being a kind of *salus*.

42. Michael G. Seaman, "The Athenian Expedition to Melos in 416 B.C.," *Historia: Zeitschrift für Alte Geschichte* 46, no. 4 (1997): 385-418, 416.

43. Felix Martin Wassermann, "The Melian Dialogue," *Transactions of the American Philological Association* 78 (1947): 18-36, 21.

44. Alexander L. George, "Coercive Diplomacy" in *The Use of Force*, eds. Robert J. Art and Kenneth N. Waltz (Lanham, MD: Rowman & Littlefield Publishers, 2009): 72-78, 72.

45. Thuc., 7.29 (trans. Benjamin Jowett, 1881, modified).

46. Ibid., 3.81.5 (trans. E.P. Dutton, 1910, modified).

47. Weber, *The Protestant Ethic*, 3.

48. Thuc., 1.22.4.

49. Fyodor Dostoevsky, *Crime and Punishment* (Vintage, 2012): 235.

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How could Artificial Intelligence create employment opportunities in Zimbabwe?

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This paper gives a background on Zimbabwe and explains how applying Artificial Intelligence (AI) in agriculture in Zimbabwe could possibly create employment, rather than take away the already existing jobs for most of the Zimbabwean population. Research on artificial intelligence says that it is going to replace many jobs without creating new working platforms for displaced workers (Petropoulos 2007). Zimbabwe, a developing country, is going to be used as a case study to support the possibility of employment creation, in its agricultural sector, using artificial intelligence. Zimbabwe is used as a case study because of its high potential to create employment in its agricultural sector since it has been a net exporter of grain in the past decade (Chidoko 2012). Labor-intensive subsectors in which AI could possibly create a range of employment opportunities will be discussed in support of this thesis. The sub-sectors include direct employment of workers in the development of artificial intelligence technology in the agricultural sector. Moreover, employment creation is a necessity in Zimbabwe and AI can create jobs in the distribution of seeds, fertilizers, and through irrigation. Subsequently, secondary employment in smart greenhouse technologies and tertiary employment opportunities in software development to support the agricultural sector could result due to the introduction of AI technologies. The research strategy applied in this paper involves understanding readily carried out research concerning artificial intelligence and employment, then giving a full analysis of the aspects in which AI could create employment in Zimbabwe. The four major aspects to be analyzed in this research paper in which there is a potential of employment creation are in the fields of computerized irrigation, software design, administration and smart greenhouse technology.

Zimbabwe, a Southern African country, gained its independence in 1980 after ninety years of British colonization. After 1980, most Zimbabweans who used to work in farms as laborers during the liberation displaced white farmers and became the owners and assumed management of the farms through the government's land reform program (Maguwu 2008). The land reform program was an initiative sponsored by the local government to redistribute land taken from white farmers among the Zimbabweans. The redistribution of land among the local people and the displacement of white farmers meant that the government could control food production, employment, and agriculture in general (Zinyama 1986). Far from empowering people, at the start of the early 2000s, the Zimbabwean local government became corrupt, leading to the instability of the economy and crumbling of the agricultural foundation already established. Also, the UK (Britain) led the imposition of economic sanctions on Zimbabwe, cutting down the line of production in the already established, intact agricultural chain and leading to massive unemployment (Mhiripiri 2018). The population of Zimbabwe is predicted to double within the next decade (Murase 2000), which implies that the modes of employment creation will, therefore, become increasingly crucial in the forthcoming decade in determining concerns over food production and agriculture to sustain the growing population. Currently, the unemployment rate in Zimbabwe stands at 85% (Aljazeera 2017) as a result of the crumbling of the economy (Rusvingo 2015). The need for creation of employment opportunities has reached its climax with this rise in the unemployment rate.

Zimbabwe has been named the food basket of Africa because of its dedication to agriculture. According to research, agriculture forms the backbone of the country's economy, contributing about sixteen to twenty percent of the country's Gross Domestic Product (Chidoko 2012). Because agriculture is a major industry and the foundation for the economy of Zimbabwe, this presents an avenue for the creation of employment opportunities. To create this employment, there is a drastic need to apply the latest technologies to support agricultural tasks such as harvesting and to be competitive on a global scale. Farmers currently employ thousands of laborers in the planting season to use mechanical machinery such as hoes and water cans to grow

crops in the traditional conservation agriculture. Irrigation is limited in most parts of the semi-arid Zimbabwe and this has led to lower yields. Hence, as of now, agriculture has created employment for the young and old based on the amount of labor needed to till the ground, not based on skills. With the communal method of rearing crops, local farmers hold traditional ceremonies where they invite community members, that is the young and old, to plow the fields in exchange for food and basic amenities. The large population that shows up for the ceremonies will serve as a source of labor to plow the farms without being paid for their time.

Regarding the employment status in Zimbabwe, there is a robust way forward focusing on creating as many employment opportunities as possible. The way forward is to establish the use of artificial intelligence to drive a computerized irrigation system in the agricultural sector in Zimbabwe and create employment opportunities. According to present research, AI is a new phenomenon and a science of engineering machines to do tasks that, if carried out by humans, would require a high degree of intelligence (Bunnell 2016). This implies that having a pre-scheduled computerized irrigation system which covers more hectares per unit time than a human worker would increases the efficiency of an agricultural firm. This also means that for every 100 people who could be employed to irrigate a one-hectare piece of land only 10 would need to be employed to operate the computerized irrigation scheme. What is seen is the loss of the 90 jobs due to the automation of the irrigation scheme. However, the automated irrigation scheme is going to cover more hectares per hour implying that the ninety people could

now be deployed into other agricultural activities such as weeding and sowing of seeds other than irrigating to improve the yield. With increased yield, more people are going to be called for work in the harvesting system to operate an increased amount of machinery in harvesting (Farkas 2003). Furthermore, there is going to be an emerging market for training youth and adults below the retirement age to operate harvesting machinery such as tractors and combine harvesters. This is an indirect emergence of educational opportunities for graduate students who are interested in instructing employees in the agricultural sector. It is a chain of employment opportunities all branching off from the application of AI and computerization to irrigation in agriculture.

Since Zimbabwe has been a net exporter of food in the southern part of Africa combined with its practice of winter agriculture (Rusvingo 2015); given the appropriate technology, the agricultural system has the potential to flourish and create employment opportunities. The emergence of AI in smart greenhouse technology in Zimbabwe, where the temperature of the crops is controlled in a heat-proof building by installed temperature sensors, could facilitate advanced winter agriculture which implies that agriculture could be carried out all year-round. With this system of winter agriculture, the young and the old will be employed to assemble the greenhouse itself and to maintain it. Smart greenhouse technology has never existed in Zimbabwe and in summary, with this emergence of AI technologies, jobs that never existed can be created (Bughin 2017). The smart greenhouse technology works by gathering large amounts of environmental data through a combination of machine vision, agricultural

sensors, and historical information. Once the environmental data is gathered, there is a need for environmental data analysts to interpret the data to the farmer and suggest mechanisms that would maximize yields during the winter season. Artificial intelligence instructors are also required to train the AI in smart greenhouse technology, and to then provide detailed advice and guidance to farmers and help them optimize their crop yields. This, in turn, creates a high demand for assemblers and maintenance personnel for the smart greenhouse technology and workers to construct the metal frameworks with automated heating during the winter

Agriculture is a diverse branch in Zimbabwe, and to operate well it needs a pool of professional knowledge. As the engineering of artificial intelligence increases in farming there is going to be an emergence of many departments within the agricultural firms such as, financial advising, management, and association departments. That means more administrative jobs to manage high cash flows being generated by high yields of corn or tobacco will arise. The financial advisors will provide farmers with specialist knowledge on how to use capital to expand their agricultural business. The AI era in Zimbabwe could mark the development of algorithms to analyze large volumes of cash flowing into and out of the farmer's hands and this can be done through employing educated graduates to do the tasks. The emergence of managerial roles to monitor the functionality of the farm will increase and associates or foremen will be hired. The equipment for artificial intelligence (which comprises of computer booths and hardware) needs management, installation, and security. Security officers who will serve

as overnight protectors of the computer booth will be called for work. In brief, the administration is going to comprise of the financial advisors, management hierarchy and associates or employees. Moreover, the diversity of the agricultural sector in terms of different crops ranging from corn, wheat, and sorghum being grown in a struggling Zimbabwean economy, means there lies a good opportunity to invest in AI technology to boost the agricultural industry and to create an administration in which financial advisors and associates can be hired.

The distribution of agricultural inputs such as seeds and fertilizer during the farming season by the government or by non-governmental organizations is a common practice to promote agriculture in Zimbabwe. Agricultural inputs must reach the intended farmers in time before the start of the farming season. Rohrbach et al (2005) compare the efficiency of distributing the agricultural input through direct handouts of seed and fertilizer, seed fairs, and the use of vouchers redeemable at seed retail shops. Direct seed handouts by the government's employees were found to be efficient but had less coverage because remote areas could not be reached. However, the introduction of AI drones (flying unmanned aerial vehicles), which is a part of AI in Zimbabwe, could mean that agricultural inputs can be distributed efficiently and quickly to farmers in order to meet their farming season deadlines. Artificial Intelligence drones (AI drones) combine computer vision with advanced robotics and can be programmed to perform the desired commands of the farmers. Engineering graduates are going to be hired to program and service the AI drones for the drones to deliver the agricultural inputs to the farmers in time. When

farmers plant their crops on time with enough fertilizers, there is a high probability of high yields. Therefore, during the harvesting season, more employees are going to be needed to operate the increased harvesting machinery and arrange the granaries to store the harvested grain. Though the employees who were once paid to distribute the agricultural inputs and to run the seed fairs could possibly lose their positions, with the emergence of AI drones, there is now an existence of a new market. Wilson (Summer 2017) of the MIT Accenture also supports the idea that AI will displace a swath of jobs such as jobs in the distribution of seed input, but strongly emphasizes the emergence and birth of new jobs that never existed before, like the manufacturing and programming of AI drones. On the positive side, the new market for the production of AI drones has emerged which was previously nonexistent. The production of AI drones will serve as a source of employment to the greater population of unemployed science, technology, engineering, and mathematics graduate students in the search for internships and research positions.

In a normal farming season in Zimbabwe, people are hired and paid to till, harrow, and disc the soils in preparation for the conventional farming season. Chiputwa et al (2011) wrote about resilience in some smallholder farmers to adopt new Conservation Agriculture technologies which use minimum harrowing, mulching, and zero tillage. With zero tillage and minimum harrowing, less soil inversion occurs (Bollinger et al 2006), meaning fewer people could now be employed in this conservation type of agriculture. The introduction of AI in the conservation agriculture technologies (zero tillage) in creating mobile

applications for farmers to control the machinery in the zero tillage process could create employment opportunities for software developers. The software developers could be hired to design computer programs to operate the automatic agricultural sprayers chosen to kill weeds over harrowing and tillage. Rose Harvey (The Yield video) strongly emphasizes the use of Microsoft AI in conservation agriculture to create employment opportunities not only limited to software development but also Environmental Facilities Manager positions which promote the production of more food by 2050 in an environmentally-friendly way. This strong annotation implies that in creating more employment in the Zimbabwean agricultural sector, a possibility is to harness the power of automation and application of AI to speed up the expansion of the agricultural sector. As with much that is new in AI research, many new jobs will also be created — jobs that look nothing like those that exist today (Wilson, 2017). That means AI, when applied to agriculture, has potential to create employment opportunities

It could possibly be a bustle of activity with 85% of the Zimbabwean population being literate (Melanie 2001) and able to work as accounting clerks, software developers, and farm attendants in the AI-led agricultural sector in Zimbabwe. The youth literacy rate and adult literacy rate stands at 90.93% and 88.63% respectively in Zimbabwe (United Nations Education Statistics Cultural Organization 2014). These high percentages signify a strong educational background, emphasizing that it is worth researching how AI could bring into existence employment in the agricultural sector. Because adopters of AI will share a global profit pool valued at $1 trillion

through global and domestic trade of capital goods such as agricultural produce (Bughin 2018), there is going to be enough funding for the agricultural projects to motivate food production and agricultural activities across Zimbabwe. More undergraduates, graduates, and adults will be on demand to be hired by agricultural institutions to carry out research or provide ideas in the development of sustainable food services and development of AI itself in the agricultural sector. Young people could possibly be taught with less difficulty the skills to develop and implement artificial intelligence in agricultural practices to create more employment opportunities for the upcoming generation. Since the Zimbabwean economy has a greater strength and reputation in agriculture, AI could be expected to provide employment opportunities for the Zimbabwean citizens in food processing and production transport equipment (Murinda 2014).

To conclude, a swath of new employment positions in agriculture, for example administration management positions, would be created if AI technology is implemented in the agricultural industry of Zimbabwe. As with so many AI innovations in smart greenhouse technology and drone and software development, the odds are that a blend of jobs requiring expertise and general job skills will certainly emerge. So, just as agricultural firms must address the urge to train one part of the workforce for the emerging AI jobs, Zimbabwean firms must refurbish their human resource processes to better attract and teach highly educated professionals whose talents will be in very high demand in the new AI era of artificial intelligence creating employment opportunities in

the Zimbabwean agricultural sector.

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"She is the sun and the moon, and anything that represents brightness." - A shift from communal worshipping to personal spiritual connection through the case of Guanyin worshipping in Hong Kong

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Wu has been "volunteering" at her temple for more than 10 years, ever since her retirement. Although she is technically employed by the temple, she has been heavily underpaid below the minimum wage, which the administration justified by providing her with free lessons from the monks and allowing her access to the temple library. One would expect to see a cynical, grumpy employee, unhappy with the compensations she received. However, Wu is gentle, friendly, and always smiling. She speaks in a soft voice that matches the atmosphere of the entire temple hall – silent, tranquil, and incredibly still. The temple is located at the top of a mountain, far away from any urban area. With the sweltering sun right above our heads, and the air almost unmovable, I was on the verge of falling asleep. But Wu, still cheerful and happy as she explained her understandings of Guanyin - one of the hundreds of deities that exist in the great hall - said something that stopped me from feeling drowsy: "Guanyin is so many things. Look at those Guanyin over there, she is the sun and the moon, and anything that represents brightness." To Wu, Guanyin is more than a thousand different things and will transform into whatever form the

worshipper needs her to be. If this is the case, then why is a statue needed? If a statue cannot transform into the form of the deity needed by its worshipper, is the statue being worshipped still responsive to people's calls? In that same afternoon, my questions were answered by another monk, Master Zhaorong, who pointed out that "Guanyin is efficacious everywhere." However, something is special about the statue at her temple that makes it more effective than the rest of the statues. Despite believing in Guanyin's omnipresence, she believes that the power from the statue she worships is more responsive.

Master's words seem to encapsulate a common contradiction found in many Guanyin worshippers. Although they believe in the omnipresence of the Guanyin deity, many also emphasized a personal connection with a particular religious object, implying that one particular statue is more efficacious (ling) than the others. How do Guanyin worshippers make sense of this connection? What does this idea that one statue can be more efficacious say about the production of "ling"? Most importantly, how does that relate to the spiritual relationship between the worshipper and the Guanyin?

According to Steven Sangren, the superpower of "ling" is attributed to territorial cult gods who defend community boundaries and centralize the collective's powers of production. The idea of "ling" is associated with communal power and territory. However, I found that my informants' spiritual relationships with Guanyin are rarely related to communal reasons. In fact, a heavy decline in organized community activities has occurred in certain temples. Religious practices seem to have become more private and individualized, a phenomenon unique to Hong Kong.

Building on the concept of religion as an increasingly personal phenomenon, I aim to examine the core question of how religious practices are shifting from a communal emphasis to a more interactive and personal connection with the deity through case studies of Guanyin worship in Hong Kong. My informants emphasize that the material aspect of the statue, offerings, and the size of the religious community are not as important as one's personal devotion to Guanyin. Moreover, one can develop individual connections with specific statues, making the statues' efficaciousness cater to the individuals' needs. My informants explained this personalization of Guanyin through

the notions of yuanfen (緣分), a "fateful coincidence" (Fan and Whitehead, 2011, 16) that connects an individual to a deity, depending on the statue's facial expression or bodily posture. I found a heavy focus on the interactive and personal aspect in my informants' relationship with Guanyin, showing that popular religious practices in Hong Kong are gradually shifting away from a communal focus that emphasizes the geographical proximity of believers and large group rituals.

Religious Life in Contemporary Hong Kong

As mentioned, Hong Kong religions are described as "overlooked." This is partly due to Hong Kong's image as a secular, fast-paced, and money-making society A survey by the Washington Post in 2015 ranked Hong Kong as having the 6th lowest percentage of religious people out of 65 countries. Although such surveys are viewed with scepticism, considering translational and cross-cultural differences, these statistics nonetheless paint a very secular image of Hong Kong.

It is also necessary to understand the pertinent religious atmosphere in urban Hong Kong society. The religious atmosphere in Hong Kong is described by scholars as being diverse, highly tolerant and adaptable. According to Liu Tik-tsang, Hong Kong religious life has much to do with the government's laissez-faire attitude toward religious groups and organizations throughout the British colonial years. Local religions are often blended with Buddhism, and in the eyes of the general public "there is no clear boundary between Buddhism, Daoism, and local religious practices" (Liu, 2003, 373). Liu argued that this nameless religion that incorporates various Buddhist, Daoist, and local rituals and beliefs is

powerful in the sense that it regulates, organizes, and structures local Hong Kong society, creating a "flexible and highly adaptable cultural institution" (Liu, 2003, 374).

However, as post-handover Hong Kong develops, one can question Liu's argument that popular religion has the power to organize society, especially outside of New Territories and native villages. Joseph Bosco emphasizes a clear distinction between rural village religious practices and urban pluralistic practices, arguing that religion is becoming less residential and communal and more individual and private precisely because popular religion is unable to organize Hong Kong society: "Religion is thus shifting from rituals relating to individuals' and communities' relationships with the supernatural to symbols of a Hong Kong identity" (Bosco, 2015, 9). For example, the Jiao festival that was once celebrated to "pacif[y] wandering ghosts, to purify the community's territory and to reach a cosmic renewal" (Liu, 2003, 381) is now viewed by most citizens as a symbol of traditional Hong Kong heritage instead of a religious activity, with its participants consisting mostly of non-villagers. As more religious rituals become more secularized cultural traditions, the differentiation between religious activities and traditional heritage is blurred. Some people, despite engaging in religious activities like the Jiao festival or the giving of incense in the New Year do not necessarily see themselves as religious. Despite the statistics from the Hong Kong Information Services Department that about 43% of Hong Kongers are religious, the actual number of people practicing religion could be much more than that, thus contributing to its overlooked nature.

Lin Fa Kung is famous for its Tai Hang

Fire Dragon Dance, a ritual dragon dance that started in the 19th century when villagers in Tai Hang were suffering from bad harvests and natural disasters. Among all the locations I visited, Lin Fa Kung seems to have the biggest communal event of all the temples. Even so, the Fire Dragon Dance has been included in China's national list of intangible cultural heritage and is featured in various government tourism websites. Along with the development of Tai Hang from a small fishing and farming village to an inland developed city due to land-reclamation, the nature of communal religion has slowly diminished and transformed into an activity that is symbolic of Hong Kong traditional identity. As religious practices are increasingly viewed by scholars as "matters of heritage and identity," their religious dimensions are being overlooked (Bosco, 2015, 9).

Rise of Buddhism

Over the past few decades, there seems to be an unrecognized but rising population of Buddhists in Hong Kong. The Hong Kong Social Development Index (SDI) tracks a set of indicators, such as political participation, education, health etc., aimed at measuring social development in Hong Kong objectively.

A survey about of Hong Kong social indicators identified the number of people declaring themselves Buddhist increased from 6.6% in 1988 to 11.6% in 1995 (Wong and Cheng, 1997, 299-329). The religious component in the SDI was removed after the handover, resulting in a lack of religious data, reflecting the assumption that religion is relatively unimportant in Hong Kong society. Since many in Hong Kong who practice popular religion may not identify themselves as "religious", the

11.6% indicated above may not have included lay believers who worship Buddhist deities but do not consider themselves "religious".

The rise of Buddhism became more apparent and prominent after the return of Hong Kong to China in 1997. In 1998, the Hong Kong Buddhist Association collected over 800 thousand signatures on a petition for the Buddha's birthday (8th day of the 4th lunar month) to become an official public holiday. The redevelopment of Chi Lin Nunnery, one of the most prominent Buddhist institutions in Hong Kong, was completed along with grand opening ceremonies and blessing (kai-guang) rituals in 1998 (Pong, 2007, 3). Recently, the second highest Guanyin statue in the world and its temple, Tsz Shan Monastery, was established and became a popular site for not only Buddhists, but also tourists and the general public. Despite a lack of statistics on Buddhism and religious development in general, Buddhist institutions and infrastructures have an undeniably growing presence in Hong Kong society.

While the idea that popular religion namelessly organizes and structures society might be questioned, Buddhist culture does permeate in Hong Kong in terms of popular culture. Popular Hong Kong comedies featuring Stephen Chow often end with the protagonist reaching some sort of spiritual enlightenment. In Kungfu Hustle, Chow reached a physical ascension and leaped so high from the ground that he encountered Buddha in the sky. From pop songs to movies, Buddhist motifs are very common in Hong Kong pop culture throughout the late 20th century.

Buddhism and Guanyin

Guanyin, the Chinese name of Avalokitesvara - the Bodhisattva of compassion- is short for Guanshiyin, meaning the "Perceiver of the World's Sounds." Along with Buddhism in general, Guanyin was introduced to China by Central Asian and Indian missionary monks during the second half of the Han dynasty (206 B.C.E – 220 C.E). However, it wasn't until the Tang dynasty that Guanyin became an increasingly popular figure among artists. Apart from the artistic aspect, Guanyin has become popular among common people, due to the lack of feminine symbols in existing Chinese religion, as well as the fact that China's state religion, neo-Confucianism, is very oriented towards upper-class, educated males. Most importantly, Guanyin was able to fill in the role as a "universal savior" (Yü, 2001, 15-21), a role that was void in Chinese religion for a long time. One of the things that sets Guanyin apart from most of the Buddhist deities is the disconnection with royalty and government structure. As mentioned by Wolf's God, Ghosts, and Ancestors, Chinese popular religion tends to associate deities with existing local government structure. Guanyin does not fit into a clearly defined role in government structure or royalty, as Avalokiteśvara did in other countries (Wolf, 1978, 131).

In 1976, C.N. Tay referred to the cult of Guanyin as "the cult of half Asia", implying the popularity of Guanyin as well as her compassion and reputation for catering towards every human being with "the desire to rise above our own karma" (Tay, 1976, 148). The meaning behind Guanyin's name – "perceiver of the world's sound" – reflected the nature of the deity as an all-encompassing savior that transcends any territorial and institutional role in Chinese popular religion, and is compassionate towards people's needs, even those with low karma.

Ling and Yuanfen

How the perception of Guanyin has changed is closely related to another important concept in Chinese folk religion: ling. Measurement of efficaciousness of a deity is associated with the concept of "ling", a magical power associated with local gods that defend communal boundaries and centralizes local communities' collective production (Sangren, 1991, 67). What exactly produces the ling of a particular deity? Sangren argues that the efficacy of the deity is not necessarily linked to the statues' resemblance to real life officials, as Wolf claims in "Gods, Ghosts, and Ancestors". Instead, the "efficacy attributed to territorial-cult deities corresponds more closely to their role as mediators of the community" (Sangren, 1987, 230).

For example, one of my informants spoke about a young child who was in a car accident. He was told by doctors that his legs were hopeless and that they needed to be amputated. His family, with no other doctors to turn to, went to seek Guanyin's help at the informant's monastery for 3 days straight, and their son's legs were miraculously cured. Since then, they regarded that particular statue in the monastery as "ling" and decided to worship the statue on a regular basis. In simple terms, ling is the power that answers a practitioner's wishes. According to Sangren, the production of "ling" is associated with communal identities and territorial-based deities. However, the modern urban Hong Kong religious setting, which shows a decline in organized religion and a rise in more diffused individual religion, (Bosco, 2015, 11-14), raises the question of how ling is produced in this new religious environment. I

argue that without a strong communal presence, ling is reproduced and made sense of with personal connection.

In addition to the diffuse religion in Hong Kong that has little to no boundary between folk religion and Buddhism, folk concepts like fate (yuanfen) appear frequently in contemporary pop music. Yuanfen, translated as "fateful coincidence" is a Chinese notion of fate that conveys both good and bad fortune (Fan and Whitehead, 2011, 16). Stemming from folk religion and fused with the Buddhist concept of karma, yuanfen emphasizes an interactive aspect, especially among connections between two or more people. In the project, yuanfen was discovered to be an important concept in explaining relationships between Guanyin statues and Guanyin worshippers.

Making Sense of Religious Space, Ling, and Yuan

During the past summer, I was working as a visiting student at the Hong Kong Institute for the Humanities and Social Sciences and had the opportunity to join a project studying why and how people need religious objects, particularly Guanyin statues. I participated in observations and semi-structured interviews in a total of thirty-two locations. Those locations included temples, shrines, religious shops, and halls, twelve of which are Buddhist, seven are folk/popular religion, three are Daoist, and those remaining are commercial enterprises. The interviews were conducted mostly in Cantonese, and our informants included temples keepers, monks, worshippers, and shopkeepers.

Most informants speak about Guanyin as an omnipresent deity but believe that one particular statue in a certain place is most efficacious. Guanyin is described as existing everywhere and manifesting as anything to her believers, according to the yuan between them.

Besides the Guanyin statue itself, most temple keepers and monks stressed the importance of the location and natural environment surrounding the religious space. Lin Fa temple (蓮花宮), one of the first temples I visited, is built around a huge rock two stories high. The front section of the temple is supported by ten to twelve foot high pillars, and the back is supported by a huge rock called the "Lotus Rock," half of which is exposed in the temple, while the other half is hidden by an exterior wall. According to the temple manager, Guanyin was rumored to have appeared on top of the rock, hence the villagers' decision to build a temple around the rock. Guanyin has since become the main deity worshipped in the temple.

Guanyin Grotto, a hall built around a stone cave on the back of the highest peak in Hong Kong, is a place very isolated from the rest of the city and can be reached only by climbing an extremely long and steep flight of stairs.

The temple master Zhaorong (照融) expressed how the natural environment and qi of the location helped the Guanyin statue in becoming more efficacious: "Guanyin is really ling, as long as you worship with all your heart." When we asked about the importance of the statue, Master Zhaorong disagreed that statues were that important at all. She brought up the important concept of yuan fen, saying that statues are only useful in catching people's attention while worshipping. Since Guanyin exists everywhere, it is efficacious everywhere. It is yuanfen that allows Guanyin to develop a personal connection with the worshipper and to manifest into anything that the worshipper needs.

In another location, Tung Po Tor (東普陀), master Tat Tong (達通) expressed similar ideas. The temple name Tung Po Tor(東普陀) is derived from Potoushan, a place in Zhejiang where Guanyin is believed to reside. When asked about the particular significance of this location in relation to Guanyin, Master Tat Tong brought up the idea of yuan – the affinity that brought their founding master all the way from Taiwan to Tsuen Wan, Hong Kong, a relatively rural area during the time the temple was founded. The yuan of the founding master to this location was matched in harmony with nature and great fengshui. Similar to Zhaorong, Master Tat Tong spoke of the omnipresence of Guanyin and its ability to manifest into whatever form suits the needs of the believer. When asked why one would need a statue if Guanyin is supposed to be without image, Master and Senior both agreed that nothingness is too difficult for common human beings to grasp. When a bodhisattva meditates, their ears can hear everything in the outside world, and according to the concept of yuan, a bodhisattva may appear in front of you to increase your confidence and faith. This is why worshipping tools are useful: they function as reminders and alarms to awaken one's soul.

According to Yü, the domestication of Guanyin had been closely related to miracle stories that change and adapt according to the times and problems of the people (Yü, 2001, 151-194). Through narratives of Guanyin's ability to solve people's problems regardless of social identity, Guanyin was able to rise as one of the most popular deities in China. All the stories that pointed to Guanyin being ling were all very

personal, usually affecting a single person's wellbeing in terms of health, career, marriage, etc., and rarely relating to communal or even family-wide problems.

Master Zhaorong had multiple miraculous stories of the particular efficacy of Guanyin Grotto. For example, in one story, a fickle playboy who was beaten up by his girlfriend's family, asked Guanyin in Guanyin Grotto whether he should undergo surgery. Guanyin said no. He chose not to undergo surgery and his head injury was still miraculously cured. He then became a good man and a regular worshipper. Another story concerns a woman who desperately wanted a child. She underwent artificial insemination twice but still did not become pregnant. She walked all the way up to the Guanyin Grotto, worshipped the Guanyin once and immediately became pregnant. By walking all the way to the desolate location in the mountains, worshippers can show their devotion to to the deity. The above stories all point towards Guanyin answering very specific personal decisions.

In certain instances, Guanyin is not just responsive in answering people's needs, but appears in corporeal form in front of her worshippers. Master Tat Tong herself witnessed Guanyin appearing in front of the blessed location. "I was in charge of the main Hall, sweeping, burning incense… That's when I saw her, in the exact same appearance (as the statue in the main hall), but the color was transparent… It was the same face, but with no color. I immediately knelt down, with head and hands on the floor (頂禮)." Disciple (師兄) Law, who works besides Master Tat Tong, added that "Bodhisattvas are originally without shape or appearance. Only those with yuanfen will see her in real life, but she

has a lot of manifestations. Guanyin is genderless, and the image we see of Guanyin are projections from our heart."

How do we see Guanyin in real life then? Master Tat Tong explains by saying that she has a lot of yuanfen with Buddhism in general, which was why she decided to become a monk. When we described the same event to Master Zhaorong, she explained in a similar way: "Guanyin manifesting in real life depends on yuanfen. It could be a man, a woman, an elderly person, or even an animal." She stressed the flexibility of Guanyin as a Buddhist deity, and that sometimes Guanyin can appear in front of us without our knowledge: "In China, Guanyin is usually a female, but in a different place she could be a Vajrayana. …Guanyin exists in a realm with no desire and lust, only consciousness. You could be talking to a stranger while waiting in line, and all of the sudden the person was gone when you turned away. That could be a Guanyin manifestation. It could be anytime, anywhere.".

Looking at all the informants' relationships with Guanyin, most of them expressed a highly personal connection with the Guanyin statue that they regarded as more efficacious. In fact, the communal and collective aspects of deity worship were rarely mentioned. This seems to be further reflected by how people buy and choose their own Guanyin statue.

At Yue Hwa Chinese Products Emporium, one of the employees introduced us to Kevin Wang, a broker between department stores and ceramic factories who happened to be visiting the store that evening. Mr. Wang is a tall, middle-aged man who speaks Mandarin. He was very friendly and enthusiastic in showing us his cura-

tions. We soon discovered that he is from Dehua, Fujian, a city famous for their ceramic industry.

As someone who has been in the ceramic statue industry for decades, Mr. Wang explained how buyers typically choose their Guanyin statue – "yanyuen" (眼緣), a kind of visually established yuenfen. According to Mr. Wang, "Beauty doesn't make a statue more efficacious, but their facial expressions say it all." Every statue made from Dehua clay required both machine-made and handmade components, which made each statue unique. Slight differences in the curve of the smile, the angle of the eyes, and roundness of the face may not be noticed by the buyers, but allow the specific statue to establish its respective yuan with the worshipper, thus encouraging the worshipper to invite the Guanyin to their homes. He emphasized that the personal connection between Guanyin and the worshipper is established by "yanyuan," and that the facial expression of the statue plays a vital role.

This opinion seems to be affirmed by disciple Po Cha (普查) at Guanyin Grotto, who finds the statue at Guanyin Grotto more efficacious precisely because of her facial expression, which particularly calls to her. "It's rare to see such a solemn and benevolent face," Po Cha explained. Our interview took place during a hot July afternoon, in an open area outside of the stone cave. The sweltering heat and swarms of mosquitoes that distracted me throughout the interview did not seem to bother our two informants, who sat in complete peace and told us to look into the statue, too. "It looks serious, yet compassionate…" Master Zhaorong also agreed with disciple Po Cha, adding that the Guanyin in the stone cave was made on-site by a

skilled artisan who has since passed away, which is why no one can replicate a Guanyin statue with the same facial expression anymore. Similarly, when asked how one would know if a Guanyin is more efficacious, they mentioned the idea of yuanfen: "There are so many statues out there, but [your choice] depends on whichever one can capture your heart. It's the same with choosing a girlfriend, other people may not think she's pretty, but perhaps you will find her very beautiful. That's yuanfen." Disciple Po Cha then recalled his experience of getting his own Maitreya statue at his home's altar: "I saw him sitting there smiling at me, and I couldn't help and smile back at him… I could sense that yuanfen between us, so I invited him home." The power of Guanyin is apparent in the personal connection between the worshipper and Guanyin. Yuanfen seems to be the main element in facilitating this personal connection, within which various things such as the facial expressions of the statue and the beauty standard of worshipper contribute to the amount of yuanfen the worshipper has with Guanyin. Ultimately, this power is what contributes to the notion of Guanyin being ling.

At another temple, we met with Wu, who has been contently volunteering almost full time in the temple with little compensation. We were walking past rows of statues as tall as a story, the Eighteen Arhats, rows of bodhisattvas, and the Buddha, all coated in gold and cared for by Wu herself. As we passed various different Guanyin statues, she stopped and told us to pay close attention. There were Guanyin sitting in the lotus position, Guanyin standing up and holding a willow, Guanyin cradling a baby with one hand, Thousand-Armed Guanyin, and many more. "See, the Guanyin is holding all sorts of treasures. They each have their respective implications, meanings, and powers; it would take me days to explain each and every one of them," she said. But how does one know which form of Guanyin suits the person? "Have you read the Guanyin sutra (Avalokiteśvara-vikurvana-nirdeśah)?" she asked. I said no, and Wu patiently sat down with us and read out this sentence from the sutra: "'To manifest in whatever appropriate form (應以什麼身就現什麼身)' - Guanyin herself will manifest into whatever form that suits you the most, and help you with her respective power." I had seen hundreds of different forms of Guanyin in various temples, yet never once had I thought of the significance of the different positions and treasures to the deities. At that moment, I was struck by the realization that there were so many meanings that my informants could see but I could not. Sitting in between hundreds of benevolent statues and faces, I felt incredibly small.

For Wu, her trust in Guanyin's power connects her to the deity and builds their personal connection: "If I ask the bodhisattva for help, she will see through my wisdom, will see through what appropriate form of manifestation I need, and will see the best treasure that can bring me what I needed the most. Guanyin is so many things. Look at those Guanyin over there, she is the sun and the moon, and anything that represents brightness." At the end of our visit, Wu revealed to us that her salary was raised after a government inspection. She cheerfully accredited her raise to Guanyin's grace, and we all felt deeply happy for her.

Conclusion

The more we explored the various relationships between Guanyin and worshippers, the more we could see 1) how these relationships are shaped by social context pertinent to Hong Kong religious life, and 2) how ling as power is generated by personal connections established by yuanfen, instead of through communal activities and territorial production. The Hong Kong religious practice is moving more towards an emphasis on personal connections with the deity, as many informants mentioned choosing their Guanyin deity through yuan, and the characteristics that define yuan include posture and facial expression of the Guanyin. Most of the time, informants visit a temple far away from the city due to the efficaciousness of the deity there; they are not motivated by communal reasons. Instead, putting in a personal effort to walk up a high mountain or a long flight of stairs shows one's dedication and sincerity to Guanyin, and is seen as beneficial in gaining yuan. In comparison, the idea that ling is created from communal production and that it organizes communal society in a non-institutional way does not seem as relevant to Hong Kong's religious context.

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Exploration of Jabba Protein Expression levels on Lipid Droplets in the Drosophila Larval Fat Body in vivo

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Introduction

Lipid droplets are ubiquitous neutral lipid storage organelles. Until relatively recently lipid storage was the only function of theirs that was considered. Though their storage of neutral lipids, such as triglycerides, steryl esters, and retinyl esters, for use in membrane synthesis, the production of signaling molecules, and energy liberation is of vital importance to the cell, we now know that lipid droplets play a variety of other roles as well. One such role is as sequestration sites for various proteins which perform far-reaching tasks in cells [1], which are sometimes incompletely understood. Lipid droplets have also been implicated in the cellular immune response to pathogens as well as the pathogenesis of certain intracellular microbes. As protein sequestration sites, it is not a far leap to conjecture that lipid droplets may serve as sequestration sites for antimicrobial peptides and proteins [2].

One candidate that has shown significant promise as an antimicrobial protein stored on lipid droplets is histones. When not bound to chromatin, free histones can be toxic to cells, and there is some evidence that they can be deployed by animal cells to dispatch extracellular pathogens. In vitro, histones have been shown to be released from lipid droplets in response to bacterial endotoxins [3]. Lipid droplets serve as important reservoirs for histones inside cells due to the volatility of histones in their unbound form. In *Drosophila melanogaster,* this association is facilitated by the histone anchoring protein Jabba. Experiments in vivo using *Drosophila* embryos and adult flies have shown that individuals lacking histones bound to lipid droplets have significantly worse outcomes in the case of bacterial infections than those with wild type levels of histones bound to lipid droplets. There is also evidence suggesting that a similar correlation can be found in mice; this in turn could indicate that histones associated with lipid droplets could be part of a hitherto unknown conserved mechanism of innate immunity in animals [3].

In order to elaborate on the earlier research on *Drosophila* embryos and adult flies, the lipid droplet bound histone mediated immune response must be explored in other stages of the *Drosophila* life cycle. One stage of the *Drosophila* life cycle of particular note is the larval stage. In the 3rd instar larval stage the *Drosophila* have an abundance of fat tissue in the larval fat body that contains ample lipid droplet stores. These larvae could also be more physically susceptible to pathogens than either embryos or pupae due to their lack of a thick outer shell acting as a physiological barrier; they might therefore rely more heavily on other immunological methods such as those associated with lipid droplets. Both of these factors indicate that 3rd instar *Drosophila* larvae could be an intriguing and vital stage of the *Drosophila* life cycle in which to study the role lipid droplet-bound histones play in associated immunity. The larval fat body has also been identified as a major immune organ in *Drosophila* larvae, making it doubly pertinent to this area of study in the larvae [4].

As mentioned previously, in *Drosophila,* histones are bound to lipid droplets by the anchoring protein Jabba, and it was in fact the expression of this protein that was used to modulate lipid droplet-bound histone levels in the experiments that worked with *Drosophila* embryos and adult flies. Jabba offers a way to vary the amount of histones bound to lipid droplets without compromising the health of the cells [3]. If a correlation between the concentration of lipid droplet bound histones in a cell and the efficacy of the antimicrobial response of the cell exists in *Drosophila* larvae, then this correlation could be elucidated by means of evaluating the efficacy of the antimicrobial response of *Drosophila* larvae in relation to the expression of Jabba protein. For this to be possible, strains of *Drosophila* expressing differing levels of Jabba on lipid droplets

in larvae must first be identified and characterized. I set about to complete this set of experimental procedures to determine if a discernible trend in Jabba expression on lipid droplets could be observed among wild type (*WT*), single chromosomal deletion (*1xJabba*), hypo-morph (*Jabba^{low}*), and null (*Jabba^{DL}*) *Drosophila* larvae for use in later experiments comparing the immunological capabilities of these four *Jabba* genotypes.

I established through previous experimentation using *Drosophila* embryos that a clear trend could be observed between the four above stated genotypes in embryos. This experimentation and an understanding of the genetic *Jabba* endowment of each of these strains informed the hypothesis that the below trend seen in embryos (fig.1) would be seen in the larvae. This would mean that Jabba associated fluorescent signals would be highest in the *WT*, lowest in the *Jabba^{DL}*, intermediate in the *1xJabba*, and in between the *1xJabba* and the *Jabba^{DL}*

in relation to the signal in the *Jabba^{low}*.

The trend seen in the embryos was, however, not seen in the larvae of the same genotypes. There was a clear difference in the Jabba signal between the wild type and null genotypes, but no discernable consistent difference in the levels of signal between the wild type and *Jabba^{low}* genotypes. This observation suggests that Jabba expression in larvae could be under feedback inhibition and indicates that alternative avenues must be pursued to explore the correlation between Jabba expression and immunological competency in larvae.. Interestingly, the *1xJabba* genotype larvae produced very little harvestable fat tissue compared to the other genotypes and further experimentation is currently being done to explore this phenomenon.

Results

The first goal of this project was to establish that there was Jabba protein expression on lipid droplets in the larval fat body. This was achieved by

comparing Jabba signals from identically fixed and Jabba immunostained wild type and null mutation larval tissues and cross referencing these images to a wild type fat body that had been neutral lipid stained (fig. 2).

The presence of greater signal observed in the wild type than in *Jabba^{DL}* indicates the procedure used is in fact capable of differentiating between Jabba expression and a lack thereof. It can also be seen that this expression occurs in the expected ring patterns associated with the peripheral structures within adipocytes visible in the bright field that were suspected of being lipid droplets; the same structures that were confirmed to be filled with neutral lipids in the neutral lipid stain. Given this information, it is reasonable to assert that the Jabba antibody was in fact indicative of of Jabba expression levels on lipid droplets in the fat body and could be used to compare the expression levels in all four genotypes.

Of the four genotypes sampled, only three produced enough fat body to
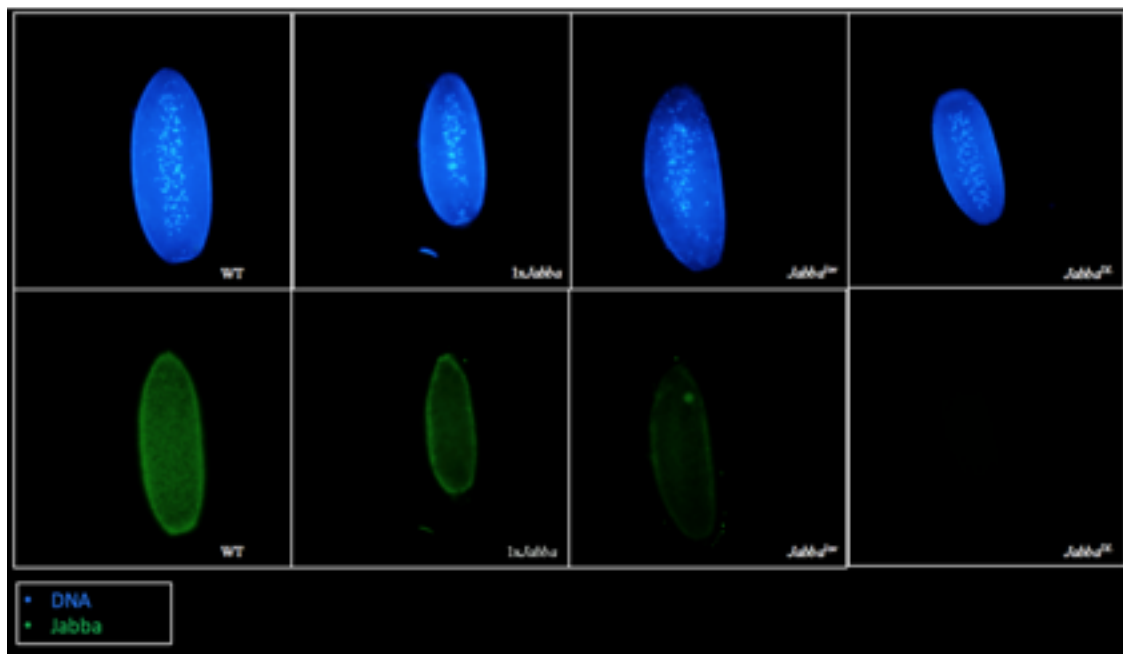
Figure 1. Jabba Expression in Stage 4 Embryos. Jabba signal was detected in all four genotypes as expected, images were all enhanced equally in PowerPoint (+40% Brightness +40% Contrast) from unpublished data collected by the author

survive the fixation and immunostaining procedures (fig. 3). The fourth genotype, *1xJabba*, did not produce sufficient fat body to yield usable results. DNA staining was utilized as a staining control. The *Jabba^{DL}* predictably had a significantly lower level of Jabba signal than the other two genotypes. The wild type and *Jabba^{low}* genotypes had indistinguishable signal levels in the fat body. These signals were also observed in the ring-shaped pattern expected of Jabba signal on lipid droplets, while the *Jabba^{DL}* sample lacked such signal patterns.

Discussion

The presence of Jabba signal in the wild type that is not present in the null genotype indicates that Jabba signal can be used to determine Jabba expression levels in the fat body. This is promising for future work with the larval fat body. That being said, the lack of difference in signal intensity between the wild type and hypo-morph genotypes would seem to indicate that this will not be a useful model for testing the effect of varying Jabba protein expression levels on the potency of the immunological response in larvae. These two genotypes have drasti-

cally different genetic endowments of *Jabba*, and in the embryonic stage they also show dramatically different levels of Jabba expression. One possible explanation for the lack of discernible difference between the two genotypes is a feedback inhibition mechanism limiting the amount of Jabba protein being expressed in the adipocytes to a level at or below the expression level of the un-inhibited hypo-morph in both strains in the larvae. This mechanism would thereby eliminate any difference in the expression levels of the two genotypes. The possibility of a feedback inhibition mechanism for Jabba expression in the larval fat body was an unexpected result, but still an interesting one. Seeing as this system does not produce a clear and traceable trend in Jabba expression levels, other avenues should be explored to better understand the role of lipid droplets and lipid droplet associated proteins in the immunological response of *Drosophila* larvae.

Perhaps the most unexpected result of this set of procedures was the lack of fat body procured from the *1xJabba* larvae. It is possible that this finding was an experimental anomaly. Over thirty larvae were dissected, but all

were dissected on the same day from only a few culture bottles. Therefore repetition is in order to determine if this is a consistent phenomenon for this genotype. If it is, there are two possible reasons for the lack of fat body found in the *1xJabba* larvae. The first is that having a single copy of the gene for Jabba is problematic in and of itself for fat body production in the larvae when compared to the wild type and the mutant strain which contain no gene for Jabba on either chromosome and both produce copious amounts of fat body. The second possible reason has to do with the nature of the mutation that creates the *1xJabba* genotype. This genotype is created by deleting a portion of one of the set of chromosomes that contain the gene for Jabba expression. This deletion contains the *Jabba* gene as well as other genes upstream. The *Jabba^{DL}* mutant, which has normal fat body endowment, has a more precise deletion of the gene for Jabba on both chromosomes. It is therefore possible that one of the genes upstream of *Jabba* being deleted in the *1xJabba* genotype is the actual cause of the lack of fat body in the mutant strain. Both of these possibilities could have massive implications for the
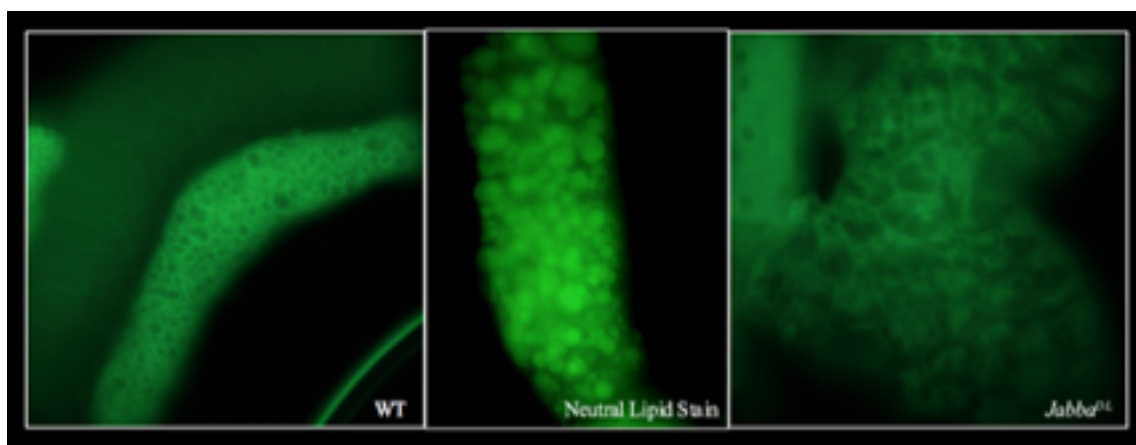
Figure 2. Verification of Jabba Expression on lipid droplets in 40x magnification images. Signal was detected at significantly higher levels in the wildtype than the in the null mutant and in ring patterns not seen in the null mutant and neutral lipid was detected in the interior of similarly shaped structures. Images were not enhanced.

health of the *1xJabba* larvae and strain overall. A cross is being done between wild type and null flies to examine whether or not a single dosage *Jabba* mutant without further genetic material deleted will show a reduction in fat body.

One future direction for this vein of research is to explore what other proteins and peptides with antimicrobial properties could be sequestered on lipid droplets for use in immunological defense. The beginnings of this study would involve looking for proteins besides Jabba that display lipid droplet patterning in signal. Since it has already been indicated that differing histone levels on lipid droplets are observable and correlated with differences in immunological competency in adult flies and embryos, it may also

be interesting to continue searching for such correlations in other animal models so as to explore the extent of the conservation of this immune response.

Methods

Larval Collection, Dissection, and Fixation

Third (3rd) instar Larvae were collected from the sides of culture bottles using tweezers. Larvae were identified as being 3rd instar both by their large size and by their high position on the sides of the bottles. Once collected, larvae were placed in 1xPBS (phosphate buffered saline) in nine-well dishes. Tweezers were used to separate the mouth parts, salivary glands, and fat body from the rest of the larval tissues, and the digestive tract was

clipped near the mouth parts to avoid it obscuring the fat body. The mouth parts and associated tissues, including fat body, were then transferred to an adjacent well also containing 1xPBS until all larvae of a given set had been dissected. Thirty (30) larval tissues were collected for each set of tissues to be immunostained for Jabba and 10 were collected for use in neutral lipid staining.

Following dissection, the larval tissues associated with the mouth parts were heat fixed. They were transferred by tweezers into a scintillation vial of boiling 1xTSS (triton salt solution), which was capped loosely and put in a boiling water bath for 1 minute before being immediately transferred to ice. Samples remained on ice while subsequent sets of tissues were dis-

Figure 3. Varying Levels of Jabba Signal in three Jabba Dosage Genotypes. A clear difference in signal intensity can be seen between the *Jabba^DL* and the other two genotypes, however the WT and *Jabba^low* genotypes appear to have approximately equivalent signal intensity in the fat body. Images were not enhanced.

sected and heat fixed. Once all sets of samples for a given experiment were on ice, they were all rinsed in antibody rinse (1xPBS and 0.1% TSS) once for 15 minutes on a nutator and then were transferred by tweezers into Eppendorf tubes containing 1 mL of blocking buffer (10% BSA, 0.5% TritonX-100, 0.02% Sodium Azide solution in 1xPBS) and incubated at 4º Celsius overnight.

Larval DNA, Neutral Lipid, and Immunostaining

In the case of larval tissues that were neutral lipid stained, the blocking buffer was removed and replaced with 980 µL of fresh blocking buffer and 20µL of Nile Red neutral lipid stain. The samples were placed on the nutator at room temperature for 1 hour. The solution was then removed from the tissues and replaced with 1 mL of antibody rinse. The samples were rinsed twice in antibody rinse for 15 minutes each time. Samples were then mounted.

In the case of larval tissues that were immunostained for Jabba and DNA stained, the blocking buffer was removed and samples were split roughly in half by volume of sample. One half of each sample was placed in a new Eppendorf tube and used as a no primary antibody control. The blocking buffer was replaced with 990 µL of blocking buffer for all samples. The experimental group received 10µL of 1:10 dilution of Jabba primary antibody (rabbit anti-Jabba), and the no primary controls did not. All samples were incubated on a nutator at 4º Celsius overnight. All samples were then rinsed 3 times with antibody rinse for 15 minutes each time on a nutator. Antibody rinse was replaced with

990 µL of blocking buffer and 10 µL of 1:10 dilution of secondary antibody (goat anti-rabbit 488 nm) and was incubated overnight at 4º Celsius on a nutator. The solutions were once again replaced with antibody rinse and the samples were rinsed 3 times in antibody rinse for 15 minutes each time. The antibody rinse was then replaced with 1 mL of blocking buffer and 3 µL of DAPI (5mg/mL 4',6-Diamidine-2'-phenylindole di-hydrochloride) and allowed to incubate for 8 minutes at room temperature on a nutator. The samples were then rinsed with antibody rinse 3 times for 15 minutes each time and were then mounted.

Larval Mounting and Epifluorescence Imaging

Larval tissues were deposited onto slides using 1000 µL pipette tips that had their tips cut off. Tweezers were then employed to separate the fat body and salivary glands from the rest of the tissues. Salivary glands and fat body remained on the slides while other tissues were removed. Once salivary glands and fat body had been spread out so samples were not on top of one another, any remaining liquid was removed and aquapolymount was placed on the larval tissues. 18x18 mm #1 thickness coverslips were placed with aquapolymount on either side of the sample to act as spacers. A single 22x22 mm #1.5 thickness coverslip was placed, bridging the two other coverslips and covering the sample. Slides were sealed using clear nail polish and stored at 4º Celsius overnight. Unless otherwise specified, 10x magnification was used for all images. All images were taken on an epifluorescence microscope. Neutral lipid staining was imaged on the green channel

at 100 msec and 1 gain. DAPI staining was imaged on the blue channel at 600 msec and 1 gain. Jabba immunostaining was imaged on the green channel at 4 gain, 600 msec for 10x images and 2 gain, 600 msec for 40x images.

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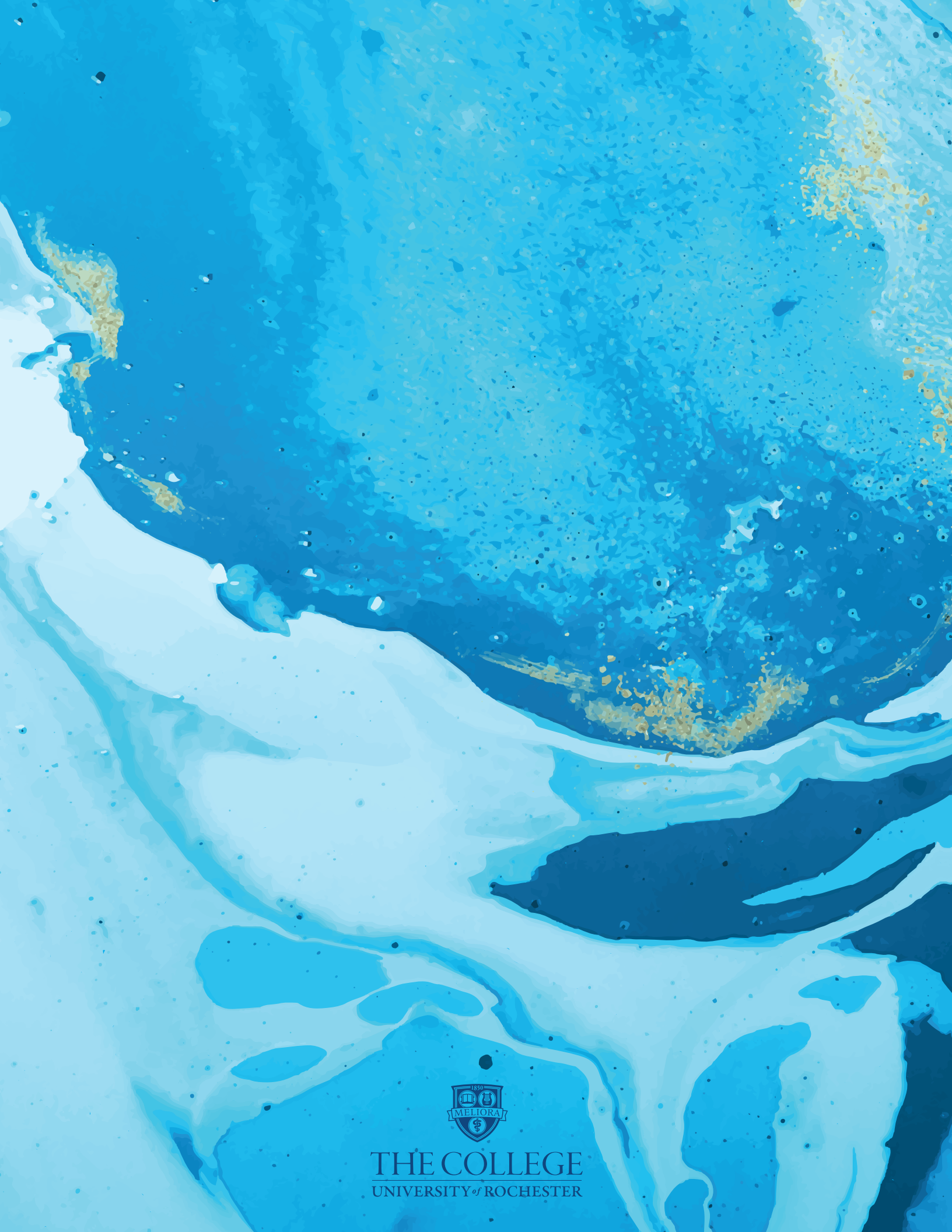*This page left intentionally blank.*

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