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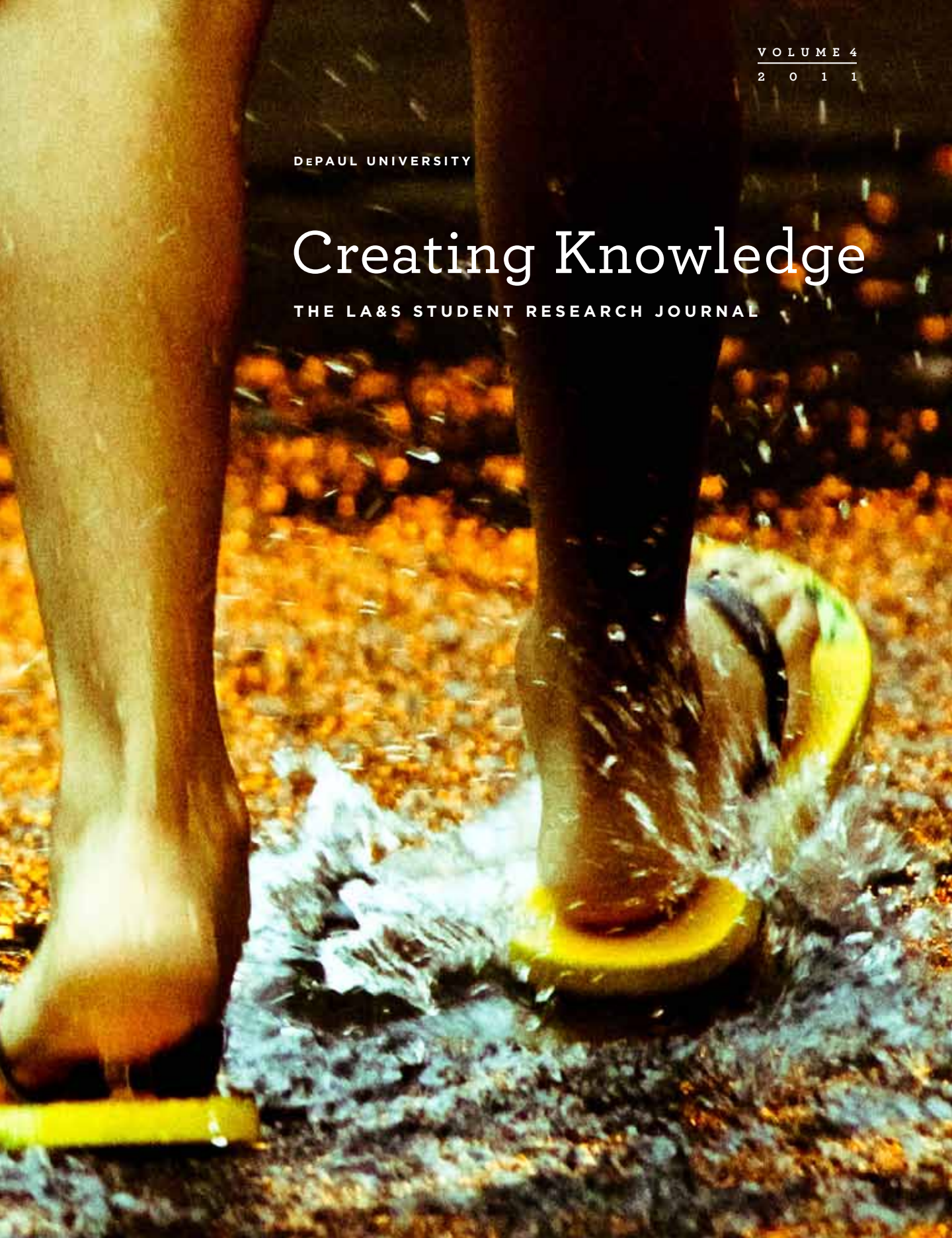
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VOLUME 4  
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DEPAUL UNIVERSITY

# Creating Knowledge

THE LA&S STUDENT RESEARCH JOURNAL



**CREATING KNOWLEDGE**

The College of Liberal Arts and Sciences Student Research Journal

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DEAR STUDENTS, FACULTY COLLEAGUES AND FRIENDS,

The College of Liberal Arts and Sciences, through the deliberations and efforts of its task force on “Students Creating Knowledge”, chaired by Professor Ralph Erber, associate dean for research in the College of Liberal Arts and Sciences, committed itself to a number of new strategic initiatives that would enhance and enrich the academic quality of the student experience within the college. Chief among these initiatives was one that would encourage students to become actively engaged in creating scholarship and research and give them a venue for the publication of their essays. The first volume of “Creating Knowledge: The LA&S Student Research Journal” was published in 2008. I am now extremely pleased to be able to introduce the fourth volume of Creating Knowledge. This year’s publication, like the ones that preceded it, gives considerable testimony to the creativity, hard work and sophistication of our undergraduate scholars. It is through the continuing, annual publication of this undergraduate student journal that we aim to encourage students across the college and the university to understand that leadership within their disciplines requires them to not only be familiar with the knowledge base of the discipline, but to have the experience of being actively engaged in understanding how creative work and/or scientific discoveries are created through research, scholarship and the dissemination and sharing of knowledge.

I want to congratulate, first and foremost, the many student scholars whose work is featured in this fourth volume of the journal. I also want to thank the students and faculty who served to make this publication possible—those who served on the editorial board that shaped this journal and who reviewed the many submissions of student work. In accomplishing this task all of you have participated in what is the heart of scholarship—the contributions to enabling and sustaining an intellectual community—one which we hope will lead you to make similar contributions beyond the college and DePaul University. To one and all, my most sincere congratulations and gratitude.

A handwritten signature in black ink that reads "Charles S. Suchar". The signature is written in a cursive, slightly slanted style.

CHUCK SUCHAR

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# THE EMANCIPATION FROM THE YOKE OF PRECONCEIVED NOTIONS: AMERICAN PRAGMATISM AND THE SOCIALLY TRANSFORMATIVE EFFECTS OF LITURGY

Adam Kamin\*

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**ABSTRACT** This paper assesses religious ritual for its qualitative elements and circumvents debates concerned with religions' relationship with a Supernatural Being. To this end, pragmatism, a uniquely American philosophy, serves as the lens through which liturgy can be examined for its social effects as opposed to how it is historically understood.

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Although great strides in recent years have brought communities together by fostering that which individuals hold in common, the propensity to define ourselves in contradistinction to others continues to be an obstacle facing the creation of wholesome communities today. Our inclination to identify ourselves by way of that which we are not extends beyond race, sex, gender, and creed. Never before in history have we been so divided over the very mechanism that fosters a shared desire for cohesive communities.

We moderns continue to divide ourselves when it comes to religion and its historical relationship with the supernatural. On the one hand, the supernaturalists tend to believe nothing is worthy of being considered religious without a Supernatural Being that exists beyond the power of nature. This is an idea that is often associated with a range of institutional religions. The opposing group, the naturalists, believe that advancements in science adequately provide the grounds to dismiss the supernatural and, by extension, religious structures and practices. The problem is not that both camps are void of the desire to build healthy communities; rather, the problem is that the tension over the existence of a Supernatural Being often

makes it difficult for these two groups to act in concert. Given this tension, what can philosophy offer to the discourse in order to help realize a common faith in shared communal ideals?

Pragmatism, a uniquely American philosophy, offers the discourse a needed breath of fresh air. As an anti-Cartesian philosophy allied with empirical naturalism, pragmatists focus on the effects of experience. Pragmatism looks at ideas and beliefs in terms of their concrete social effects instead of preconceived notions and inherent truths. However, this is not to say that pragmatism is a full-blown version of scientism, that is, the excessive belief in the power of scientific knowledge. Pragmatism goes beyond observing the measurable and quantifiable in order to emphasize the value of the qualitative dimension of experience as well. In what follows, I will examine liturgy through the lens of pragmatism to account for the manner in which the qualitative element of experience can help facilitate a shared realization of practical and socially beneficial ends.

As is well known, medieval thinkers greatly influenced dogma and doctrine by reconciling Neo-Platonic discourse with religious thought. As philosophies concerned with the afterlife and the immortality of the soul began to seep into Europe, thinkers began using the texts to prove the

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existence of God through reason. The debate over faith versus reason found in the works of theologians such as Avicenna, Averroes, Anselm, and Augustine can be seen as attempts to address theological problems and discover “truth” through Platonic and Aristotelian ideas of logic, dialectic, and analysis. This relationship remains with us today as seen in the countless ways that moderns equate organized religion with an alliance with the supernatural.

Our modern conception of liturgy often rests on the historical connection between organized religion and the supernatural. The Latin word for liturgy, *liturgia*, the etymology of which I will examine later, carries a supernatural connotation due to the manner in which liturgical practices have been dogmatized within organized religion. The tendency we moderns have to rely on preconceived notions to inform our understanding of liturgy not only allows some supernaturalists to extract value from liturgy due to a believed connection with the supernatural, but also arms some naturalists with reason to discredit the function of liturgy due to its relationship to religion and, by extension, a relationship with an empirically un-provable Supernatural Being. The manner in which both groups ignore the history of compromises made between religion and Neo-Platonic philosophy is the major cause of their disunity.

What is interesting to note, however, is that the original Greek word for liturgy, *leitourgikos* (λειτουργία) from which the Latin word *liturgia* stems, points to a practical social service done by the ancient Athenians on behalf of the state. The first half of the word, “*liet*,” comes from the Greek word “*lêitos*,” meaning public and is built off the Greek word “*lâos*,” meaning people. The second half of the word, “*ourgos*,” is related to “*ergon*,” meaning work, deed, and/or function. In its entirety, the Greek word *leitourgikos* refers to an act by which the people, on behalf of the public, do a public work. Such works were considered a financial burden undertaken by the wealthy citizens. In exchange for providing liturgies—such as financing the construction of a gymnasium or outfitting soldiers with war materials—

liturgists were rewarded with public honors. These honors were typically accompanied with dramatic performances, dance, and music.

It is also interesting to note here that the ancients made no substantive distinctions between the natural and supernatural. The gods, although immortal, were subject to fate and therefore considered a natural part of the universe. The absence of the concept of a Supernatural Being akin to that of the Judeo-Christian faiths in ancient Greece leads one to surmise that *leitourgikos* catered solely to the ideals that the *polis* felt beneficial to the community. In other words, ancient Greek liturgical practices were absent of institutional dogma reliant upon an all-powerful Supernatural Being to assure its value.

A pragmatic understanding of liturgy echoes the original Greek understanding of the word *leitourgikos* in that both approach the term without preconceived notions and belief in inherent truths. Just as the ancient Greeks operated without the dogma and doctrine dictated by an authoritative church, the method of pragmatism clears a space where the concept of liturgy can also be emancipated from the yoke of historical definitions.

As defined by Charles Sanders Peirce in 1878, the “pragmatic maxim” addresses the difficulty of coming to definitively defined and universally accepted concepts:

Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then our conception of these effects is the whole of our conception of the object.<sup>1</sup>

In other words, the pragmatic maxim asks that instead of defining concepts by the way they are historically understood, we should understand them by the practical effects they produce.

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<sup>1</sup> Charles S. Peirce, “How to Make Our Ideas Clear”, *Popular Science Monthly* 12 (January 1878): 287.

Peirce offers the difference between the Catholic and Protestant conceptions of transubstantiation as an example: unlike Catholics, Protestants speak of the sacrament of Eucharist as consuming wafer-cake and watered down wine, and Christ's flesh and blood in the metaphorical sense. In contradistinction, the Catholics, says Peirce, refer to the sacrament as literally flesh or body and blood of Christ although they possess qualities that may be measured otherwise. Peirce continues, "[I]t is foolish for Catholics and Protestants to fancy themselves in disagreement about the elements of the sacrament, if they agree in regard to all their sensible effects, here and hereafter."<sup>2</sup> In short, Peirce concludes that if both Protestants and Catholics agree that transubstantiation nourishes the soul neither group need venture into the details of the disagreement.

Applying the pragmatic maxim to how both the supernaturalists and naturalists interpret liturgy encourages an understanding of the practice based on its sensible effects. In both cases, liturgy provides a service to the community. On the one hand, *liturgia* provides individual practitioners with existential sustenance and a shared sense of community found in the participation of traditional ritual. On the other hand, *leitourgikos*, or the doing of a public deed, aims to hold citizens accountable and provide for the shared health of the community. The pragmatic maxim allows for a working definition of liturgy in which both groups can agree that its social effects result in a communal desire for, and contribution to, ideals concerned with the community's health. Moreover, the pragmatic maxim rids religious ritual from a dependency on a Supernatural guarantee.

When turning to the "effects" and "practical bearings" of concepts, newcomers to pragmatism may be inclined to assume this is synonymous with looking at the hard facts of science. However, science offers little regarding the role of the aesthetic in conveying emotion. Science can, of course,

quantify emotions through the observation of biochemical reactions, but these measurements cannot account for how the imagination functions as a tool for negotiating the relationship between the aesthetic expression of the religious and the intersubjective quality of the emotional experience being communicated. Although liturgy's sensible effects are not necessarily dependent on a belief in the existence of a Supernatural Being, liturgy is still dependent on an immeasurable qualitative element beyond the grasp of science—the very element needed to convey the communal desire for, and contribution to, ideals concerned with the community's health.

Patrick Collins, a Catholic priest who draws on the thought of John Dewey, believes that two pitfalls must be avoided when authoring and practicing religious ritual in order for the aesthetic to effectively convey a religious experience. First, ritual must be "this-worldly," this is to say, here in God's kingdom and not out of this life and taking place in some fantasy utopia. Second, an "other-worldly" element must be present that differentiates religious ritual from the purely "this-worldly" striving for human community found in functions such as rock concerts and town hall meetings.<sup>3</sup>

Collins' use of the word "God" may inadvertently draw a connection to the idea of a Supernatural Being. However, given that Collins' work is strongly influenced by Dewey, and by extension Hegel, his use of "God" should not be understood as existing beyond the power of nature. God is natural—this-worldly—but dwells in the intersubjective—other-worldly—realm of the imagination. For Hegel, God is "absolute spirit" and becomes manifest through its particularization in the imagination of material creatures. In other words, the shared "other-worldly" emotive element conveyed in the aesthetic depends on the imagination's ability to realize that the experience is beyond the individual and can manifest itself in the shared intersubjective consciousness of "this-worldly" creatures.

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2 Peirce, 293.

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3 Patrick Collins, *More Than Meets The Eye: Ritual and Parish Liturgy* (New York: Paulist Press, 1984), 79-80.

Participating in religious ritual is not simply the means by which individuals express their desire for a healthy community. It is also the mechanism needed to realize a shared religious experience. What Hegel calls “absolute spirit,” Dewey refers to as a shared account of “the religious.” The part shared by both, however, is that because ritual is rooted in history, it adds to the quality of experience. The community not only celebrates and expresses the religious in the present, but also acknowledges that these practices connect them to a larger community from the past.

Ultimately, pragmatism offers both the supernaturalists and the naturalists a means to work together through religion by way of understanding it as the aesthetic representation of a shared desire for communal ideals. This expression plays a larger role than simply harboring and cultivating community ideals rooted in history. Religious ritual provides the means by which ideals can be modified and created anew to facilitate the creation of new communities who share a common faith in the qualitative value of religious experience.

Arguably, something akin to this bridging between organized religion and the secular realm can be seen in the manner in which Martin Luther King Jr. facilitated the realization of freedom, liberation, and equality. King’s liberation theology and his harmonization of the Southern Christian Leadership Conference with followers of Asa Philip Randolph, a secular labor union organizer, serves as a prime example of what can be achieved when debates over metaphysical concepts are put aside in favor of achieving practical and socially beneficial ends.

# SET IN STONE: NATIONALISM AND THE BATTLE OVER THE ELGIN MARBLES

Colleen Foran\*

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**ABSTRACT** For close to 200 years, modern Greece and Britain have argued over which nation is the rightful owner of the Elgin marbles. In reality, neither has more entitlement to the marbles than the other, and both sides' arguments have ignored the statues' real allure: their ties to ancient Greece's republican society. The marbles are no longer art objects, but, rather, are pure symbols of an idealized history of egalitarianism which both nations wish to claim for themselves. The Elgin marbles can guide us in understanding the complicated relationship between nationalism, symbolism, and historicization.

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In history books, art is often forgotten. Politics, economics, and battles almost always trump culture when fighting for inclusion in our world's long and storied past. However, works of art are not footnotes to history. Rather, they have played an integral role in societal, diplomatic, and monetary happenings on an international scale. Make no mistake: every piece of art is a political, economic, and cultural statement, and, as we can see from the labored case of the Elgin marbles, every decision regarding where those pieces reside is one of gravity.

The issue of the Elgin marbles has a very long history and some notoriety. Their cause has been championed by the actress and cultural minister Melina Mercouri and is the subject of many journalistic and scholarly investigations.<sup>1</sup> The 5th century B.C.E. marbles were removed from Greece in the early 19th century by Lord Elgin, who brought about half of all the sculptures from the Parthenon back to Great Britain (the other half still remain in Greece).<sup>2</sup> A decade later they were installed in the British Museum, where they

have resided ever since.<sup>3</sup> However, they have never been peacefully settled there. Mercouri points out that Greece has argued for their return practically since their removal, as have large portions of the British public.<sup>4</sup> But despite an international community pushing for a resolution, the fate of the Elgin marbles remains unresolved.

While this argument is typically posed in such high-minded terms as how best to preserve the marbles and where the marbles belong ethically, I argue that these, while valid concerns, are not really what fuels the controversial fire surrounding these ancient statues. Above all, this conflict indicates a struggle of nationalism and national cultural identity; what is at stake is each nation's historicized legacy. Both nations have invested these objects with a symbolic power: the epitome of re-constructed Hellenistic republican ideals around which they have constituted their nationhood, and which ownership of the Elgin marbles inherently proves and reinforces.

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1 For a survey of this cultural biography, see Yannis Hamilakis, "Stories from Exile: Fragments from the Cultural Biography of the Parthenon (or 'Elgin') Marbles," *World Archaeology* 31.2 (October 1999): 303-320.

2 Hamilakis, "Stories from Exile": 304-305.

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3 Edward P. Alexander and Mary Alexander, *Museums in Motion: An Introduction to the History and Function of Museums* (Plymouth, United Kingdom: AltaMira Press, 2008), 58-60.

4 Melina Mercouri, "1986 Speech to the Oxford Union," in *Critical Perspectives on Art History*, ed. John C. McEnroe and Deborah F. Pokinski (Upper Saddle River, New Jersey: Prentice Hall, 2002), 25-27.

In 1798, Thomas Bruce, Seventh Earl of Elgin, was appointed the British ambassador to the Ottoman court, located in then-Constantinople (now Istanbul).<sup>5</sup> This was a tumultuous area of the world at the time as the powerful, far-reaching, and very quickly fading Ottoman Empire fought to retain its control in the Middle East and Eastern Europe. One of the empire's many territories was Greece, the ancestral home of the ancient Greek empire and its many ruins. Of all these ruins, none was quite so storied as the Parthenon, the 5th century B.C.E. ancient Greek temple to Athena which overlooks Athens from its perch at the top of the Acropolis.<sup>6</sup>

The Parthenon was home to some of the greatest art from a society known expressly for its great art. On the pediments of the temple were some of the most beautiful and perfected statuary from all of the classical period, representing the most canonical attributes of ancient Greek sculpture. It is from these classical characteristics that traditional Western art has long been understood to have sprung,<sup>7</sup> making the Elgin marbles some of the most-studied and oft-taught art objects in the world.

However, when Elgin himself came across the Parthenon, it had seen better days. Centuries of neglect and recent fierce warfare had practically destroyed the building.<sup>8</sup> The Parthenon lay in neglected ruins, its treasures scattered and practically unrecognizable on the ground. Elgin, however, well-educated and versed in classicism, had just come from Great Britain, the center of a growing craze and market for classical Greek and Roman sculpture. These sculptures were valued not just for their aesthetic appeal, but also for the ideals and ethics they represented: "traditions of liberty, civic virtue, morality, and sacrifice."<sup>9</sup> Soon,

classical artifacts came to be seen not just as hallmarks of human civilization's highest achievements,<sup>10</sup> but as symbols of something much more potent.

Ancient Greece was the first recorded and recognized republican society in the Western world, a commanding, vindicating narrative at a time of "great political upheaval"<sup>11</sup> when many industrialized Western nations were moving toward republican government. This narrative of classicism would become what Hamilakis calls one of the era's "main ideological forces,"<sup>12</sup> its forms innately linked to republicanism. In this political sphere, classical art and its offspring, the neoclassical, became a new, powerful tool. Use of the classical and neoclassical style was an automatic and commanding way of legitimizing a political system, particularly a democratic one.

It isn't surprising, then, that there was such a scramble for classical artifacts. And yet many of the people of war-torn Greece had no idea that they daily coexisted with what most of the West considered immense cultural, political, and economical treasures. Lord Elgin, however, certainly knew the power of these objects and the almost mythic symbolism surrounding them. He also knew that the Ottomans had little idea of the value of the ancient statues and buildings they were daily destroying.<sup>13</sup> And so, as Merryman's study shows, he took advantage of his privileged position to acquire the Parthenon marbles

From 1801 to 1812, Elgin, with the help of a team of excavators, packed up some of the best examples of classical statuary from the Parthenon.<sup>14</sup> However, Elgin did not simply excavate and take the marbles without any legal consideration, as it is often depicted. The document that he procured from the Ottoman administration

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5 B. F. Cook and Gordon Campbell. "Bruce, Thomas." In *Grove Art Online*. *Oxford Art Online*, oxfordartonline.com.ezproxy2.lib.depaul.edu/subscriber/article/grove/art/T011653 (accessed March 7, 2011).

6 Hamilakis, "Stories from Exile": 304.

7 Fred S. Kleiner, *Gardner's Art Through the Ages: A Concise Global History* (Boston: Wadsworth Cengage Learning, 2009), 70-71.

8 Hamilakis, "Stories from Exile": 306.

9 Kleiner, *Gardner's Art Through the Ages*, 331.

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10 Hamilakis, "Stories from Exile": 306-308.

11 Kleiner, *Gardner's Art Through the Ages*, 331.

12 Hamilakis, "Stories from Exile": 306.

13 John Henry Merryman, "Thinking About the Elgin Marbles," *Michigan Law Review* 83.8 (August 1985): 1905-1907.

14 Hamilakis, "Stories from Exile": 307-308.

guaranteed him “...liberty to take away any sculptures or inscriptions which do not interfere with the works or walls of the Citadel.”<sup>15</sup> There is no doubt that Elgin, known to use bribery and threats,<sup>16</sup> engaged in some shady dealings to attain the marbles, but he did so with proper legal documentation. While people can frown on his ethics, they cannot claim that Elgin stole the marbles that bear his name.<sup>17</sup>

The marbles remained in flux for over a decade after their initial removal. Elgin wished to sell the statues to the British government, but there was serious consternation among the public and among policy makers that Britain had any right to own them at all. Britain’s support of the Ottomans was controversial and unpopular and many British citizens viewed Greece’s fight for freedom as highly honorable and glorious, ironically, in part, since admiration of classicism had pushed Elgin to acquire the marbles in the first place. Finally, after a fierce battle in the House of Commons, the marbles were purchased by the British government for £35,000<sup>18</sup> (about \$4 million today<sup>19</sup>) and installed in the British Museum in 1816.<sup>20</sup>

When purchasing and installing the marbles in the British Museum, the museum and the government of Great Britain that supports it made several crucial promises. First of all, included in the statute was the understanding that this group of artifacts must be called “the Elgin marbles”<sup>21</sup> as a reminder of the nationalistic and imperialistic character of this acquisition.<sup>22</sup> Any reference to the marbles’ Greek heritage was removed by law and replaced by the title of a prestigious, noble British family with no real connection to

the Parthenon or its carvings. The naming of the marbles thus reinforced attempts to create a national British character, one that took advantage of its leadership in the world and co-opted a classical history for itself.<sup>23</sup>

However, by installing the Elgin marbles in its collection, the British Museum made a much more overt statement than a change of name. Museums by law are required to care for the objects in their possession in perpetuity; by accepting Elgin’s offer, the British government was declaring that it planned to keep the marbles forever. The International Council on Museums (ICOM) states that one of the main principles of museums is “the duty to acquire, preserve and promote their collections as a contribution to safeguarding the natural, cultural and scientific heritage.”<sup>24</sup> With this pledge in mind, Britain has long argued that, while perhaps the Greeks were the creators of the Elgin marbles, the British have been their caretakers. From this perspective, Elgin is a hero, the savior of great art and great civilization. This argument does hold some merit, and, until recently, Greece’s ability to care for the marbles was truly in doubt. More importantly, however, it points to a nationalistic high-mindedness, an imperialistic understanding that privileges Britain’s “virtuous” interactions with the marbles over Greece’s “neglect.”<sup>25</sup>

To answer this call, Greece recently spent \$180 million to prove their cultural worth with the recent completion of the Acropolis Museum.<sup>26</sup> The glass and concrete museum replaced the former small, dingy one, which many worried could not properly care for the fragile Parthenon relics.<sup>27</sup> The crowning glory of the certain tourist attraction is

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15 Merryman, “Thinking About the Elgin Marbles”: 1898.

16 Gavin Stamp, “Keeping Our Marbles,” in *Critical Perspectives on Art History*, ed. John C. McEnroe and Deborah F. Pokinski (Upper Saddle River, New Jersey: Prentice Hall, 2002), 22-23.

17 Merryman, “Thinking About the Elgin Marbles”: 1902.

18 Hamilakis, “Stories from Exile”: 308.

19 Cathleen McGuigan, “Romancing the Stones,” *Newsweek*, June 2009: 62.

20 Hamilakis, “Stories from Exile”: 308.

21 *Ibid*: 304.

22 Mercouri, “1986 Speech to the Oxford Union,” 21.

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23 For a fuller discussion of the shifting meaning of classicism, see

Debbie Challis, “The Parthenon Sculptures: Emblems of British National Identity,” *British Art Journal* 7.1 (Spring/Summer 2006): 33-39.

24 International Council of Museums, *ICOM Code of Ethics for Museums*, 21st General Assembly (Seoul, Republic of Korea: ICOM, 2006), 3.

25 Stamp, “Keeping Our Marbles,” 18.

26 Suzanne Stephens, “Bernard Tschumi Architects Presents a Case for Bringing the Elgin Marbles Back to Athens in its Design for the New Acropolis Museum,” *Architectural Record* 197, no. 10 (October 2009): 76.

27 *Ibid*: 76.

its top floor exhibit. This entire top tier is dramatically tilted to get the very best views of the Acropolis with the Parthenon presiding over the city.<sup>28</sup> All around the room are the pediment statues, installed in their original order. The statues that Greece still retains are beautifully restored and in their proper places—and look strikingly different from the bright white, clearly reproduced statues that fill the places where the British-owned friezes should reside.<sup>29</sup> By significantly marking these marbles out as fakes, as obviously missing, the museum is making a million-dollar statement: Look not at what is here, but at what is not here, what should be here. Greece wished to make a major declaration with this museum. The Acropolis Museum was built to be a contemporary temple for Greece’s impressive cultural history. It is not just Greece’s attempt to grandly prove that something has been taken from them, but that they are the rightful and worthy heirs of those taken things.

Attempting to lay claim to this cultural history has been a constant theme for both Britain and Greece. In 1816 (notably the same year that the British Museum gained the statues), the British government proposed a Napoleonic War monument in Trafalgar Square based on “the Parthenon, adapted to the purpose of a National Monument.”<sup>30</sup> The Parthenon, then, was not only a ruin in faraway Greece, but a potent symbol that could divest itself of its Greek-ness and be “adapted” into a British national monument.<sup>31</sup> But if Britain attempted to claim Hellenistic culture for itself, so did Greece after its incorporation as an independent nation in 1830.<sup>32</sup> Some have pointed out that the creators of the Parthenon and the marbles lived millennia before modern Greece even existed; in this

view, the two cultures have no real connection, apart from geographic location.<sup>33</sup> Regardless, the new nation placed much of its worth on a re-imagined common ancestry with the Hellenes and on the relics they left there,<sup>34</sup> going as far as saying “it is to these stones that we owe our political renaissance.”<sup>35</sup>

With so much power attributed to what was once just barely more than rubble, it is no wonder that the argument over the Elgin marbles is so impassioned and often embittered. If a nation loses its claim to things with which it has long identified its cultural worth, does it permanently lose that worth as well? This is what Great Britain and Greece see as at stake. The dispute over the Elgin marbles, then, is not really about the ownership of the artifacts themselves; indeed, these artifacts are no longer simply things to be owned—they are ideological symbols to be claimed. Because they represent Hellenistic culture, the artifacts are emblematic of civic pride, glory, national prestige, and republicanism, and possessing the Elgin marbles also gives Greece or Britain possession of those virtues.

What these nations really wish to own is what the marbles symbolize, and they want it all for themselves. As Merryman has argued, this sort of symbolic and narrowly culture-based nationalism is dangerous, especially in an increasingly global world. Nationalism favors absolutism and, clearly, in this case, absolutism just won’t do. The Elgin marbles are treasures, there is no doubt about that, but the intense feud over them is threatening to return these precious artifacts to ruins of war, nothing more than collateral in a self-serving battle over national identity.

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28 Ibid: 76.

29 Mcguigan, “Romancing the Stones”: 63.

30 Andrew Robertson, *The Parthenon: Adapted to the Purpose of a National Monument, to Commemorate the Victories of the Late War: Proposed to be Erected in Trafalgar Square, or Hyde Park* (London: Hume Tracts, 1838).

31 Challis, “The Parthenon Sculptures”: 35-37.

32 James B. Cuno, *Who Owns Antiquity?: Museums and the Battle over Our Ancient Heritage* (Princeton, New Jersey: Princeton University Press, 2008), x.

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33 Merryman, “Thinking About the Elgin Marbles”: 1912.

34 Stamp, “Keeping Our Marbles,” 18.

35 Cuno, *Who Owns Antiquity?*, xi.



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# BURQA IN THE BALANCE: THE PRINCIPLES OF FRENCH UNIVERSALISM REVISITED THROUGH THE LEGISLATION TO BAN THE BURQA IN FRANCE

Jonathan Lam\*

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**ABSTRACT** In 2010, French lawmakers drafted a bill that bans the *burqa*, or full Islamic veil, in public spaces in France. President Nicolas Sarkozy, who raised the question of women wearing the *burqa*, argues that the veil is a symbol of women's oppression that contradicts the egalitarian values of the state. This paper retraces the burqa debate during the bill's promulgation. In addition, it examines the ways in which two underlying principles of French universalism, *laïcité* and republicanism, have influenced the legislation.

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## Introduction

In 1989, three Muslim girls refused to remove their headscarves at a middle school in the town of Creil in northern France. The school headmaster expelled the students for not observing the principle of *laïcité*, which is, in the simplest of terms, the French version of secularism. In order to quell the state's clamor, the Council of State<sup>1</sup> ruled that students could wear signs of religious affiliation in public schools insofar as their display was not ostentatious or polemic. In 2003, however, the question of religious signs, namely the Islamic veil<sup>2</sup>, in schools once again became the focus of national debate. After reviewing the report by the Stasi Commission, sanctioned by President Jacques Chirac to reassess the principle of *laïcité* and its current application, the French government

banned the veil and all conspicuous religious signs from the public school system the following year (Stasi, 2004; Scott, 2005a; Scott, 2007). Since then, President Nicolas Sarkozy has yet again raised the question of the Islamic veil when he recently announced his intent to ban the *burqa*, or full Islamic veil, in France. This paper chronicles this legislation. It also examines two fundamental principles of French universalism, *laïcité* and republicanism, and their influence in a seemingly endless debate.

I begin by tracing the timeline of the legislation from its introduction in 2009 to its approval by both houses of the French parliament and other government bodies in 2010. This section explores the reasons why President Nicolas Sarkozy and supporters proposed the measure, its specifications, and reactions from the public, government officials, and social organizations. I then turn to a discussion of the principles of French universalism. This section begins with an investigation of the history and application of *laïcité* and republicanism in France. I then show the ways in which they have played significant roles in the current *burqa* ban and in the discourse of French universalism. In my conclusion, I examine some broader social and cultural implications that the impending law may have on the future of French-Muslim relations.

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1 The Conseil d'État is the highest judicial body of the French government that advises on the preparation of bills, ordinances, and certain decrees.

2 I am referring here to the Islamic head covering known as a foulard (headscarf) in France. French journalists use a variety of terms to describe Islamic head coverings without providing much distinction between them. In this paper, I have decided, for simplification, to use the term "veil" when describing the incidents and legislation concerning Islamic head coverings prior to my study of the burqa ban. The debates on Islamic head coverings and ostentatious symbols of religious affiliation prior to the burqa ban concerned public schools in France. The impending law concerns the wearing of the burqa or attire designed to cover the face in public spaces.

## Bye Bye Burqa

In the summer of 2009, President Nicolas Sarkozy became the first modern French president to give a U.S.-style State of the Union address to both houses of parliament at the Palace of Versailles. The speech ended a more than 100-year-old French tradition of parliamentary independence that barred the leaders of the French Republic from addressing senators and members of parliament (MP) directly. Sarkozy had arranged the speech to review his plans for the remaining half of his five-year presidency. Amidst discussions on retirement, taxes, and environmental reforms, Sarkozy raised the issue of women wearing the *burqa* in France. Contrary to his comments in a speech to the Union of the French Islamic Organizations in 2003<sup>3</sup>, in which he merely insisted that Muslim women remove their veils for official identity photographs, Sarkozy made his opposition to the full Islamic veil clear by stating that the *burqa* was not welcome on French soil (Scott, 2005a; Winter, 2008; Carvajal, 2009).

Immediately following his address, Sarkozy formed a 32-member government panel to investigate the issue in further detail. The president appointed Deputy André Gerin of the French Communist Party to preside over the commission, which aimed to demonstrate the ways that wearing the *burqa* contradicted the egalitarian values of France. In January, the commission published a final report in which its members concluded that the *burqa* was incompatible with three fundamental principles of the republic: (1) the principle of *laïcité* or French secularism; (2) the principle of liberty and dignity, namely for the veiled women; and (3) the principle of fraternity or cohabitation. The commission proposed a procedure to remove the *burqa* from France. The process included voting on a resolution to reaffirm republican values, reinforcing educational and advocacy programs to strengthen mutual respect, and drafting a bill, the latter of which the French

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3 The Union des organisations islamiques de France (UOIF) is the most influential Muslim organization in France. Founded in 1983, it unites local associations throughout France, most of which are cultural associations with affiliated mosques (Bowen 2007).

government completed within weeks of the report's publication (French National Assembly, 2010a).

Although the commission concluded that the *burqa* defies the principle of *laïcité*, Sarkozy and his delegates insist that they are acting primarily on behalf of sexual equality for women, public safety, and cohabitation. In his address to parliament, senators and MPs applauded the president as he stated, "Le problème de la *burqa* n'est pas religieux, c'est un problème de liberté, c'est un problème de la dignité de la femme."<sup>4</sup> Sarkozy identifies the *burqa* as a symbol of oppression, subjugation, and abasement, to which no woman should be subject. Moreover, supporters of the measure raised the question of public safety. Jean-François Copé, the parliamentary leader of the Union for a Popular Movement (UMP), for instance, contests that the *burqa* violates public safety measures because it covers the entire body and face. This defies, he suggests, the general expectation in France for people to bare their faces in public (Bremner, 2009). Sarkozy and supporters also believe that wearing the *burqa* restricts citizens and immigrants from proper cohabitation, which can only happen if citizens and immigrants completely adopt French values. The *burqa* thus symbolizes an obstacle towards the full assimilation of French culture.

In late January, Jean-François Copé drafted a preliminary bill that bans the *burqa* in the public spaces of France, including parks, hospitals, and public transportation systems. The Minister of Justice, Michèle Alliot-Marie, presented an updated bill to the Council of Ministers<sup>5</sup> in mid May, which by then had adopted the term *voile intégral*, meaning full veil, instead of the term *burqa*.<sup>6</sup> The

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4 "The issue of the burqa is not a religious issue. It is a question of freedom and of women's dignity" (Carvajal 2009).

5 In France, the Conseil des ministres is a body of top governmental administrators that may propose new laws and amendments during parliamentary sessions.

6 The bill assumed the title *le projet de loi interdisant le porte du voile intégral dans l'espace public* during the early stages of its draft. American and British journalists have translated the bill's title into English as "the legislation to ban the full Islamic veil in public."

bill then moved to the two houses of French parliament. In July, the National Assembly passed the legislation with a final vote of 335 to 1 with 241 members abstaining. In September, the Senate passed the legislation with a final vote of 246 to 1 with 100 senators abstaining. A month later, the Constitutional Council of France<sup>7</sup> ruled that the bill displayed a reasonable balance between personal liberty and constitutional principles, such as sexual equality and dignity of veiled women and public order. With approval from the latter and both houses of the French parliament, the law is set to go into effect in the spring of 2011.

The law is comprised of seven articles. Article 1 reads, “nul ne peut, dans l’espace public, porter une tenue destinée à dissimuler son visage,” translated to mean that no person may, in public, wear clothing that is designed to cover the face (French National Assembly, 2010b). Violators of the law will be subject to a 150-euro fine. Moreover, anyone who forces another individual through violence, coercion, pressure, or abuse of authority and power to cover his or her face will be subject to a 15,000-euro fine and up to a year of imprisonment. This amendment aims to guarantee the liberty and dignity of women who are sometimes forced to wear the *burqa* or other forms of the veil by family members, significant others, and communities. There are, however, a few exceptions to the restriction. As outlined in Article 2, the prohibition will not apply to attire required or permitted by law or regulation, such as motorcycle helmets. Second, it will not apply to attire justified by medical and professional concerns. Third, it will not apply to attire that falls within the purview of sporting activities, festivals and holidays, or artistic and traditional demonstrations, such as carnival masks (Laurent, 2010).

The French public has responded in a variety of ways to the *burqa* ban. Although a majority approves the measure, others, namely members of the Socialist Party, question the feasibility and necessity of a law when less than 2,000 women actually wear the *burqa* in France (Cross, 2010; Erlanger, 2010). Mohammed Moussaoui, the leader of the French Council of the Muslim Religion,<sup>8</sup> fears that the law will only stigmatize Islam. Although Moussaoui does not oppose the idea of discouraging women from wearing the full veil, he believes that a law targeted specifically at Muslim women may aggravate relations between France and its Muslim population. The pending law has also generated reactions from political and social organizations. French feminist group Ni Putes Ni Soumises, for example, supports the law for its stance on female equality and ending the practice of forced veiling. Amnesty International, however, unsuccessfully urged French lawmakers to reject the ban because it violates, its members argue, rights to freedom of religious expression.

### **A French Universalism**

A French native may find the translation of *laïcité* as secularism to be quite rudimentary, but the term is rather difficult to define, let alone translate. The secular principles of *laïcité* originated in the 1789 French Revolution when the masses briefly transferred services like marriage, education, and healthcare from the authority of the Catholic Church to the state. The Declaration of the Rights of Man and of the Citizen<sup>9</sup>, decreed by the Revolution, stipulated that no one shall be disquieted for his or her religious beliefs, provided that their manifestations do not disturb the public order established by law (Spencer, 2009; Pena-Ruiz, 2003). The official application of *laïcité*, however,

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However, during its promulgation, the bill adopted the title le projet de loi interdisant la dissimulation du visage dans l’espace public to avoid reference to religion or Islam (French National Assembly 2010b). Translated into English, the bill becomes “the legislation to ban the concealment of the face in public.”

7 The Conseil constitutionnel is the highest constitutional authority in France. It guards the constitutional principles and rules of the republic.

8 The *Conseil français du culte musulmane* (CFCM) is an elected body that serves as an official liaison between the French state and the regulation of Muslim religious affairs.

9 The *Déclaration des droits de l’homme et du citoyen* defined the individual and human rights of French citizens in the wake of the French Revolution. In regard to religion, Article 10 stipulates, “Nul ne doit être inquiété pour ses opinions, même religieuses, pourvu que leur manifestation ne trouble pas l’ordre public établi par la loi” (Stasi 2004), which I have translated above.

began in 1905 when France passed a law that separated church and state.<sup>10</sup>

The principle of *laïcité* is equally rooted in French republicanism, which is “a way of thinking about the individual, the state, and society that strongly shapes public discourse and decisions” (Bowen, 2007, 11). Republican ideology in France requires individuals to agree on basic values for proper cohabitation. Inhabitants must adhere, for instance, to the expectations outlined by *laïcité*. Historically, republican ideology emerged in 1958 when General Charles de Gaulle drafted a new constitution for France’s fifth and current republic. France had experienced a wave of executions of former Vichy regime officials for having supposedly collaborated with occupational Nazi German forces during World War II. In order to unify the nation, de Gaulle introduced the concept of indifferent citizenship, which means that any individual who complies with republican ideology is just French, and no longer possesses a skin color, ethnic origin, and religion before the state (Baycroft, 2008; Nadeau and Barlow, 2003).

The principles of *laïcité* and republicanism belong to the discourse of French universalism. Universalism is the oneness of all individuals. In France, it serves as the definitive feature of republican democracy. French universalism holds that uniformity is the foundation for equality. In France, therefore, equality requires the assimilation to a singular culture, language, and history. French universalism demands that every citizen and inhabitant relinquishes personal ethnic values and adopts the democratic, secular, and social values of the republic.<sup>11</sup> In examining the impending law, the *burqa* symbolizes a

threat to French universalism due to its religious affiliation with Islam, which contradicts not only an established public order via *laïcité* but also the idea of a France with no clear distinctions among its people.

The *burqa* ban also defends French universalism against the concept of *communautarisme*, which best translates into “communalism.” In France, *communautarisme* characterizes a strong allegiance to one’s own ethnic group instead of the nation as a whole. French republican ideology negatively associates *communautarisme* with the concept of American multiculturalism because it indicates the priority of a specific group over the shared national identity. Inhabitants of France must swear allegiance and assimilate to the values of only one group, and that is France. French universalism is therefore the antithesis of *communautarisme* (Scott, 2005a). The legislation regarding the *burqa* speaks to the negative effects that *communautarisme* could have on France and its discourse on universalism. The simple act of wearing the *burqa* is perceived as a rejection of French democratic, secular, and egalitarian values and a prioritization of the Muslim community.

## Conclusion

The legislation drafted in 2010—a bill that prevents not just women from wearing the *burqa* but anyone from wearing an article of clothing designed to cover the face in public—was approved by both houses of the French Parliament and the Constitutional Council and will go into effect in the spring of 2011. As the implementation of the law approaches, statements made by Mohammed Moussaoui about the potential stigmatizing effects of the law on Islam in France remain ubiquitous. What does the law mean for France, its Muslim population, and their relationship in a growing multi-ethnic country? Although the Quran does not prescribe the wearing of the *burqa* or any other form of veiling, the custom remains a significant cultural practice for Muslims, who may or may not heed the law. With tensions already high between France and its Muslim population due to issues of immigration, unemployment,

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10 Under the law, *laïcité* guarantees three principles: (1) the freedom of conscience and religious expression insofar as it does not undermine public order; (2) the equal status of all religious and spiritual options; and (3) a neutral state that does not favor one religion over another (Zarka 2004; Chanet and Pelletier 2005; Bowen 2007).

11 By eliminating all social, cultural, and ideological differences, everyone is literally equal before the law, hence the reason for why the French census does not record the religion, ethnicity, and national origin of its population (Scott 2005a; Scott 2005b).

and poverty, the two must move towards a convergence to avoid further conflict. For example, France, must extend established legal and moral categories to include Muslims, such as offering food that meets Islamic dietary restriction in social institutions. France, then, may be able to avoid said stigmatization and learn to coexist with its Muslim population (Bowen, 2010).

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David Edward Sims | *Flower and Fabric Series: Amity* | Digital Photography



# TWO INCARNATIONS OF “THE IMMOVABLE ONE,” A JAPANESE GUARDIAN KING

Anna Clark\*

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**ABSTRACT** The guardian king *Fudo* (“The Immovable One”) is a central figure in Japanese art associated with Shingon Buddhism. From the heavy, abstract sculptures of the early Heian period to the dynamic, realistic sculptures of the Kamakura period, the images of this protective king were made to help Buddhist practitioners with many challenges. As a wrathful yet compassionate deity, *Fudo* is one of the most empathetic figures in the Buddhist pantheon, a unique figure whose distinctive qualities persist across many centuries and styles.

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Two notable sculptures of the Esoteric Buddhist deity *Fudo Myo-o* are a work from the early Heian period (c. 839) and a work from the 12th-14th century held at The Art Institute of Chicago.<sup>1</sup> These sculptures—both carved from wood and covered with polychrome and gilt-bronze accessories—depict the aggressive appearance of this deity, known as “The Immovable (or Unshakeable) One.” Meant for devotional ceremonies, the first work utilizes the stylistic traditions of the early Heian period while the second follows the Kamakura-period style, yet both convey the essential qualities of the deity *Fudo*.

In the early Heian period, the Chinese and Indian foundations of esoteric Buddhism began translating into new and distinctive Japanese Buddhist traditions. Founded by the monk Kobo Daishi (Kukai), the Shingon esoteric school of Buddhism aimed to restore Buddhist practice to a focus on enlightenment, with various bodhisattvas and Buddhas making an appearance in ritual worship. Known in Japanese as *mikkyo* or “secret teachings,” Shingon

Buddhism claimed that the Buddha Shakyamuni was just “one aspect of the all-encompassing esoteric deity known as Vairocana Buddha (Japanese: Dainichi Nyorai).”<sup>2</sup> Shingon differs from other sects of Buddhism in that it stressed the possibility of achieving enlightenment in one lifetime. Complicated and mystical, esoteric Buddhism holds that only initiates should receive the information necessary to practice its many rituals.

The origins of *Fudo*, one of the five Lords of Light (*Myo-o*) and guardian of the Law of Buddhism, can be traced to India. Introduced into the Japanese Buddhist pantheon in the 9th century<sup>3</sup> and known in Sanskrit as *Acala*, *Fudo* transmits the teachings of Dainichi Nyorai to all terrestrial beings, though the individual must choose whether to accept his teachings. *Fudo* is typically depicted with a ferocious facial expression to symbolize the might of his will to draw people to follow the teaching of the Buddha. Despite this ferocity, he is in fact a compassionate being, evocative of the bodhisattvas, and has vowed to be of service to mankind for eternity. As a wrathful deity, he helps Buddhist practitioners move past temptation and toward

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1 For illustration of the sculpture dated c. 839, see Penelope Mason, *History of Japanese Art*, 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 2004), plate #158. For illustration of the sculpture dated to the 12th-14th centuries, see Art Institute acquisition #1958.321 at [artic.edu/aic/collections/artwork/8085?search\\_id=2](http://artic.edu/aic/collections/artwork/8085?search_id=2) (accessed 1/27/2011).

2 Barbra Teri Okada and Kanya Tsujimoto, “The *Fudo Myo-o* from the Packard Collection: A Study During Restoration,” *Metropolitan Museum Journal* 14 (1979): 51.

3 Okada and Tsujimoto, 51.

enlightenment. Fudo removes obstacles with his sword and subdues evil spirits with his lasso. He demonstrates furious power and energy to destroy the evil that impedes an individual's quest for enlightenment.

The first of the two sculptural images discussed here comes from the early Heian period and is displayed in the *kodo*, or lecture hall of Kyoogokokuji in Kyoto. The early Heian period was a time of artistic transition, when artists moved away from the classical Nara-period style and developed a more voluminous and geometric bodily style. With the influence of the Tang dynasty in China and the appearance of new Buddhist schools of thought, innovative artistic techniques began to appear in Japanese religious works. Carved from a single block of wood, Fudo's body appears substantial and heavy, demonstrating his intense authority and power over ignorance. Seated in the lotus pose, his limbs appear thick and geometric and the folds of his drapery appear weighty. The base of the sculpture is rectangular, meant to be an abstraction of a rock formation which reinforces the "immovable" qualities of his character.<sup>4</sup> Surrounded by a halo and an abstract flame-patterned background, Fudo appears to be emanating radiance and authority. As in many other representations, Fudo is surrounded by the flames of fire, which according to Buddhist lore, represent the purification of the mind by the burning away of all material desires.

The facial expression of this Fudo from the Heian period is stern and intense, with a furrowed brow and powerful stare. His protruding fangs express an otherworldly nature as well as his designation as a wrathful deity. He possesses the elongated earlobes of a traditional Buddha or bodhisattva, suggesting he has achieved enlightenment. His hair is braided and pulled to the side and his face slightly turned, resulting in a gaze that is brooding and concentrated. The braid represents the deity's commitment to service, as it is knotted in the style of a servant. This Fudo holds his typical implements, a lasso and a

sword with a *vajra* handle. The lasso is meant to contain those who are ruled by their vices and violent emotions, while the sword cuts through delusion, ignorance, and the three poisonous hindrances of sentient beings.<sup>5</sup> Fudo translates anger into salvation; his furious glare works to frighten people into accepting the teachings of Dainichi.

Typical of wood sculptures during the Heian period, this work is made of cypress wood. Soft and durable, the wood lends itself to a finished effect that mimics the softness of the corporeal body, adding to the realistic quality of the work. This focus on representing the body in a naturalistic manner is an important component of sculptural works of the Heian period. In addition, the beautiful grain of cypress made it the favorite material for Heian sculpture.<sup>6</sup>

Fudo became increasingly popular as an iconic image in the late Heian and Kamakura periods. He is also present in Japanese Buddhist traditions other than esoteric sects. The practice of invoking Fudo for rebirth in the Pure Land developed in the Late Heian and Kamakura periods.<sup>7</sup> Fudo was especially popular with the nobility for his effectiveness in restoring health and defeating enemies. Records of calling upon Fudo at the hour of death appear in the early twelfth century, with many members of the ruling class invoking him in the hopes of being reborn in heaven. In the Kamakura period, images of heaven appeared in *Raigo* paintings with Fudo on a rock next to the Buddha's entourage.<sup>8</sup>

A little known religious tradition that involves Fudo worship is Shugendo, influenced by esoteric Buddhism, Taoism, and Shamanism. A number of Shugendo rituals, performed to meet the needs of people in small mountain communities, invoke the spirit of Fudo in fire ceremonies,

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4 Mason, *History of Japanese Art*, 131.

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5 Karen Mack, "The Phenomenon of Invoking Fudo for Pure Land Rebirth in Image and Text," *Japanese Journal of Religious Studies* 33.2 (2006): 299.

6 Okada and Tsujimoto, 60.

7 Mack, 316.

8 Mack, 301.

exorcisms, spells, and charms. A typical ritual involves a ceremony in which Fudo is invited to the altar “for the purpose of identification with the deity.”<sup>9</sup> This “invitation” serves to openly employ the deity’s supernatural power or that of his attendants and to control and defeat the evil that prohibits an individual’s spiritual growth.

The Kamakura period saw new imagery of Fudo with a focus on realism, more heavily modeled drapery, and stronger modeling of the figure. The influence of Chinese Sung internationalism was instrumental in the development of this style. The idealized spirituality of previous periods was replaced with a desire for more realism, and sculptures took on a weighty, more substantial quality. The works were created with a sense of naturalism and the presence of the deity was represented in a more direct manner.

Sculptural works like the *Fudo Myo-o* at The Art Institute of Chicago demonstrate a focus on solidity and steadfastness. The figure is modeled in a delicate manner that demonstrates the highly realistic direction taken by Japanese sculptors during this period. Seated on an abstract rectangular formation that suggests the appearance of a rock, Fudo rests upon a literal reference to his unyielding and persistent nature. His bulging eyes and vicious stare communicate the force of his personality and strengthen the focus of his mission to help the Buddhist practitioner eliminate evil forces. Though he no longer holds his traditional implements (the sword and lasso have been removed for conservation at the museum), he does have a large gilt-bronze accessory that is reminiscent of a necklace or chest plate and gives a regal effect.

His furrowed brow has a wavelike pattern in the center, and his eyes are made of crystal, giving them an otherworldly

effect. Fudo’s steadfast gaze draws the viewer in, and reinforces the emotional intention of the work. The gaze gives the work the impression of ferociousness and purpose. The use of crystal for the eyes was an innovation of the Kamakura period and when combined with the highly naturalistic qualities of the figure, highlights this unique style and emphasizes the union of compassion and fierceness.

Fudo is seated in the lotus pose, his body rigid and solid, and creates the effect of serious authority. His drapery is heavily modeled, adding to the naturalistic quality of the figure. He has the elongated earlobes and snail-shell curls of a Buddha, suggesting that he has already achieved enlightenment. Fudo’s fangs protrude from his mouth, reinforcing the vicious facet of his personality and signaling his vow to battle evil.

The two examples of Fudo discussed here use much of the same iconography, albeit with different stylistic effects. Sharing a spiritual and devotional purpose and differing only in size and particulars, these works were meant to help the Buddhist practitioners achieve their goal of enlightenment. The Late Heian and Kamakura periods saw a rise in the popularity of Fudo as a devotional deity, responding to the changes in Buddhist practice. This resulted in an increased incidence of Fudo as a subject matter in sculptural works. From the stylized, geometric works of the Late Heian to the realistic and more natural works of the Kamakura, Fudo became a central figure in Buddhist works. His role as a wrathful yet compassionate deity helped many Buddhist practitioners with everything from daily activities to dealing with the death of loved ones. He truly is a unique and empathetic figure in the Buddhist pantheon.

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9 Hitoshi Miyake, “Religious Rituals in Shugendo: A Summary,” *Japanese Journal of Religious Studies* 16 (1989): 101.

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# SŌGYŌ HACHIMAN: A JAPANESE AVATAR

Melanie Jacobs\*

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**ABSTRACT** The tenth-century statue of *Sōgyō Hachiman* reveals a unique development in Japanese religious art: the integration of Shinto and Buddhist representations of deities. The figure of *Sōgyō Hachiman* is shown as a figure from the Buddhist pantheon, but he is actually the Shinto god of war. It was the belief in avatars that allowed a Buddhist divinity to be seen as a reincarnated Shinto god.

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In recent years the concept of an avatar or substitute self has fascinated many in the Western world, but in Japan it has long conveyed a different meaning. One image of a Japanese avatar is the *Sōgyō Hachiman* (acquisition number 1960.0755), a wooden sculpture from the Heian period (794–1185) on display at The Art Institute of Chicago.<sup>1</sup> Like other Japanese avatars, this image combines native notions of the sacred with adopted foreign notions in its portrayal of an embodied deity. The sculpture of *Sōgyō Hachiman* is a concrete representation of the merging of two main religious traditions in Japan: Shinto and Buddhism.

The sculpture of *Sōgyō Hachiman* shows a seated male figure dressed as a Buddhist monk. The figure's shaved head, elongated earlobes, and lotus pose indicate that the sculpture is related to Buddhist images. However, this is a representation of a Shinto deity in the guise of a Buddhist monk. The name *Sōgyō Hachiman* implies a dual spiritual meaning: the word “*sōgyō*” means “in the form of a Buddhist priest,” and *Hachiman* is the name of a Shinto deity.<sup>2</sup>

Shinto, which translates as “the way of the gods (*kami*),” is the indigenous religion of Japan. Although the first use

of the word “Shinto” occurs in the *Nihon shoki* of 720, it is widely believed that an earlier version of the religion dates back to the Yayoi period (400 B.C.E.–300).<sup>3</sup> Core beliefs of Shinto revolve around the sun goddess, Amaterasu Omikami. Shinto mythology tells of Amaterasu creating Japan and sending her grandson, Ninigi, to the islands to establish a kingdom in her honor. According to Shinto, Japan and its inhabitants are special divine creations and its emperors are direct descendents of Amaterasu. The emperors literally have divinity running through their veins and a direct connection to the heavens. The gods are the life energy of the whole world. Two other important aspects of Shinto are the corruption of the life energy caused by the pollution of the human life force and the resulting need for purification. Every person is connected to the energy force of the gods, and “the pollution, whether moral or natural, diminishes our sense of participation and involvement in this creative power inherent in all life.”<sup>4</sup> The disruption of the life forces contaminates the world, severing the link to the life forces of the world and creating a need for atonement through purification. Overcoming natural circumstances and human deeds that pollute the world restores “the life giving power, that is, a condition of purity.”<sup>4</sup>

An excellent illustration of Shinto beliefs and practices is found in the design of the Ise Shrine.<sup>5</sup> This is a prestigious Shinto landmark that demonstrates the significance of

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Amaterasu and the importance of purification. Dedicated to Amaterasu, this is the main shrine of the imperial court and Shinto. Each new emperor travels to Ise to enter into seclusion and commune with the sun goddess. Inside the shrine the emperor is believed to have direct contact with the divine being. Only the emperor, the one with the divine right to enter the shrine, is allowed to convene with Amaterasu. Abiding by Shinto traditions of purification, the shrine is rebuilt every twenty years in order to keep it free of pollution.

Early in Japanese history, Shinto was not only the most prevalent religious belief, but it was also a crucial part of the government. According to Shinto principles, the emperor had a divine right to rule the people, because he himself was a divine being. Clans like the Nakatomi (later changed to Fujiwara) were entrusted with the task of performing Shinto ceremonies at the imperial court.<sup>6</sup> Shinto beliefs helped to solidify the different social classes and permeated many aspects of Japanese life.

Buddhism, which originated in India with the teachings of Shakyamuni, was introduced to Japan during the Asuka period (542–645). Shakyamuni, or Shaka as he is called in Japan, was born a prince and abandoned his life of comfort to seek spiritual understanding. After many years of meditation and deprivation, Shaka experienced enlightenment under the *bodhi* tree. Shaka then embarked on a journey to spread the truths he had discovered, and he came to be known as the “Enlightened One” or the Buddha.

The main belief of Buddhism is karma, which suggests that current actions determine a future state. Bad karma will direct one to a lower level of reincarnation than one’s current life, possibly even reincarnation outside of the human form. Good karma will direct one to a higher level than the previous life, possibly even to a godly state. The Buddha’s objective was to escape the cycle of reincarnation and realize the state of true harmony (*nirvana*).

Triad sculptures representing a Buddha and two savior beings (*bodhisattvas*) are perhaps the best visual representations of unique aspects of Buddhist art. Often artists show Shaka, the historical Buddha, in the center of the triad with two bodhisattvas as attendants, one bodhisattva on each side. The two attendants are holy beings who have decided to postpone attaining the level of enlightenment of the Buddha; they stay in the world and help others achieve enlightenment. In these images, the Buddha frequently sits in the lotus pose of meditation on a throne in front of the *bodhi* tree. The throne may have lions at the base. The lion is a powerful guardian and a symbol of royalty. Above the Buddha’s head are *apsaras* or floating angels. The Buddha has an *ushnisha* or bump on his head that indicates wisdom and signals that he is not an ordinary person. The *urna* or dot between the eyebrows represents the spot from which the Buddha emits illumination into the world. Sculptors often portrayed the historical Buddha with the *abhaya mudra* or hand gesture of reassurance. Although the Hachiman sculpture does not include all the traits typically seen on a Buddha, it is easy to see why the sculpture at the Art Institute would be associated with Buddhist art. The elongated earlobe and lotus position of the statue most certainly link the sculpture to Buddhist art. However, the lack of *ushnisha*, *urna*, and bodhisattvas indicate that the sculpture is not that of a Buddha. The artist appears to suggest that the sculpture is connected to traditional Buddhist art, while also alluding to other elements of influence as well.

During the sixth and seventh centuries, Buddhism began to play a part in Japan’s government, but not without opposition. Because Shinto was so intertwined with the ruling order, the introduction of Buddhism was met with resistance. Those attached to past traditions—especially Shinto practice—were not receptive to the new ideas of Buddhism. Clans such as the Nakatomi opposed Buddhism and defended their administrative duties as custodians of the native Shinto ritual ceremonies. During the sixth century, one emperor ordered the torching of a Buddhist temple and all of its religious relics when

petitioned by a Buddhist monk to establish Buddhism as the national religion. In 587, a civil war broke out between the Buddhist promoters and the Nakatomi clan. The Buddhist supporters were victorious and the Nakatomi clan was forced to accept the new religion.<sup>7</sup>

While Shinto and Buddhism are generally complementary and artwork such as the Hachiman sculpture could possess elements from both religions, there are a few significant differences between Shinto and Buddhism that, if left unaddressed, could have caused major problems for Japan. Complete abandonment of the Shinto faith would signify a desertion of the notion of a divine origin of the emperor. The avatars like *Sōgyō Hachiman* were important in bridging the gap between the two religious and political systems. An avatar embodies the concept of reconciliation and proved useful in uniting Shinto and Buddhism within one government. According to art historian Tomita Kojiro, Shinto demonstrates the way “to receive inspiration from those who have gone before...[while Buddhism leads] toward salvation in the future life.”<sup>8</sup>

During the Heian period, priests consulted Amaterasu to create a cordial relationship between the indigenous beliefs of Japan and the newly adopted religion. The priests conveyed Amaterasu’s message that she and Shaka were merely “emanations of one another...[and this] started a process of philosophical melding together [of] the two belief systems.”<sup>9</sup> After announcing Amaterasu’s declaration, priests revealed the “Theory of Origin and Manifestation” to further clarify her statement. The theory explained that all Buddhas and bodhisattvas were basically manifestations of Shinto kami.<sup>10</sup> This understanding allowed Shinto deities to be just as important as Buddhist divinities. In later periods, the line between Shinto and Buddhism became blurred. Buddhist temples were built as attachments to Shinto shrines, and Shinto shrines were built within Buddhist compounds.

The Shinto god Hachiman had long been one of the most popular gods of the Shinto pantheon, but he also came to be seen as a Buddhist being who adopted human form for a short time. In 783, Hachiman was recognized as a bodhisattva who would reach Buddhahood in his next incarnation. Hachiman was added to the class of avatars and helped to solidify the lasting bond between Buddhism and Shintoism. Some believed that Hachiman was the embodied spirit of Emperor Ojin. Others believed that Hachiman represented the soul of Hikohohodemi-no-Mikoto, the grandson of Amaterasu.<sup>11</sup> Hachiman was also worshipped as a guardian of the state and the people. In the twelfth and thirteenth centuries, he came to be honored as a god of war due to patronage by the Minamoto shogunal family.

Knowing this historical background, we come to understand why the *Sōgyō Hachiman* sculpture at the Art Institute of Chicago is represented as a Buddhist monk and that Shinto and Buddhist deities are simply different expressions of the same divine concept. Shintoism and Buddhism could not coexist in Japan as peacefully as they do today without the concept of the avatar. Totally abandoning Shintoism would have been abandoning the fundamental beliefs upon which Japan was built. By the sixth and seventh century, Buddhism had become so engrained in the Japanese framework that abolishing Buddhist beliefs would have been impossible. Neither religion could be done away with and so something had to be done to allow the two religions to coexist peacefully. The concept of the avatar filled this need. Belief in avatars allowed Shinto beings to be avatars or reincarnations of the Buddha and bodhisattvas allowing both religions to be accepted as true. *Sōgyō Hachiman* is a concrete representation of the reconciliation of Shinto and Buddhism. This sculpture embodies the merging of two religions that have defined Japan for centuries and a tenth-century testimony to Japan’s religious past.

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- 1 For illustration of this sculpture, see [artic.edu/aic/collections/artwork/12341?search\\_id=1](http://artic.edu/aic/collections/artwork/12341?search_id=1) (accessed on 1/25/2011).
  - 2 For more on a similar sculpture see, Christine Guth Kanda. "Kaiket's Statue of Hachiman in Todaiji," *Artibus Asiae* 43.3 (1981-1982), 190-209.
  - 3 Nihongi, Trans. W.G. Aston (Upper Saddle River: Prentice Hall, 2005); Penelope Mason, *History of Japanese Art* (Upper Saddle River: Prentice Hall, 2005): 53.
  - 4 James W. Boyd and Ron G. Williams, "Japanese Shinto: An Interpretation of a Priesly Perspective," *Philosophy East and West* 55 (2005): 34-35
  - 5 For more on the Ise Shrine see Cassandra Adams, "Japan's Ise Shrine and Its Thirteen-Hundred-Year-Old Reconstruction Tradition." *Journal of Architectural Education* 52.1 (September 1998): 49-60, and George Williams, *Shinto* (Philadelphia: Chelsea House Publishers, 2005).
  - 6 For more see Daisuke Mikoshiha, "Empress Kōmyō's Buddhist Faith: Her Role in the Founding of the State Temple and Convent System," in *Engendering Faith: Women and Buddhism in Premodern Japan*, ed. Barbara Ruch (Ann Arbor: Center for Japanese Studies, University of Michigan, 2002): 26.
  - 7 *Ibid.*, 27.
  - 8 Tomita, "Statue of Sōgyō Hachiman by Kōshun, A Japanese Wooden Sculpture Dated 1328," *Bulletin of the Museum of Fine Arts* 35.212 (1937): 78.
  - 9 Mikoshiha, 161.
  - 10 Mason, 57.
  - 11 For more on belief in Hachimna see Ross Bender, "The Hachiman Cult and The Dokyo Incident," *Monumenta Nipponica* 34.2 (Summer 1979), 25-153.



# RETHINKING ISABELLA: CONCEPTIONS OF FAITH IN SHAKESPEARE'S *MEASURE FOR MEASURE* AND KIERKEGAARD'S *FEAR AND TREMBLING*

Lindsay Ansai\*

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**ABSTRACT** Critical and cursory characterizations of Isabella in William Shakespeare's play *Measure for Measure* paint her as an unfeeling religious votary, clinging to a seemingly outdated faith and lacking in compassion. Her dogmatism seems to ultimately diminish the value of religion in the play. This essay argues that by considering Isabella's dramatic dilemma in terms of the Abrahamic conception of faith explored by Soren Kierkegaard in *Fear and Trembling* a more complex and forgiving view emerges of both Isabella's character and religion in *Measure for Measure*.

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Written in 1604, *Measure for Measure* opens in a decaying, corrupt Vienna, headed by the proxy-duke Angelo, a puritanical leader who has sentenced the young Claudio to death for fornication; Claudio's only hope lies in the persuasive abilities of his sister, a novice nun named Isabella. But Isabella's rhetorical skills come to naught as Angelo gives her instead a choice of a carnal and ironic nature: Isabella can save her brother's life, but only by having sex with Angelo. Isabella's decision to remain chaste condemns her brother to death; she, in turn, is condemned as cold, lacking compassion, and a moral absolutist unable to acknowledge the nuances of life. Moreover, as Isabella is an explicitly religious character, devout to a fault, her decision has been seen as lowering the status of religion within the play, rendering religious faith culturally irrelevant and even socially irresponsible. This critical conception of Isabella and religious faith within *Measure for Measure*, however, ignores the complexities of Isabella's situation and what it reveals about the value of religious faith within a secular society.

Isabella's trial of faith is perhaps best contextualized in terms of the sacrifice of Abraham as explored by Danish philosopher Soren Kierkegaard in his 1843 text, *Fear and Trembling*—Abraham is, after all, a figure who by all accounts created the mold for trials of faith. Read within the context of an Abrahamic sacrifice and faith, Isabella is not unfeeling or morally fixed, and neither is religion, though both are problematized all the same. The parallels between the sacrifice and faith of Isabella and the sacrifice and faith of Abraham prompt an exploration of the re-characterization of Isabella as well as the value of religion within the textual world of Vienna and *Measure for Measure* as a whole.

One of the unfavorable critical characterizations of Isabella is both helpful and necessary. Most simply, Isabella is a sister: she is both the earthly sister of Claudio and a spiritual sister as a novice nun within a monastic order. It is the conflict between the two shades of her sisterhood that provides the tension within her character arc, since being one kind of sister means she must sacrifice being the other. Isabella's dilemma of whether to save her brother or her chastity is simultaneously simple and complex, but altogether perplexing to any person who values human life—how could being a religious sister ever

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truly trump the ties of family sisterhood? Indeed, when she informs Claudio of her decision to preserve her virginity, stating, “Better it were a brother died at once / Than that a sister, by redeeming him, / Should die for ever,” it is initially easy to cast Isabella as a cold votary, rightfully fit for nothing but religious seclusion.<sup>1</sup> Isabella’s fellow citizen, Lucio, for instance, twice calls her “too cold.”<sup>2</sup> In the Introduction to *Measure for Measure* in the Riverside Shakespeare, critic Anne Barton characterizes Isabella as a “virtuous absolutist ... a narrow-minded but passionate girl afflicted with an irrational terror of sex” who dissolves into “hysteria and intolerance” when confronted with an impossible choice.<sup>3</sup>

Isabella’s piety appears starkly out of place in Shakespeare’s Vienna, where nothing is absolute and where the actual Duke has seen “corruption boil and bubble / Till it o’er run the stew.”<sup>4</sup> Is she merely an anachronism, a frigid example of outdated religious piety, lost in the decadent sexuality that surrounds her? Since Isabella is the explicit example of unwavering faith within *Measure for Measure*, is faith thus characterized as outdated and useless? Or is one to acknowledge her faith as sincere and legitimate, such that characterizations of moral absolutism and frigidity are largely a reflection of reader or audience anxieties? If one engages with her character as a sincere person of faith, Abrahamic in her belief and sacrifice, possibility does indeed emerge.

Though Isabella’s situation differs in countless ways from the parable of Abraham and Isaac, certain striking similarities might help to illuminate another reading of her character and faith. The most important parallels between the two tales are how both Isabella and Abraham are devout followers of their religions, and how each is asked

to sacrifice something immensely dear at the expense of losing someone they love deeply. Both characters defy conventional expectation, choosing spiritual salvation in the face of profound societal disapproval. For the sake of this parallel, Isabella’s choice to preserve her virginity corresponds with Abraham’s choice to raise his knife over Isaac’s throat. Although her choice lies in inaction and his in action, but both directly result in the death of someone they love. In considering these two figures’ deep faith and commitment to profound sacrifice, one can think of Isabella as an Abrahamic figure, while Abraham becomes a point of access to alternative conceptions of Isabella’s status within *Measure for Measure*, one of which emerges by applying some of Soren Kierkegaard’s theories on faith.

Considering Abraham was richly rewarded for his deep faith, receiving both his son and the love of future generations of people, one must wonder what reward Isabella anticipates. If one treats as legitimate Isabella’s awareness of the ephemeral quality of the earthly realm such that the potential for spiritual immortality outweighs the concern for mortal existence, her decision to save her and, potentially, her brother’s souls at the expense of their bodies is not so nonsensical.

For Kierkegaard, faith is at once simple and exceedingly impossible, since it quite literally defies rational explanation: an individual of faith must rely “on the strength of the absurd, for there [can] be no question of human calculation.”<sup>5</sup> In his introduction to Kierkegaard’s *Fear and Trembling*, Alastair Hannay writes, “Kierkegaard’s Abraham is great because of what he suffers in a trial of faith.”<sup>6</sup> Hannay further argues that the unintelligibility of faith renders it insufficiently explicable, whether through spoken language or writing, where we can never use it to “fully justify [our] actions and attitudes to one another.”<sup>7</sup>

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1 William Shakespeare, *Measure for Measure*, 1604, edited by Grace Ioppolo, Norton Critical Editions, (New York: Norton, 2010), II.iv.105-8.

2 Ibid, II.ii.47, 59.

3 Anne Barton, “Introduction to Measure for Measure,” in *The Riverside Shakespeare*, edited by Herschel Baker et al. (Boston: Houghton Mifflin Company, 1997), 580.

4 Shakespeare, *Measure for Measure*, V.i.318-319.

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5 Soren Kierkegaard, *Fear and Trembling*, translated by Alastair Hannay (London: Penguin Books Ltd., 1985), 65.

6 Alastair Hannay, *Introduction to Fear and Trembling*, by Soren Kierkegaard (London: Penguin Books Ltd., 1985), 7.

7 Hannay, Introduction, 11.

Abraham, for Kierkegaard, is humbling because of his faith but also because of his profound embodiment of a seeming paradox, “great with that power whose strength is powerlessness, great in that wisdom whose secret is folly, great in that hope whose outward form is insanity, great in that love which is hatred of self.”<sup>8</sup> Applying these ideas to Isabella reveals that there might be room for the irreconcilable conflict between her two sisterhoods, the paradox that drives the action of *Measure for Measure*.

Isabella’s integrity, her faith in her beliefs, allows her to embody paradox. She is the best sister she can be to Claudio precisely because she upholds her spiritual vows. Isabella decides to preserve her virginity and sentence her brother to die out of a deep religious conviction that could theoretically be considered absurd; but insofar as religious faith is defined precisely by its absurdity, Isabella’s choice is arguably the choice that any who consider themselves faithful would make. It is no wonder then that in the Vienna of *Measure for Measure* most other characters regard Isabella’s choice as foolish and unfeeling; none besides her have ever expressed any interest in being religious or demonstrating faith. Judging a choice from only one perspective does not encapsulate its contextual complexity—in regards to Isabella, both those who make favorable and unfavorable judgments of her decision do well to approach the matter from an appropriately religious context.

Even if Isabella is thus contextualized and partially redeemed, what does her presence within *Measure for Measure* suggest about the relationship between society and religion? Granted, Isabella is in no way a simple, allegorized representation of religion. However, as the most devout character within the play, she becomes an axis around which conceptions of religion turn. One might consider Kierkegaard’s assertion that faith is nothing but the supreme paradox, that “the single individual as the particular is higher than the universal, is justified

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8 Kierkegaard, *Fear and Trembling*, 50.

before the latter, not as subordinate but as superior... stand[ing] in an absolute relation to the absolute.”<sup>9</sup> This is where concerns emerge over the relationship between an individual’s choices and society’s needs. This is where we can address the question of the relevance and value of religion within *Measure for Measure*, as prompted by and accessed through Isabella.

With regard to the role of a religious individual in a society, many critics argue that Christian ethics or individualist ethics work to the detriment of the Viennese society of *Measure for Measure*. Perhaps the greatest problem is that the devoutly religious individual is unable to interact with the society in which she lives and which she arguably seeks to offer spiritual solace, an issue of both practicality and justice. Critic M.W. Rowe rightly identifies that “The difficulty with such absolute restraint is that...it cracks, and the agent is overwhelmed by desires that have grown huge and distorted through long repression.”<sup>10</sup> In this view, “virtue has become deeply unattractive and life-denying,” and Rowe echoes the argument timelessly lodged against ascetics that denial and extreme religious piety are simply impractical.<sup>11</sup> In other words, the average citizen of Vienna could not so easily abstain from the pleasures of their lives to the extent that a monastic order would require.

Religious or individualist ethics create a conflict between the private person and public forms of justice: the spiritual individual who “judges not” is required to withdraw from the world, or be subject to justice without mercy or mercy without justice. Applying the Christian model of forgiveness to the lawbreakers of a city might induce chaos in short order, for society would have to forgive and be free all fornicators, assaulters, and murders. Without any forgiveness, justice has the potential to transform into sanctioned and remorseless vengeance.

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9 Kierkegaard, *Fear and Trembling*, 85.

10 M. W. Rowe, “The Dissolution of Goodness: ‘Measure for Measure’ and Classical Ethics,” *International Journal of the Classical Tradition* 5 (1998): 24.

11 Rowe, “Dissolution of Goodness,” 25.

A conventional solution to this problem is to somehow join together the public model of justice and the private model of faith. According to critic Stacy Magedanz, only the unification of public and private, something that is impossible and undesirable for the truly pious individual, can elicit “Isabella’s personal sense of compassion” while also meting out due justice for the other characters.<sup>12</sup> In such social contexts, the problem of religious faith moves beyond how it might cause an individual to become too cold; religious faith seems both too forbidding for the average citizen and too forgiving of the lawbreaker to be possible in a secular society.

These conclusions do not stand, however, when considered against the soteriological concerns of Kierkegaard in *Fear and Trembling*.<sup>13</sup> Not to be mistaken as a justification for every radical and illogical act an individual might take, Kierkegaard’s encouragement of Abraham’s ethical individualism might actually be, according to Ronald M. Green, “a prophetic defense of the individual in a world increasingly dominated by herd morality.”<sup>14</sup> This can be easily misread as a convenient justification for individual acts of immorality or insanity, but Green seeks to highlight how “ethics sometimes permits and even requires us to transcend parochial group loyalties”—this aspect of ethics requires us to admit, “Abraham’s conduct merits our highest praise.”<sup>15</sup> Unpacking this idea further, the individual who embodies an unpopular but ethical tenet is all the more praiseworthy because she embodies the tenet in its unpopularity. This is nothing new in a modern consideration—think of the person who stood against slavery in its heyday or advocated women’s suffrage when it was most unpopular only to be lauded retroactively—or in regards to the justification of actions based on religious ethics. It is still useful to reconsider this point in relation to

Isabella and her society. At best, religious ethics can guide an individual living under corrupt government, dangerous mob mentality, and times of state mandated nonsense; at worst, religious ethics can create these very problems. If the Kierkegaardian conception of individualist and religious ethics demonstrates anything, it is that the status of the religious individual and religion in society is complicated, suggesting multiple meanings and possibilities.

At the end of the play, the real Duke resolves the tensions caused by his proxy and offers marriage to Isabella, whose answer the audience does not learn. Because we do not know Isabella’s answer, it is unclear whether the Duke’s offer is an ironic reward or an earthly punishment, begging the question of whether her trial of faith was worth it, in the end. Overall, Isabella’s willingness to have faith in a figure that the audience knows to be fallible (the Duke) or suspects to be fake (God) challenges the wisdom of having faith in the first place, of being religious in a society that shuns religion. Wisdom, however, is not a factor in the presence or absence of faith. Of course one might argue that Isabella’s true reward is prolonged, since she is still in the mortal realm. A Kierkegaardian conception of faith embraces paradox, unintelligibility, and the absurd as valid measures of sincerity, sanity, and wisdom, precisely because faith is the religious manifestation of irrationality, covering all manner of virtue and vice, and sanctioning uncertainty. Thus, asking whether it was worth it for Isabella to undergo her trial of faith yields the same answer as asking how Isabella responds at the end of the play—the most we can ever say is that we can never know.

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12 Stacy Magedanz, “Public Justice and Private Mercy in ‘Measure for Measure,’” *Studies in English Literature, 1500-1900* 44 (2004): 324.

13 Kierkegaard, *Fear and Trembling*, 85.

14 Ronald M. Green, “Enough is Enough! ‘Fear and Trembling’ is Not about Ethics,” *The Journal of Religious Ethics* 21 (1993): 194.

15 Green, “Enough is Enough!,” 194.

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# SYMBOLISM, SURREALISM, AND THE SPACE BETWEEN

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**ABSTRACT** *Jacob's Ladder*, a painting by Alexander "Skunder" Boghossian (1937–2003) from the DePaul Art Museum, reveals the influence of religious traditions on Ethiopian art. This essay integrates a formal analysis of the painting with a discussion of its content the cultural heritage of the artist, and the context of the artwork.

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Many contemporary African artists look to their past to examine and express their identity. One such artist is the painter Alexander "Skunder" Boghossian, born in 1937 in Addis Ababa, Ethiopia. While studying abroad in Paris as a young artist, Skunder first began exploring what it meant to be an artist and an African in the international art world. Through his unique treatment of traditional subject matter in his 1984 painting *Jacob's Ladder*, Skunder captured a sense of his Ethiopian heritage. This painting reveals that he was influenced by theories of Negritude and Pan-Africanism, both of which he encountered as a student in Paris where he was swept up in the "conjuring capacity of surrealism."<sup>1</sup>

Due to its dynamic composition and rich texture, *Jacob's Ladder* exudes an invisible yet profound energy. White, yellow and blue flecks peek out from beneath layers of murky greens, deep blues and austere grays. Skunder created most of his paintings by first splashing water on his canvas and then lightly spray-painting the surface.<sup>2</sup> This technique, known as *eclaboussure*, is one of the surrealist methods Skunder learned during his years studying in Paris. By using *eclaboussure*, he was able to create a sense of space and atmosphere. A dense black horizontal band

at the top of the canvas abruptly stills the ebb and flow of the background. Skunder's treatment of the canvas with surrealist painting techniques creates a curious mood while also capturing a divine subject, transforming the image into a quiet space for contemplation and reflection.

Skunder pictured Jacob's Ladder rising from the bottom of the frame and extending beyond the pictorial space. This is the ladder to heaven presented to Jacob as he slept according to a story in the Old Testament: "and behold, a ladder was set up on the earth, and its top reached to heaven; and there the angels of God were ascending and descending on it."<sup>3</sup> Dangling from the uppermost rung of the ladder are two narrow strips of inscribed and tattered cloth, which seem to sway with the ladder in the wind. It has been assumed that these cloth strips are scrolls of the Torah. With further investigation, however, we realize that they are actually ancient Ethiopian magic scrolls, which were used by Ethiopian Muslims, Christians, and Jews. Muslim and Orthodox Christian pilgrims often tied a piece of cloth to the shrine or tomb of a saint. The geometric and figurative designs on the scrolls suggest a connection to talismanic traditions. Talismans, including painted scrolls, are used to heal and protect the faithful. In Ethiopia, the most widely used Judaic talisman is the Jewish *tallis* or prayer shawl, similar in form to the strips of cloth that Skunder represented in his painting. He thus integrated iconographic features of Christian, Judaic, and

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1 Wendy Kindred, "Skunder and Modern Ethiopian Art," in *Aspects of Ethiopian Art: From Ancient Axum to the 20th Century*, ed. Paul B. Henze et al. (London: The Jed Press, 1993), 128.

2 *Ibid.*

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3 Genesis 28:12



Islamic art through the use of magic scrolls pointing to Ethiopian background for this painting.

The Imperial House of Ethiopia, also known as the Solomonic Dynasty, claimed descent from King Solomon and the Queen of Sheba. As described in the ancient Ethiopian text, *Glory of the Kings*, Sheba gave birth to a son named Menelik upon returning from a visit with King Solomon. Menelik supposedly brought the Ark of the Covenant to Ethiopia and became the first emperor of Ethiopia.<sup>4</sup> This explains in part the Ethiopian Christian emphasis on the Old Testament and its particularly close relationship with Judaism. Magic scrolls are said to have emerged during the Christian era and have their origins in the stories of Old Testament figures, Abraham and Solomon. The oldest extant books of protection date from the fourteenth century and feature designs of knotwork, as do religious books today.<sup>5</sup> The Torah, typically found in scroll form, is bound as a codex among many of Beta Israel, or Jews of Ethiopia, who drew from Orthodox Christian teachings.<sup>6</sup> These Judaic texts frequently contained decorative illuminations similar to those in Christian illuminated texts. Islamic influence is also seen in medicine, magic, and talismanic art, and Egyptian Muslims made extensive use of protective scrolls.<sup>7</sup>

In *Jacob's Ladder*, Skunder recalls his spiritual heritage through images of Ethiopian painted scrolls. Talismanic scrolls are inscribed with various symbols and figures akin to the geometric patterns seen on the two linen scrolls hanging from Skunder's ladder. Each scroll was created by a *dabtara*, a cleric who is typically learned in singing,

poetry and literature, but is not ordained. The specific symbols, text, and length of the scroll are measured and designed according to the recipient. The *dabtara* "cuts the prepared parchment into three strips of equal width, so that when sewn end to end with a leather thong the total length will equal the height of the person the scroll is intended for."<sup>8</sup> This ensures the user's head-to-toe protection from demons. Skunder captured this effect by altering the lengths and designs of the scrolls he portrayed in *Jacob's Ladder*.

Among the most popular designs employed on the talismanic scrolls is the rectangle inscribed with an "X." A crossbar in a rectangle is depicted in the left-most scroll of *Jacob's Ladder*. Known as the seal of the angels, this symbol references the net of Solomon and is intended to drive away demons.<sup>9</sup> According to tradition, the net of Solomon was presented to him, along with wisdom from the eternal.<sup>10</sup> The presence of the seal of angels hanging from the ladder with ascending and descending angels suggests that the figure of the woman on the right scroll is indeed an angel. The shape and style of the figure's clothing, along with the yellow incorporated in the rightmost scroll, parallel the imagery of a guardian angel found in Ethiopian painted scrolls: "The robe is haloed in yellow, a symbol of the resplendent light of God's angels. The angel stands against a dark sky scattered with stars."<sup>11</sup> Skunder's placement of the scrolls amid an inky setting shimmering with specks of light is appropriate as the image is meant to ensure that the owner does not suffer "nocturnal fears and nightmares."<sup>12</sup>

Born to an Armenian father and an Ethiopian mother, Skunder was brought up in an environment teeming with artistic energy. As a young boy, he studied art informally with Jacques Godbout at Tafari Makonnen

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4 Jacques Mercier, *Art That Heals: The Image as Medicine in Ethiopia* (New York: Prestel, 1997), 35.

5 Jacques Mercier, *Ethiopian Magic Scrolls* (New York: George Braziller, Inc., 1979), 7-10.

6 Richard Pankhurst, "Falasa-Christian or Christian-Falasa Art?," in *Aspects of Ethiopian Art*, ed. Henze et al., 44. Falasa is a term still commonly used to refer to Ethiopian Jews, despite its pejorative connotations.

7 Mercier, *Ethiopian Magic Scrolls*, 10.

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8 *Ibid.*, 16.

9 Mercier, *Art that Heals*, 57.

10 Mercier, *Ethiopian Magic Scrolls*, 8.

11 *Ibid.*, 104.

12 *Ibid.*



High School. Godbout challenged his students to explore and experiment with modern painting. Skunder took to the arts and won second prize at the 1954 National Art Exhibition held for the Jubilee Anniversary Celebration of His Majesty Haile Selassie I. In 1955, Skunder was awarded a scholarship to study art in England. Two years into his studies abroad, he discovered artistic inspiration in France and in 1957 moved to Paris, where he was exposed to work by the Surrealist artists Andre Breton, Max Ernst, and Paul Klee.

Because Paris was the center of an art world and African art had been important to artists working in Paris, such as Pablo Picasso, Skunder took to the invisible and irrational realm of the Surrealists. Surrealism, which was an important artistic development in Paris in the 1920s and 1930s, has been described as “an organized movement, iconoclastic and revolutionary in nature.”<sup>13</sup> The Surrealist interest in revolution and unrest was perfect for the young Skunder as he experimented to develop his painterly style. Instead of simply borrowing European artists’ approaches to connect with his African identity, he looked inward. When discussing his methods in the 1966 *Ethiopian Observer*, friend and Ethiopian poet Solomon Deressa wrote, “Skunder doesn’t use symbols consciously—he says they come forth because they were [already] there.”<sup>14</sup>

For Andre Breton, one of the founders of Surrealism, a key concept of the movement was channeling the unconscious by practices of automatism. Breton’s emphasis on automatism parallels a surrealist theory of the imaginary. “The surrealist idea that ‘the imaginary is what tends to become real’ is calculated on the causality of desire. Desire tends in effect to realize what it imagines.”<sup>15</sup> In Freudian terms, desire is played out in dreams, which are ultimately

an expression of the unconscious mind.<sup>16</sup> This recalls the story of Jacob’s Ladder, as the ladder was presented to Jacob in a dream. Skunder also suggests the image of the guardian angel protecting the sleepers’ dreams against invasive demons in *Jacob’s Ladder*. Perhaps the Surrealist conception of the imaginary could explain Skunder’s inner desire to express his identity in painting. His use of the symbol of Ethiopian magic scrolls seems authentic in part because of the artist’s own heritage, as well as his personal interests and inspirations. Wendy Kindred points out that Skunder, in his personal exploration of traditional Ethiopian art, “was especially drawn to the indigenous beliefs surrounding Ethiopian Christianity, to magic scrolls with their cryptic formulas and idiosyncratic lines, and to manuscripts with words that spoke to the imagination, words that were pregnant with images.”<sup>17</sup> However, Surrealism was not necessarily the driving force behind the spirituality of Skunder’s paintings. Instead, he made use of Surrealist philosophy to express his spirituality.

While studying art abroad, Skunder also encountered the theories of Pan Africanism and Negritude. Pan Africanists stressed the unity of an African identity realized through an emphasis on ancient history and a resistance to foreign occupation of African countries. Negritude, in the words of Achameyeh Debelu, “signifies attempts to maintain a positive racial identity.”<sup>18</sup> Among those who contributed to these theories were Aime Cesaire and Cheikh Anta Diop. Diop was born in Senegal but left at the age of 23 to study physics in Paris, where he became deeply involved in the political resistance to French colonialism along the West African coast. Similarly, as a young African artist in Paris, Skunder was eager to find a deeper connection to his African roots. Through embracing the theories of Pan Africanism and Negritude, he discovered a stronger connection to his African identity.

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13 Wallace Fowle, *Age of Surrealism* (Bloomington: Indiana University Press, 1960), 11.

14 *Ibid.*, 128.

15 Ferdinand Alquié, *The Philosophy of Surrealism* (Ann Arbor: The University of Michigan Press, 1965), 126.

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16 Fowle, *Age of Surrealism*, 128.

17 Kindred, “Skunder and Modern Ethiopian Art,” 130.

18 Debelu, “Alexander (Skunder) Boghossian: A Jewel of a Painter of the 21st Century”; available from [blengrafix.com/blenmagazine/skunder\\_jewel.htm](http://blengrafix.com/blenmagazine/skunder_jewel.htm); Internet; accessed 27 May 2010.

Unfortunately for Skunder, Ethiopia's emerging engagement with modernism was disrupted by the socialist revolution of 1974.<sup>19</sup> Upon returning to his native land, he found that the abstract and expressive effects that he and fellow artists had introduced to Addis Ababa were shunned, while Socialist Realism was encouraged. The socialist regime, which placed a stranglehold on Ethiopia, did not tolerate opposition.<sup>20</sup> This ultimately led Skunder and numerous other artists to leave for the United States. He took up residence in Washington D.C. where he taught as an associate professor at Howard University until his retirement in 2000.

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19 Achamyelch Debelu, "The Addis Ababa Fine Arts School: A Critically Important Institution in the History of Ethiopian Art," in *Continuity and Change: Three Generations of Ethiopian Artists*, ed. Rebecca M. Nagy et al. (Gainesville, FL: Samuel P. Harn Museum of Art, 2007), 10.

20 Alemu Esthe, *The Cultural Situation in Socialist Ethiopia* (Vendome, France: Unesco, 1982), 16.

Returning once more to *Jacob's Ladder*, we find the artist's name twice within the composition: once near the bottom and again inside the dark, negative shape occupying the upper fifth of the pictorial space. Could this be an allusion to Skunder himself, ascending and descending the ladder? Are the scrolls perhaps representative of the history and identity of Ethiopia bridging a gap between heaven and earth? Could a connection be made between the spiritual creativity of the *dabtara* and the imaginative experimentation of the surrealist painter? After all, the artist's journey is made in the act of creation, and as Skunder stated about the process of painting: "Where I want to go is actually more fun for me [than the final work] because the finished product, most of the time, I am not happy with."<sup>21</sup>

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21 Debelu, "Jewel of a Painter."

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# A PHILOSOPHICAL INQUIRY INTO EDUCATION

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**ABSTRACT** Despite philosophy's necessary role in education, it continues to be marginalized from education.

If this continues, then educators' ability to enlighten students will continue to suffer. While there are scholars, such as Marcuse and Chomsky, who write about the societal dynamics related to education and society, the lack of succinct discussion about the relationship between philosophy and education allows education to be oppressive. That said, what is the necessary role of philosophy in education and what does it consist of? Hence, through textual analysis and summation, this paper is a philosophical inquiry into education.

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## Introduction

How is philosophy relevant to enlightenment and education? The purpose of this paper is to demonstrate the necessary relationship between philosophy and education. In particular, this philosophical inquiry into education reveals the dynamic processes that enable people to broaden their capacity to discover meaningful purpose. That said, I begin by addressing how people must take up philosophy in order to begin the journey towards a life without alienation. Then, I explain how philosophy enables people to grasp the process that G.W.F Hegel calls experience. In addition, I argue that Herbert Marcuse's principle of *play* and Randolph Bourne's description of the principle of *struggle* tie into Hegel's analysis of the concept of experience. Furthermore, I clarify how the process of experience necessarily leads to enlightenment. To be clear, term "enlightenment," refers to discovering knowledge through Hegel's term "experience," not to the historical period. After elaborating on the meaning of enlightenment, I discuss enlightenment's necessary relationship to the meaning of purposefulness and harmonious sensation. I refer to this entire system as the good life. Equally important, I explain how the good life system necessarily relates to education and how education could operate with this viewpoint in mind. Finally, I demonstrate

an aspect of how free market ideology dominates current American education as a comparison to good life education.

## The Journey towards Harmonious Sensation

A fundamental aspect of philosophy is that it allows people the opportunity to obtain enlightenment. The reason philosophy ought to do this is that it offers one the possibility to establish a systematic body of knowledge in response to the feeling of alienation; that is, a feeling of detachment while living and of not understanding the reason to live. Hence, if philosophers become more involved with the public, and vice versa, then the public will have a better opportunity to begin a journey towards living without dwelling in alienation. I emphasize philosophy as a device for the public to lift itself from a life of alienation because it offers a holistic and interdisciplinary appreciation for knowledge that helps deepen the understanding of life through reflection and critical thinking. With this quality of reflection and critical thinking that philosophy offers, the possibility for people to venture into the process that Hegel refers to as experience becomes viable.

In particular, in *Phenomenology of Spirit*, Hegel provides a compelling way of thinking about reality in terms of essence and existence through the process of experience. According to Hegel, experience is a "dialectical movement

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which consciousness exercises on itself and which affects both its knowledge and its object” (55). Simply put, Hegel views a person’s process of experience as an expectation of how reality functions, a test of that expectation, the determinate negation of that expectation by reality, and a revision by consciousness to accommodate what reality determinately negated. People perform this experience simply by living. With that said, I argue that the “simply living” aspect of experience is actually the dynamic between Marcuse’s principle of play and Bourne’s principle of struggle. I will elaborate on these principles in the subsequent paragraphs. Still, to say that someone is simply living the process of experience indicates a failure to see that living consists of emotions. Ultimately, in the process of experience there will be no determinate negation of one’s expectations on how reality functions. To be clear, determinate negation occurs when a particular aspect of the expectation is rejected as false, not the entire expectation. Then, one can say he or she has arrived at an unconditionally truthful viewpoint about an aspect of life.

As I said before, I have the understanding that the method of going through experience as simply living actually consists of the principles of play and struggle. These two principles complicate the process of experience because people’s unfamiliarity with conceptualizing the dynamic between play and struggle often causes mental pandemonium. Nevertheless, I believe this to be a crucial dynamic in the process of experience. Consequently, I will begin to articulate the dynamic between play and struggle by first explaining what play is and then what struggle is.

One emotional aspect of play that I identify in the process of experience is what Marcuse, a prominent thinker for human progress, calls *play*. With a Freudian perspective, Marcuse analyzes society in his book *Eros and Civilization*. He acknowledges an oppressive society that forces the public to repress its true ambitions, that is, ambitions that one would pursue without repression. This repression arises out of the original, legitimate need for an economic system to sustain humanity. Hence, initially it is

understandable that people repress their true ambitions to work for food and shelter as members of society. Marcuse accepted this as the *reality principle*. Specifically, he states, “[b]ecause of the lasting gain through renunciation and restraint, according to Freud, the reality principle ‘safeguards’ rather than ‘dethrones,’ ‘modifies’ rather than denies, [true ambitions]” (13). Once society has obtained this initial system, the repression of people’s ambitions becomes unnecessary. However, those in advantageous positions implement repressive socioeconomic policies—what Marcuse calls “surplus-repression”—to maintain the need for the repressive system for their socioeconomic benefit. Thus, oppression in society is now illegitimate and demolishes people’s ability to play.

Without repression, people would be able to see that play is a holistic appreciation for discovering knowledge about reality. In other words, play is the deepest involvement with one’s deepest ambitions. Therefore, play describes ideas that have been indescribable given oppression in society. Play consists of imagining the world without repressed sensation. Marcuse states, “[p]lay... [as one principle] of civilization, [implies] not the transformation of labor but its complete subordination to the freely evolving potentialities of man and nature” (195). This is the beautiful aspect of experience; play is how humanity enthusiastically attempts to synthesize the meaning of life from an experimental perspective. In this sense, life is a hypothesis. People are always creating expectations about how reality functions through creativity.

Alternatively, life becomes periodically depressing because experience is also a *struggle*. Bourne, a prominent American thinker, describes *struggle* as the more daunting aspect of experience. In particular, this aspect of experience encompasses internal and external struggles for identity (8). In this sense, identity refers to the ability to withstand the constant scrutiny of being determinately negated by reality and coming to terms with this realization. Specifically, under oppression, few understand their identity outside of social roles. However, the process

of experience forces people to question their social roles and motives for living. This aspect of experience is the epitome of a serious attitude. If people take the discovery of purposefulness for granted, they will quickly realize how fast another will decide their purpose for them. Many people fear the seriousness of life, and if there are no obvious alternatives to experience besides some form of submissiveness—and there are not—life could become unbearable. Their fear arises out of the realization that life necessarily includes struggle for comforting comprehension.

Furthermore, when Hegel demonstrates how consciousness actually goes through the process of experience to find unconditional truth about reality in his *Phenomenology of Spirit*, he reveals an understanding of reality that he calls *absolute knowing*. Absolute knowing is the understanding of the fundamental structure of reality: for something to be itself, which is subjectivity, then it has to become other than itself, which is objectivity (14). In a social sense, for people to be individuals they have to recognize the public and recognize that they are the public. Likewise, for the public to be “the public” it has to recognize individuals and that individuals make up what it is. Within this social form of absolute knowing, there is no room for individual fundamentalism or public fundamentalism. There is only what Hegel calls the constant reciprocal recognition between the two entities. It is important to note that Hegel saw the concept of absolute knowing as only understanding the fundamental structure of reality, not every aspect of reality. Understanding various aspects of reality as a form of absolute knowing is the task of the people. Thus, from this point on I refer to experience as a process by which understanding an aspect of reality implies striving for a form of absolute knowing.

When one subsequently goes through experience and arrives at an aspect of reality that is a form of absolute knowing, then one is living the phenomenon of enlightenment. From this perspective, one has to view

the accomplishment of reaching enlightenment as a part of a process and not as a decisive moment. This notion of enlightenment carries the understanding that no one is born with such intuition that allows one to spontaneously obtain enlightenment. Still, just because enlightenment is a part of an emotional straining process does not mean that people should dismiss it as unreachable. Rather, in regards to enlightenment alone, Immanuel Kant has an influential perspective on the power of enlightenment. In *An Answer to a Question: What is Enlightenment?*, Kant says, “[h]ave courage to use your own understanding” (54). There should be minimal timid behavior in striving to obtain enlightenment on the behalf of people. When one obtains a new thought or idea, one should not hesitate to share it when appropriate. For this reason, tradition and dogma should not hinder people’s ability to strive for enlightenment because the characteristics of tradition and dogma serve only those who are in dominating positions most of the time (55). Thus, an enlightened society involves people using reason to negate ideas that were once sensible but are now fruitless. The point is that people should attempt to create a world that makes more sense to them. Through sharing thoughts and ideas people create and sustain a dialogue about the possibilities in the universe.

As more people become enlightened through experience and discover various forms of absolute knowing in life, finally a sense of genuine purposefulness arises. What makes this sense of purposefulness different from many other understandings is that it embodies the understanding that one’s essence and one’s existence is a holistic phenomenon. This caliber of purposefulness concerns one’s life in its entirety, including the necessary bond between self and others. Martin Luther King Jr. describes this sense of purposefulness best when addressing the problem of children and adequate education: “For you will never be what you ought to be until they are what they ought to be” (King). The reason one’s sense of purposefulness necessarily relates to others is that one

cannot be an individual without embracing the public and vice versa, which is the fundamental structure of reality referred to as absolute knowing. On the other hand, if people take the meaning of purposefulness for granted, they present the possibility for others to exploit their meaning of purpose in life. A life without acknowledged purposefulness, or purpose that derives from one's own comprehension in conjunction with recognizing others, is a life of alienation.

In the end, the accumulation of the sense of genuine purposefulness that derives from enlightenment as part of the process of experience leads to harmonious sensation. From this standpoint, harmony refers to spiritual and worldly unity. However, harmonious sensation is only a possibility and is never a given. The degree to which one can access harmonious sensation depends on how well one can conceptually graph one's understanding of purposefulness in life. In other words one must take up philosophy because it allows one to become more critical of life and interdisciplinary in studying life. This ought to enable the process of experience if one is willing to accept this process, which leads to understanding through a dialectical process in a Hegelian sense. In addition, I identify and argue that experience consists of at least two notions of living, which are Marcuse's *play* and Bourne's *struggle*. With this understanding, experience offers the possibility for one to obtain enlightenment upon beginning to learn through experience and arrive at unconditionally truthful viewpoints about life. The more enlightened one becomes, the more one begins to understand his or her purpose in life. This sense of purposefulness necessarily embodies one's relationship with one's self and one's relation with others.

How well one conceptually grasps purposefulness in life is how well one can experience harmonious sensation. This is what I refer to as the "good life." It is a complex and vigorous way of life that may seem chaotic. In one sense, the good life is a complex system because of the tedious

and frustrating process of experience. In another sense, the good life is chaotic because of the particular dynamic between the principles of play and struggle in the process of experience. With all that said, what makes the good life "good" is that it is an alternative to a life soaked in the feeling of alienation, which is something most humans can relate to and would rather live without.

### **Philosophy of Education**

How can people capitalize on taking up philosophy to conceptually grasp the process of experience and enlightenment to better understand their purposefulness and ultimately live life with harmonious sensation? For this pursuit, people need to actualize the good life physically in order to understand it conceptually. Thus, allowing philosophy to become public yet intimate is significant. The system that makes knowledge most accessible to the process of experience for the public is education. The necessary role of philosophy in education is to provide the framework for school curricula that acclimate students towards understanding the good life system. This requires a partial divergence from existing curricula. Rather than focusing primarily on subject classes, such as math and English, students should also focus on content-based classes that explore and experiment using a theme as non-suffocating guidance. Acquiring basic knowledge is not adequate for attaining harmonious sensation.

If teachers take experience seriously, then they should welcome the dynamic between play and struggle. Students should question why it is important to live in order to encourage thoughtfulness about the importance of purposefulness. To this end, in content-based classes, students and teachers would attempt to discover their identity from various thematic scenarios, such as romanticism, poverty, and space exploration. They could give any type of creative assignments to express their comprehension of a scenario. Going through such thematic scenarios allows participants to think

beyond social roles. That allows students themselves to examine purposefulness from a different perspective. To be clear, social roles are not entirely irrelevant. I am saying that a focus on social roles should not reduce the conceptualization of purposefulness.

Concurrently, students should learn how to embrace play and struggle to become more acquainted with their capacity to discover purposefulness and ultimately harmonious sensation. Dedicating time to one's deeper ambitions, to what one would do without social oppression, is a task that students and teachers must face. Of course, this is not the same as advocating for some form of individualist fundamentalism because one is always striving to recognize the necessary respectful reciprocal relationship between an individual and the public. Thus, the content-based classes that focus on play and struggle permit students to create ideas and objects that relate to the content. Such creations should arise from individual and group work. Students need to learn how to discover knowledge that may contribute to the discussion of what is possible in this universe.

### **Education Today: Free Market Ideology**

While in public school, I never had a philosophy class. There were no assignments concerned with the process of experience as discovering new ideas and purposefulness through critical and artistic thinking. When I attended my first high school, which is socioeconomically poor, I saw many peers who had conflicting passions about school. The school taught mundane knowledge: teachers prepared students for standardized testing. However, when I transferred to a wealthier high school, I quickly realized that it had the same methods as my previous school, but the school expected students to become the managers of the world. In hindsight, famous American intellectual Noam Chomsky's argument that free market propaganda dominates public schools to train students for wage-slavery seems accurate (165).

The type of education I had was a form of *nationalistic free market education*, an education dominated by free market ideology. Knowingly or not, many teachers educate students to become accustomed to a free market worldview. Hence, it does not surprise me that the discourse about American education, especially public schools, is leaning towards a vision where schools teach students to have a "free market oriented" life. In *The Gift of Education: Public Education and Venture Philanthropy*, Kenneth J. Saltman argues that "in the United States, public education has become increasingly privatized and subject to calls for further privatization" (17). That said, the intention of shaping students to become seasoned consumers and workers helps explain the lack of time my peers and I spent questioning purposefulness in public school.

Furthermore, educators shaping students to become seasoned consumers and workers creates a cruel dynamic that enhances a competitive nature that free market fundamentalists assume is natural. Many teachers, consciously or not, implement discipline techniques that require students to conform to curricula or face repercussions. Classroom management is one aspect of this oppressive dynamic. For instance, Henry A. Giroux and Saltman explain that, "many youth of color in urban school systems, because of harsh zero-tolerance policies, are not just being suspended or expelled from school. They are being ushered into the dark precincts of juvenile detention centers, adult courts, and prison" (Saltman 150). Fear of punishment is a reality that many public school students acknowledge. This oppressive dynamic traps students' deeper ambitions through fearful anxiety.

The other dimension of this oppressive dynamic is that teachers reward students who do assimilate to the oppressive curricula. Most obedient students receive recognition that feels and looks more appealing than the harsh punishment that nonconforming students experience. The most obvious rewards that conforming

students receive are good grades and recommendations, which offer better socioeconomic opportunities. Consequently, a major implication of students receiving substituted rewards rather than pursuing deeper ambitions is that they lose the chance to question purposefulness.

### **The Future of Philosophy and Education**

Philosophy's necessary role in education is, therefore, to bring a holistic appreciation for knowledge in order to give students the possibility to grasp the good life system, along with each of its components, conceptually. By approaching knowledge as a philosophical inquiry, people will have the opportunity to begin welcoming the journey of experience and ability to comprehend purposefulness in order to obtain harmonious sensation, which is the good

life. This stands in contrast to the reward and punishment dynamic in current education curricula. Indeed, free market discourse ties purpose to exploitation. Hence, there ought to be more discourse about purposefulness. Furthermore, the implication of understanding philosophy as dedicated to harmonious sensation and living is that it encourages research about the power of philosophy of education, in and outside of classrooms. Possible future research projects concerning philosophy and education should take a more explicit look at how to shape curricula to eliminate oppressive elements. Philosophy needs to be at the heart of any educational proposal for transformation because it offers the holistic inquiry needed to think about ideologies rather than to think simply with an ideology.

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# FROM NATIONAL HERO TO FLAWED CELEBRITY: HOW THE MASS MEDIA ERODED JACQUELINE KENNEDY ONASSIS' SYMBOLIC FUNCTION IN AMERICAN CULTURE

Megan Ashley\*

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**ABSTRACT** Jacqueline Kennedy Onassis was a hero to the American public during her time as first lady. However, upon marrying Aristotle Onassis in 1968, Jacqueline transitioned from a “hero” to a “celebrity” at the hands of the media. Through its coverage of the nuptials, the press manipulated Jacqueline’s symbolic function and questioned the ways in which she represented the nation. Media and discursive analyses of Jacqueline’s second marriage offer insight into the media’s longstanding relationship with the executive office.

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## Introduction

*McCall's* referred to her as “a living legend in her own time.”<sup>1</sup> *The Ladies' Home Journal* once said she was “the most-famous, most-photographed and, according to Gallup polls, most-admired woman in the world.”<sup>2</sup> Jacqueline Kennedy Onassis had a long-standing relationship with the mass media, often to her dismay. As a private person, Jacqueline did not care for the “Jackie-watchers,” a term *Newsweek* once used to refer to the fans, photographers, and reporters who seemed to follow the woman’s every move.<sup>3</sup> She never managed to escape this public attention, as the press’ love affair with Jacqueline lasted until her death in 1994.

During her term as first lady, Jacqueline Kennedy became an American hero.<sup>4</sup> She was born Jacqueline Lee Bouvier

in 1929, and on September 12, 1953, she married John Fitzgerald Kennedy—the junior senator from Massachusetts. Once John F. Kennedy was elected to the presidency in 1960, Jacqueline assumed a persona of mythical proportions for the American public. During her thousand-day reign,<sup>5</sup> the first lady was idolized for everything from her fashion sense to her political interests, her upper class airs to her diplomatic abilities, and of course, for her perfectly placed bouffant. Jacqueline’s public responsibility grew exponentially after her husband was assassinated in 1963. For comfort, the nation looked to its leading lady, then only 34 years old. Many grieved according to her example, leaning on the woman who, despite her own grief and trauma, shouldered the nation’s heartache.<sup>6</sup>

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1 Liz Smith, “Jacqueline Kennedy Onassis’ Stepchildren,” *McCall's*, April 1969, 80.

2 G. Cameron, “Caroline and John F. Kennedy: The Happy Years are Now,” *The Ladies' Home Journal*, June 1968, 54.

3 “Eye spy,” *Newsweek*, March 4, 1968, 23.

4 My subject’s full name is Jacqueline Lee Bouvier Kennedy Onassis. ‘Lee’ is her middle name, ‘Bouvier’ is her maiden name, ‘Kennedy’ is a result of her first marriage, and ‘Onassis’ is a result of her second. Throughout the paper I will refer to her in accordance with the period

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being discussed. That is, she will be ‘Jacqueline Bouvier’ prior to her first marriage, ‘Jacqueline Kennedy’ prior to her second marriage, and ‘Jacqueline Kennedy Onassis’ or simply ‘Jacqueline Onassis’ after her second marriage takes place. When appropriate, she may also be referred to as simply ‘Jacqueline.’

5 “John F. Kennedy,” *The White House*, 2010, <http://www.whitehouse.gov/about/presidents/johnfkennedy> (accessed October 28, 2010). John F. Kennedy’s term in the White House lasted just over one thousand days—specifically 1,036 days.

6 “The New First Lady of Skorpios,” *Newsweek*, October 28, 1968, 38.

In 1963, the American public assigned Jacqueline Kennedy a kind of “heroic symbolism” that was expected to remain intact forever.<sup>7</sup> To help us understand the significance of what it means to be ascribed as a “hero” we might turn to communication theorist Gary Gumpert who argues that heroes “are generally vivid two-dimensional figures whose persona and portraits appear to have been painted with broad bold strokes. They are figures whose deeds inspire, awe, and overshadow the simple ordinary human folk.”<sup>8</sup> Likewise, sociologist Orrin E. Klapp identifies a link between the hero and heroic symbolism, arguing that “the hero is properly conceived as a symbol rather than a real person.”<sup>9</sup> Even beyond being first lady of the United States, Jacqueline herself was symbolic of the nation writ large, and the media’s pervasive and constant coverage of her husband’s assassination reinforced this. Circulating imagery—such as photos of Jacqueline kneeling before her late husband’s flag-covered casket and later clutching that same American flag, now folded-up, after services at Arlington—cemented her status as an American hero, complete with a persona that was “two-dimensional” and “painted with broad strokes.”<sup>10</sup>

The American public harbored this image—and consequently, this symbol—until Jacqueline’s engagement to Aristotle Onassis was announced mid-1968. Jacqueline’s heroic symbolism had remained for nearly five years before the mass media waged its war. Through its coverage of her engagement and marriage, the press alleged that in marrying Aristotle Onassis, Jacqueline was in fact rebuking the United States. Creating such conflict fostered public interest and ultimately sold newspapers and magazines. But perhaps more importantly, in stripping

Jacqueline of her function as a symbol for the nation, the press transitioned her from an American hero into the realm of a mere “celebrity.”

While those ascribed with celebrity status may be painted with just as broad a stroke as the hero, they do not have the symbolic importance afforded to those cast as heroes. Historian Daniel J. Boorstin argues that a celebrity is a person known only for his or her “well-knownness.”<sup>11</sup> According to Boorstin, the celebrity is a product of the media and “is a creature of public opinion, of magazines, newspapers, and the ephemeral images of movie and television screen.”<sup>12</sup> Furthermore, Gumpert’s “wrinkle theory” defines a key aspect of American celebrity culture. Whereas the hero is without blemish, Gumpert maintains that the media creates the celebrity out of his or her flaws, or “wrinkles”—which Americans take pleasure in finding.<sup>13</sup> In announcing her marriage to Aristotle Onassis in 1968, Jacqueline Kennedy transitioned from a blemishless hero to a flawed celebrity at the hands of the media—a demotion according to Gumpert.<sup>14</sup> The press deliberately challenged how Jacqueline functioned symbolically for the public through its critical coverage of the nuptials. Whereas a hero represents a larger symbol, standing taller than mere mortals, the celebrity is an average person who lives on through gossip and scandal, never serving a larger purpose.

The growth of the celebrity in the 1960s is linked with the growth of television. Television popularized invasive reporting techniques, leading print media to adopt similar methods. As a result, coverage of the Kennedy-Onassis marriage became laden with enough conflict and scandal

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7 Ibid.

8 Gary Gumpert, “The Wrinkle Theory: The Deconsecration of the Hero,” in *American Heroes in a Media Age*, ed. Susan J. Drucker and Robert S. Cathcart (Cresskill, NJ: Hampton Press, Inc., 1994), 48.

9 Orrin E. Klapp, “Hero Worship in America,” *American Sociological Review* 14.1 (February 1949), 61.

10 Gumpert, “The Wrinkle Theory,” 48.

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11 Daniel J. Boorstin, *The Image: A Guide to Pseudo-Events in America* (New York: Atheneum, 1982), 57.

12 Ibid., 58-63.

13 Gumpert, “The Wrinkle Theory,” 59. Gumpert argues that “the revelation of the wrinkle” is the new national pastime.

14 Gumpert, “The Wrinkle Theory,” 48.

to dethrone a hero.<sup>15</sup> Such an intimacy with “Jackie”<sup>16</sup> simply eroded her nobility.<sup>17</sup> Her flaws were highlighted, her private life was revealed, and controversy was created. Jacqueline joined the ranks of other celebrities most famous for their social lives, a group that included Marilyn Monroe, Natalie Wood, and Elizabeth Taylor. The media’s motives were relatively transparent, yet the public responded with enough vigor that the press justified continuing its attack for over a year. As such, this study ultimately addresses more than how the media demoted someone from hero status. It tells us something larger about American culture itself in 1968.

Scholars of all fields point to 1968 as a historical turning point,<sup>18</sup> ushering the American public into a newfound awareness and activism. To be sure, in focusing on press coverage of Jacqueline Kennedy’s engagement and marriage to Aristotle Onassis in 1968, this essay addresses an episode that is not typically included in the laundry list of foundation-changing 1968 events. But while the Kennedy-Onassis nuptials may not carry the same historical significance as the 1968 Democratic National Convention, the media did give the marriage a substantial amount of attention—so much, in fact, that its coverage

spans over a year. Understanding the media’s resistance to the marriage could influence the way historians interpret the more reactionary events of 1968. The fact that the press was eager to attack a symbol of the nation in 1968 may point to a larger crisis of national identity within the mainstream media and its supporters—those that subscribed to the dominant ideology of the period.

In studying Jacqueline Kennedy Onassis’ mediated shift from hero to celebrity, I have performed a media and discursive analysis of late 1960s press coverage of her second marriage. I have examined roughly seventy articles in a sampling that ranges from 1968 to 1969. The articles cover a wide range of topics, including the speculation of the relationship, the wedding ceremony, the honeymoon, the fifth anniversary of John F. Kennedy’s assassination, and the new couple’s first wedding anniversary.

The press does not explicitly name Jacqueline as a symbol for the nation. Rather, in studying how it repositioned Jacqueline Kennedy Onassis from American hero to American celebrity, I have identified this transition. Ultimately, I argue that the media eroded Jacqueline’s symbolic function in its 1968–1969 coverage by waging war and this particular symbol was simply the target of that war.

### From National Hero to Flawed Celebrity

The president “stands for the nation, he acts for ‘the people,’ he serves as an access point for emerging interests, and he safeguards the national or general interest.”<sup>19</sup> As the president’s wife, the first lady also occupies “one of the most watched and evaluated positions associated with the American presidency.”<sup>20</sup> When Jacqueline Kennedy was first lady, the position became unprecedentedly royal. For example, *Newsweek* described her as having “reigned

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15 See *Ibid.*, 57. Gumpert argues that “radio, television, motion pictures, and the print media of books, magazines, and newspapers are interconnected in terms of subject matter, content, and treatment. The content featured in one medium often is adapted to the technical and social needs of another.”

16 The press often refers to Jacqueline Kennedy Onassis as “Jackie in 1968-69 coverage, regardless of the article’s content. The nickname is one that Onassis admittedly disliked—as reported by the press, no less—and yet its use conveys a familiarity with the woman. Such a familiarity only serves to further erode Jacqueline’s mythic, hero-forming qualities. For an example, see “Onassis Divorce Stirs Questions of Church Law,” *Chicago Tribune*, October 19, 1968, A1. For the article that claims Jacqueline does not like her nickname, see Gwen Morgan, “Orthodox Rites Set for Jackie; Date Indefinite,” *Chicago Tribune*, October 19, 1968.

17 Gumpert, “The Wrinkle Theory,” 56.

18 See Jules Witcover, *The Year the Dream Died: Revisiting 1968 in America* (New York: Warner Books, 1997); Charles Kaiser, *1968 in America: Music, Politics, Chaos, Counterculture, and the Shaping of a Generation* (New York: Grove Press, 1997); Robert Giles and Robert W. Snyder, eds., *1968: Year of Media Decision* (New Brunswick: Transaction Publishers, 2001); Susan Douglas, *Where the Girls Are: Growing Up Female with the Mass Media* (New York: Times Books, 1994).

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19 Kathy B. Smith, “The Representative Role of the President,” *Presidential Studies Quarterly* 11.2 (Spring 1981): 207.

20 Lewis L. Gould, “Modern First Ladies: An Institutional Perspective,” in *Modern First Ladies: Their Documentary Legacy*, eds. Nancy Kegan Smith and Mary C. Ryan (Washington D. C.: National Archives and Records Administration, 1989), 3.

over the American republic as its uncrowned queen.”<sup>21</sup> Drawing on a metaphor that Jacqueline herself employed, many in the press glamorized her symbolic function by referring to the Kennedy years as an American Camelot—a time of prosperity and promise with the bodies of the royal couple (John F. Kennedy and Jacqueline Kennedy) symbolically representing the national body.<sup>22</sup> By the end of the 1960s, however, the press discredited Jacqueline as a national symbol. While a *Time* article titled “From Camelot to Elysium (Via Olympic Airways)” demanded that Jacqueline “abdicate the throne that Americans had made for her,”<sup>23</sup> *Life* presumed that in marrying the Greek magnate, she was “bid[ding] goodbye to Camelot.”<sup>24</sup>

To undermine Jacqueline’s hero status, the press actively provided “evidence” that she was no longer a worthy symbol of the nation; after all, they claimed, she was forsaking both her citizenly duties and the American government’s protection. *The Chicago Tribune* reported that Jacqueline had cast an absentee ballot in the 1968 presidential election, and disputed her legal name, an act that evoked the larger symbolic erosion at hand: “She voted under the name of Jacqueline Kennedy, but to vote after this year she must register under her [new] name.”<sup>25</sup> With regards to American politics, *Time* suggested that “Jackie obviously opted out of U.S. politics by her marriage to Onassis.”<sup>26</sup> Likewise, *U.S. News & World* called her tax status into question after marrying a “resident alien.”<sup>27</sup> Voting

and paying taxes are two of the most “American” acts, and yet, the press revealed that Jacqueline Onassis did not satisfactorily perform either after her second marriage. In keeping with the narrative, the media also suggested that Jacqueline refused the country’s protection upon remarrying. She quit accepting her presidential widow’s pension and the media reported dissonance over her Secret Service detail.<sup>28</sup> For example, the *Chicago Tribune* reported that one of Jacqueline’s Secret Service men wore Kennedy memorabilia in Greece at the wedding.<sup>29</sup> Here, the security detail seemingly showed more respect to John F. Kennedy than his widow. By providing multiple examples of how Jacqueline was “less American” than she was in 1963, the media suggested that she was no longer worthy of being an American hero; she was cutting ties with the United States and slipping away from the country’s grasp.

Another blow to Jacqueline Kennedy’s symbolic function as an American hero came when the Soviet media defended her second marriage. *The Chicago Tribune* quoted the Soviet journal *New Times*, which defended Jacqueline’s reputation, claiming that she had married Aristotle Onassis to escape “the merciless surroundings of the notorious American way of life...to begin another life in another country among other people.”<sup>30</sup> During the Cold War, the Soviet Union was the United States’ primary enemy. Having the Soviets defend Jacqueline’s actions suggested that she, too, was now an enemy of the United States. Of course, the American press dismissed the Soviet Union’s “Marxist-Leninist view of her [Jacqueline’s] reasons,” but the anti-American sentiment lingered over her already damaged symbol nonetheless.<sup>31</sup>

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21 “The New First Lady of Skorpis,” *Newsweek*, October 28, 1968, 38.

22 Ed. Philip B. Kunhardt Jr., *Life in Camelot: The Kennedy Years* (Boston: Little, Brown, and Company: 1988), 14. The term ‘Camelot’ technically references the Arthurian legend but is often synonymous with the Kennedy presidency. Jacqueline Kennedy herself referenced a song from a musical of the same title: “Don’t let it be forgot / That once there was a spot / For one brief shining moment that / was known as Camelot.”

23 “From Camelot to Elysium (Via Olympic Airways),” *Time*, October 25, 1968, text available online.

24 Paul O’Neil, “For the Beautiful Queen Jacqueline, Goodbye Camelot, Hello Skorpis,” *Life* 65:18 (November 1, 1968): 18.

25 “Jackie Casts Hyannis Port Absentee Vote,” *Chicago Tribune*, August 22, 1969, 3.

26 “People: Nov. 1, 1968,” *Time*, November 1, 1968, text available online.

27 “Complicated Tax Status of Mr. and Mrs. Aristotle Onassis,” *U.S. News & World*, November 11, 1968, 97.

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28 “Jackie Solves Pension Issue,” *Chicago Tribune*, January 9, 1969, W9.

29 Gwen Morgan, “Jackie’s Wed; Wine Flows,” *Chicago Tribune*, October 21, 1968, 1. The exact line is “one of the Secret Service men in Greece at the wedding wore a Kennedy P.T. boat pin.”

30 “Jackie Wed Onassis to Flee U.S.:Russ,” *Chicago Tribune*, October 26, 1968, 5.

31 *Ibid.*

Every mention of Jacqueline’s newly acquired “jet set” status contradicted the idea that she symbolized America.<sup>32</sup> She had access to homes in six cities and Onassis’ monstrous yacht, Christina—itsself the subject of several articles.<sup>33</sup> Mention of the newlyweds “island-hopping” in the Caribbean contributed to the media’s narrative that Jacqueline had outgrown America.<sup>34</sup> *Good Housekeeping* echoed the sentiment: “She [Jacqueline] will be one of the most dominant figures, if not the most dominant figure, in international society.”<sup>35</sup> Reports of Jacqueline Onassis embracing Greece and its culture suggested that she was perhaps more suited for international life. Jacqueline was speaking Greek, shopping in Athens, and “baptized into Athenian night life” on her birthday.<sup>36</sup> Finally, *Newsweek* openly claimed that Jacqueline Onassis had moved up and away from her native land and her first husband:

Once she had been the wife of the most powerful man in the world; now she was the wife of the richest (between \$500 million and \$1 billion). Once she had been the mistress of the White House; now she was mistress of Skorpios and homes in Athens, Paris, Buenos Aires, Montevideo, Monte Carlo and New York.<sup>37</sup>

The comparison drawn between Jacqueline’s late husband and her new—and even richer—one is significant. Historian John Hellmann argues that “Americans saw the ideals of American mythology” incarnated in John F. Kennedy.<sup>38</sup>

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32 “Jacqueline and Aristotle,” *Life* 66 (January 10, 1969): 75. One example of Jacqueline actually referred to as part of the “jet set” community.

The term, “jet set,” refers to someone who is wealthy and travels internationally for pleasure.

33 See “Onassis Floating Country,” *Vogue*, December 1968, 229; “Christina—Jackie’s New Floating Home,” *Chicago Tribune*, October 24, 1968, B1.

34 Aileen Mehle, “Suzy Says: Island Hoppers,” *Chicago Tribune*, March 18, 1969, B3.

35 “Caroline Kennedy: A Little Girl in New Turmoil,” *Good Housekeeping*, January 1969, 67.

36 “40th Birthday Fete,” *Chicago Tribune*, August 2, 1969, W5.

37 “The New First Lady of Skorpios,” *Newsweek*, October 28, 1968, 39.

38 John Hellmann, *The Kennedy Obsession: The American Myth of JFK* (New York: Columbia University Press, 1997), ix.

The press actively contrasted Aristotle Onassis with the late president in an effort to show a new, less American Jacqueline. *Time* questioned the morality of Onassis’ business by comparing his career to that of the late president: “Aristotle Onassis seemed to be on the verge of becoming the public partner of a regime that does not exactly mirror the ideals of his wife’s first husband.”<sup>39</sup> *Life* compared the men without specifically naming Kennedy: “He [Onassis] is not a philanthropic, socially rich man; he is a self-centered, Onassis-conscious rich man.”<sup>40</sup> Visual imagery was also important here as the two men differed greatly in terms of stature, age, and appearance. While Kennedy was popularly remembered as tall, tan, and the youngest president ever elected to office<sup>41</sup> Onassis was described as a “short, swarthy man of 62”<sup>42</sup> and visual images circulating at the time reinforced this negative impression. Ultimately, the negative press copy focusing on Onassis, coupled with reports of a “less American” Jacqueline, supported the media’s end goal. In stripping Jacqueline of her symbolic function as a representative of the nation, the media destroyed her status as an American hero. At that same time, they had effectively created “Jackie” as their newest celebrity, worthy of gossip-columns perhaps, but unworthy of hard news headlines.

## Conclusion

Media studies expert Geoffrey Baym argues that the media’s disenchantment with the presidential institution does not reveal itself until President Bill Clinton’s impeachment in 1998.<sup>43</sup> While the media still protected the presidential institution in 1968, the Kennedy-Onassis marriage hints at

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39 “People: Nov. 1, 1968,” *Time*, November 1, 1968, text available online.

40 Paul O’Neil, “For the Beautiful Queen Jacqueline, Goodby Camelot, Hello Skorpios,” *Life* 65.18 (November 1, 1968): 20.

41 “John F. Kennedy,” The White House, 2010, [whitehouse.gov/about/presidents/johnfkennedy](http://whitehouse.gov/about/presidents/johnfkennedy) (accessed October 28, 2010).

42 Aileen Mehle, “Suzy Says: Proposed in May,” *Chicago Tribune*, October 18, 1968, 1.

43 Geoffrey Baym, *From Cronkite to Colbert: The Evolution of Broadcast News* (Boulder: Paradigm Publishers, 2010), 25–42. Baym analyzes broadcast news coverage and finds that the mass media does not ‘narrativize’ the presidency until Clinton’s transgressions. He argues that the press is still respectful of the presidential institution during its coverage of Watergate in the 1970s.

the beginning of public disenchantment with the executive office *vis a vis* their disenchantment with the first lady of the mythical “Camelot” administration. As the twentieth century wore on, the press increasingly treated first ladies and presidents more as gossip-worthy, flawed celebrities than as praise-worthy heroes, often by focusing on details from these individuals’ private lives—from Betty Ford’s alcoholism to Michelle Obama’s lavish vacations. In this manner, press coverage of Jacqueline’s second marriage can be understood as a precursor to the media’s coverage of Watergate and subsequent presidential transgressions. An analysis of the 1968 coverage shows the media reaching backward *and* forward in journalistic methodology. Traces of both yellow journalism (the sensationalized news most often associated with the early twentieth century) and infotainment (the “corporate-produced entertainment masquerading as worthwhile information” that dominates today’s television) are evident in the media’s attitude towards the presidential institution.<sup>44</sup> Whether intended or not, the mass media’s attack on Jacqueline in the late 1960s laid the foundation for today’s political climate, where politicians are in fact the biggest mediated celebrities of all.

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<sup>44</sup> *Ibid.*, 3.

# GREEN CITY ON A BLUE LAKE: RE-IMAGINING CLEVELAND

Adrian Vincent Marti\*

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**ABSTRACT** Cleveland's local economy is currently repositioning itself as its competitive advantage of industrial manufacturing has been lost to foreign competition. City leaders and community activists have focused on creating a green, sustainable city by developing a new economy based on green industries such as urban agriculture, fuel cells, and wind power generation, and manufacturing. One component of this restructuring has been the growth of the local food movement. Recently, the city of Cleveland ranked first in the "Access to Local Food" category of a list created by a leading sustainability group. This ranking creates a powerful symbol of Cleveland in terms of how cities vie to lead the pack in quality of life measurements and their ability to stay visible within the fast growing industry of city rankings. This paper studies the development and structure of Cleveland's local food movement in order to explain how this ranking was achieved. Does it represent Cleveland's re-imagining within the intense competition by cities to attract labor and capital, or a populist, ground up movement to develop the local economy based on local food?

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## Introduction

Cleveland, Ohio was recently named a leader in access to local food and urban agriculture by [sustainlane.com](http://sustainlane.com), a website dedicated to urban sustainability. City rankings have become an increasingly important industry with the emergence of neoliberalism, an economic ideology that emphasizes privatization and a market driven approach to social policy. Neoliberalism has deeply influenced city governments and civic groups in Cleveland and across the country that are eager to compete for investment from highly mobile capital (Harvey, 1989). This has driven city governments to reposition themselves away from providing services and social welfare toward designing economic development policy using traits once only seen in the private sector, such as risk taking, inventiveness, promotion, and profit motivation (Hall & Hubbard, 1996). This modern development has led to the theory of the Entrepreneurial City. Appearing at the top of rankings lists, especially ones ranking quality of life issues, has important implications in the modern economic

environment of urban competitiveness (McCann, 2004). Key to the city's high ranking is a local coalition of non-profits, local universities, community development organizations, and policy initiatives by members of Cleveland's city government. Their initiatives all seek to develop a new, green economy that would represent Cleveland not as the industrial, polluted, rust belt city, but as the Green City on a Blue Lake (GCBL, 2010).

This paper will explore the forces that have motivated both communities within Cleveland and the Cleveland city government to create policies focused on urban sustainability by supporting the emerging and rapidly expanding local food movement. Using the theory of the Entrepreneurial City, I analyze the structure of the local food movement in Cleveland. I will try to evaluate whether or not these initiatives represent an attempt by city economic and political leaders to attract the workers and corporations that make up the new economy, the principle agenda of the entrepreneurial model. Or does the emergence of Cleveland's local food economy represent a challenge to neo-liberal urban policy through a grassroots

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approach to create a more equitable economic model based on sustainable development?

### **Competitive Cleveland**

With the emergence of neoliberal economic policy, Cleveland has for the most part been bypassed by investment and to date has not been terribly successful in identifying its position in the new economy. In the era of Post-Fordist urban development—characterized by the end of mass production, de-industrialization, and the export of manufacturing jobs to cheaper labor markets—Cleveland has lost many of the key comparative advantages it once held. Cleveland had a recipe for success during the American Industrial Revolution. It boasted a key location as a major Great Lakes shipping and manufacturing center. Its proximity between Detroit and Pittsburgh allowed for the development of many factories related to the auto industry and steel production.

Cleveland's development since the 1980s, which aligns with the beginning of neoliberal economic policy, shows striking similarities to the Entrepreneurial City thesis. In an effort to move beyond its industrial past and be a competitive global player, Cleveland has literally tried every trick in the urban regeneration book: from massive tax breaks to lure BP and major financial institutions to publicly funded downtown skyscrapers to a waterfront revitalization project with cultural institutions like the Rock n Roll Hall of Fame and the Great Lakes Science Center lining Lake Erie. There is a collection of sin-tax sponsored baseball, basketball, and football stadium complexes anchoring entertainment districts, and recent proposals for a new convention center, casino, and medical mart round out about every large scale planning project in the entrepreneurial city's arsenal.

These flagship developments can be the “serial reproduction of policies” (Harvey, 1989). This strategy tends to foster ‘weak competition’ and a ‘crowding’ in the marketplace that hurts most cities by creating a ‘treadmill’ effect in which every city feels external pressures on its

policies, facilities, and amenities so as to maintain its position in the competitive urban hierarchy (Harvey, 1989).

Does this new narrative of Cleveland as the Green City on a Blue Lake fit nicely as the logical next step of the Entrepreneurial City practice? The appearance of Cleveland on Sustainlane's rankings may suggest that the city's growth machine has decided to continue the “serial reproduction” of policies, one where urban sustainability adds to or perhaps even replaces the capital-intensive gleaming flagship projects of the past two decades.

This ranking is a powerful symbol used for urban representation. It promotes a quality of life that is at the heart of urban competitiveness and is the goal of economic development. Urban sustainability is an outcome of the political economy of place, which emphasizes the actions of locally-dependent factions of capital—for example rentiers (whose increased profit margins are dependent on the intensification of local land uses) and allied individuals and institutions (from the local media to developers and labor unions)—in branding cities, shaping urban landscapes, and framing urban policy in reference to inter-urban competition (Jonas & Wilson, 1999). Eugene McCann argues that these rankings and the reaction to their publication should be seen as more than entertainment. Their development and use in the policy process can be analyzed in the context of the neoliberal shift towards a view of cities as fundamentally competitive entities and consumption spaces (McCann, 2004).

Best places rankings frame the complex U.S. urban world through two related simplifications. First, they define the urban system as primarily competitive and individual cities as fundamentally and naturally competitive entities driven to vie with each other for first place. Second, the rankings focus the terms of policy debate by defining cities' success relative to high levels of attention to middle-class livability or to providing the proverbial ‘good business environment’ of low operating costs and highly skilled workers (Jessop, 1997).



Researching how Urban Sustainability policy plays out within the Entrepreneurial City, While et al. (2004) focus on efforts in the post-industrial cities of Manchester and Leeds, England. Their case studies provide many important parallels to Cleveland's experience, as these cities have made a shift towards urban sustainability and share Cleveland's industrial past. The authors state that positive urban environmental externalities or the internalization of negative externalities exert a powerful influence on urban growth policies. It would appear that urban entrepreneurialism might depend on the active remaking of urban environments and ecologies. This is especially true of the ex-industrial area most often associated with the rise of the entrepreneurial city. Claims about the transition to a post-industrial city have depended, in part, upon promoting images of the city as clean and attractive— "a place for business" yet devoid of factories (Short, 1999). Environmental policies and interventions such as river restoration, the cleaning up of old industrial sites, eco-investment in public transport, or in Cleveland's case urban agriculture, have not only been significant in re-imagining cities. They have also been important in opening up urban spaces for new waves of investment and bringing back the middle class to the city or stabilizing working-class communities (While et al., 2004).

While et al.'s research begins to define a potential paradox that forms when the Entrepreneurial City incorporates sustainability into its competitive strategy. Emphasis on higher expectations with respect to quality of life in cities, which is associated with middle-class "back to the city" movements, has meant that urban managers now face more stringent demands in terms of environmental protection and promotion of sustainable development. In other words, at least in the discursive and policy realms, the urban and environmental are being reconnected in various ways with potentially far reaching implications for our understanding of the dynamics of urban politics, whether oriented toward growth or toward redistribution (While et al., 2004). One effect of this has been the emergence of new strategic players in urban governance, such as non-profit

organizations and community and environmental groups (Krueger & Gibbs 2007).

### **Sustainable Cleveland**

Cleveland's local food movement fulfills much of the re-imagining that is needed to promote the new quality of life necessary for the competitive Entrepreneurial City. The structure and history of the local food movement make visible the paradox concerning the rising prominence of actors outside of mainstream power (While et al., 2004). An example of this process is the changing role of universities and their involvement in the "greening" of Cleveland. The region's universities have laid the foundation for the current wave of local food and urban agriculture. Cleveland's current local food movement began in 2003 when The Ohio State University Extension and Oberlin College's new Agrarian Center collaborated to develop the City Fresh Program (NAC, 2010). This program's goal is "to build a more just and sustainable local food system in Northeast Ohio" (NAC, 2010). Its business model is based on a share fund that offers subsidies to lower-income shareholders, which allows City Fresh to service "800 families per week (2008) about which 30% of which are below poverty" (NAC, 2010). The success of this program was a catalyst for the expansion of regional farmer's markets, local food use in Cleveland restaurants, and more collaborative projects between regional universities and community development organizations.

Cleveland's Entrepreneurs for Sustainability, a non-profit focused on creating green business, lead an initiative with Kent State University's Urban Design Center and the non-profit Neighborhood Progress Incorporated to develop a vacant land use study within the city to map out and develop strategies for sustainable land reuse (CUDC, 2008). The program entitled "Re-imagining a more sustainable Cleveland" was developed to actively locate vacant land and patterns of foreclosure to reuse in ways that reflect a shrinking population and a new mindset that vacant land can be an engine for social, environmental, and economic opportunity (CUDC, 2008). Using a \$25

million federal Neighborhood Stabilization Program grant, Cleveland initiated projects around the city based on this research. \$450,000 of this grant will be awarded to 58 projects focused on urban agriculture and phytoremediation projects that use plants to pull toxins from brown fields throughout the city (GCBL, 2010).

This project has moved forward in concert with a movement to enact city ordinances that provide more leverage for local food distributors. Council member Joe Cimperman of the Detroit Shoreway neighborhood, a district with a high percentage of vacant land on Cleveland's west side, has introduced legislation giving local food businesses a 5% discount on bids for city contracts, has created an urban garden zoning law, and has established a law allowing the development of food stands in front of neighborhood homes (GCBL Food, 2010). The expansion of food policy in Cleveland is led by the Cleveland-Cuyahoga County Food Policy Coalition, a project of Case Western Reserve University, The Ohio State University Extension, Oberlin College, and the Cleveland Department of Public Health. The culmination of Cleveland city government's support for urban sustainability policy came last year as the city organized its Sustainability Cleveland Summit 2019, a ten-year initiative to become a leader in the emerging green economy, with 2012 being specifically focused on local food.

Could food policy be an opportunity to create socially just sustainability in the Entrepreneurial City? Research on

Vancouver's scaling of food policy to the municipal level has identified where and when concepts and practices of environmental and social justice enter into mainstream politics (Krueger & Gibbs, 2007). The city council's enactment of the Action Plan for creating a just and sustainable food system for the City of Vancouver brought concerns from city council members about the perceived appropriateness of such a policy in a city committed to competitiveness (Krueger & Gibbs, 2007). Similar to Cleveland's main focus of finding productive use from vacant lots throughout the city, this research concludes that "food policy was ultimately successful because it could be aligned with preexisting policy directions and organizational expertise in sustainable development and not because it was understood as a tool to address social justice concerns like hunger and food insecurity" (Krueger & Gibbs, 2007). The Vancouver research also shows that "As economic and political elites in entrepreneurial cities seek to be seen as good stewards of their environment, the urban scaling of sustainability politics becomes a necessary possibility (Krueger & Gibbs, 2007).

Cleveland's local food movement and increasing visibility in quality of life rankings may symbolize the power of local elites to reimagine Cleveland and make the city a destination for mobile capital, middle and upper class residents, and the creative class. This movement may also represent an opportunity to create a more democratic and just urban governance, with urban policy driven by public health and social justice.

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Ross Hoppe | *Silver Lake* | Digital Photography

# THROUGH THE DECADES: SPATIAL TRANSITIONS AND TENSIONS AT THE HALSTED-DIVISION INTERSECTION

Ana Luna\*

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**ABSTRACT** The urban fabric of Chicago has long demonstrated the changing functions of the city's land uses. Examining the intersection at Halsted and Division reveals legacies from the industrial era and public policies of the 1960s, which expose present power dynamics and tensions. Geographic assets, such as location, space, and proximity to downtown identify this particular intersection as an ideal location for future development. The uses of the intersection reveal past and present tensions and changing city priorities, specifically the changing commitments to specific demographic groups within Chicago.

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## Introduction

The intersection of Halsted and Division is at the mouth of an industrial corridor. Division runs east-west a mile north of the Loop; Halsted runs parallel to the lakeshore. Kingsbury, a diagonal street that was once a railroad, intersects Division from the north. Adjacent to the North Chicago River Branch, development trends serve as visual indicators of Chicago's evolution through the decades (Figure 1.1 and 1.2). Analyzing the intersection through a visual lens reveals a historical geography of transitions and tensions. I argue that such indications of the past allow for speculation of what is to come. Such shifts and subsequent tensions in occupying social classes are also visible at other Chicago intersections. However, the dynamic traces of the past at Halsted and Division, which stand in sharp contrast with the new real estate development of the present, make this area significant in monitoring the progression of ideas and their significant role in urban development. The combination of visual, architectural, and geographic analysis allows for an examination of the intersection, which transcends aesthetics and infrastructure, to reveal the manifestations and fluctuations of the city of Chicago's changing commitment to specific socio-economic groups.

In this way, through the decades, transitions and tensions between the material buildings and societal trends can be investigated by examining properties and landscapes at Halsted and Division. When viewing the space, I focus on three main components: the visual remnants of Chicago's industrial era in the early 1900s, traces of public policy in 1960s, and potential developments in the future.

## FIGURE 1.1

Standing on the corner of Kingsbury, looking North. Note the debris, weeds and old road blocks indicating the abandonment of the space.



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**FIGURE 1.2**

Railroad tracks on Kingsbury. Although the rail is no longer being used, the tracks remain in the middle of the intersection.



### Methodology

Data for this project were collected using Sanborn Insurance Maps, historical archives, City of Chicago Zoning Ordinances, on-site photography, and other documents. In this way, I am able to record specific details about the intersection, indicating past and present land uses. Analysis through photography exposes the “current state of the area’s transitional character against the longer historical process of transformation.”<sup>1</sup>

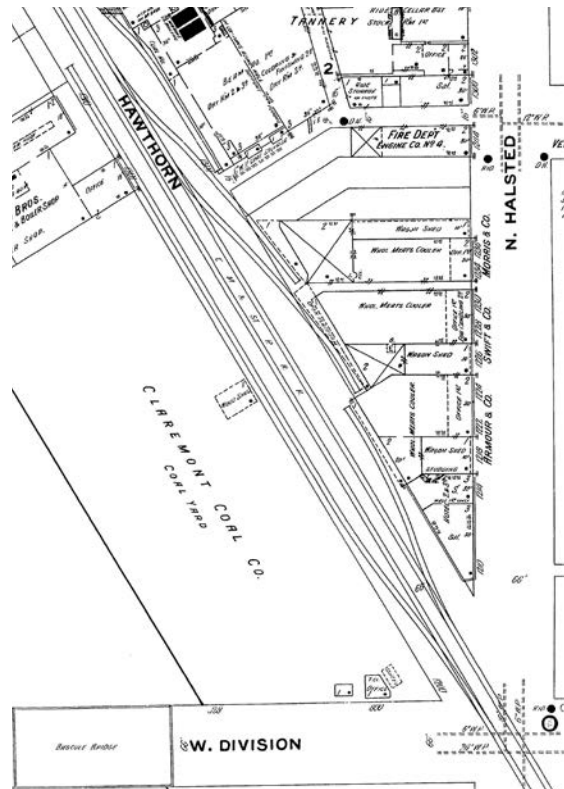
### The Industrial Era

Industrial traces in architecture and on the streets, coupled with Sanborn Insurance Maps from 1906, indicate the primacy of industry in the early 20th Century. Division goes through Goose Island, an industrial center ending just north of the Loop. Halsted runs north-south, bypassing the congested Loop, connecting to southern Chicago’s industrial zone. The intersection indicates that production was key to Chicago’s business and political community. An ideal location for manufacturing, the intersection is adjacent to the North Chicago River and has an intersecting railway. Both served to facilitate commercial shipping.<sup>2</sup> Unprecedented success of production led to the implementation of “widening and sanitary reform of industry” on Halsted, as proposed in the 1909 Burnham Plan.<sup>3</sup>

In 1925, Ernest Burgess charted the expansion of Chicago.<sup>4</sup> The intersection of Halsted and Division is on the border between the Zone of Transition, characterized as “being invaded by business and light manufacture” and the Zone of Workingmen’s Homes, an area of two and three-flat buildings.<sup>5</sup> Indeed, 1906 Sanborn Maps indicate that there were small residential properties on the North East Corner (Figure 2.1 and 2.2), in addition to industrial facilities like the Kelmer Lumber Co., Chicago Wood and Co., Transo Paper Co, and The People’s Gas North Station. Hence, manufacturing uses dominated much of the land around the intersection. In addition, the presence of a single Fire Department on Halsted, surrounded by industrial buildings, demonstrates industry’s overwhelming presence and potentially hazardous conditions.

**FIGURE 2.1**

1906 Sanborn Insurance Map. NW corner of Halsted and Division. Note the Fire Department.

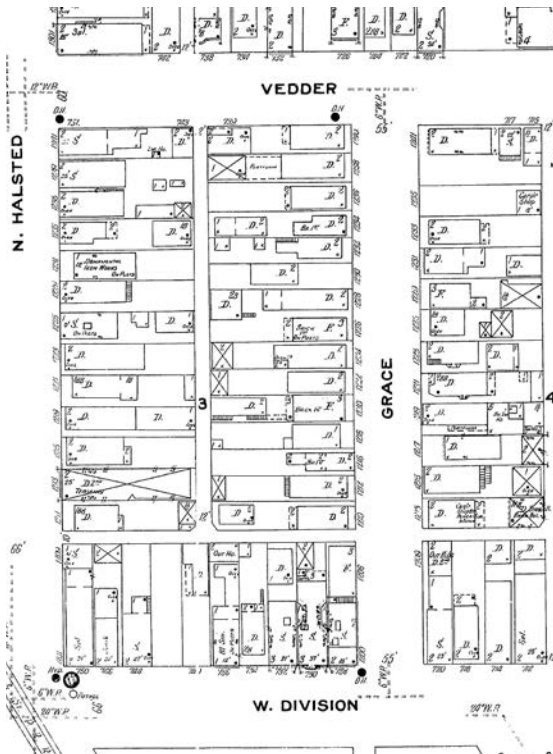




**FIGURE 2.2**

1906 Sanborn Insurance Map. NE corner of Halsted and Division.

Note the 2-3 flats in the Zone of Workingmen's Homes.



### The Era of Public Housing

The current landscape also suggests transitions in public policy. Catherine Bauer, a driving force behind the 1937 Housing Act, demanded that safe and affordable housing be made available by “direct government aid” after WWII.<sup>6</sup> Consequently, the “futuristic” vision of Le Corbusier, a French architect,<sup>7</sup> influenced the design of Cabrini-Green high-rises, which were viewed as modern architectural symbols of innovative thinking.<sup>8</sup> Replacing the small residential buildings of the Zone of Workingmen’s Homes, Cabrini-Green structures were built between 1942-1962, situated along Evergreen Avenue to the north, Orleans Street in the east, Chicago Avenue on the south, and Halsted Street on the west. One high-rise on the corner of Division and Halsted is what remains of this large-scale

project. Indeed, Cabrini-Green was composed of various building types (row-houses, high-rises, and apartments). These minimalist, geometric structures literally towered over the industrial structures of the past, symbolizing the rise in public over private interests.

Today, Cabrini-Green housing exudes urban decay and symbolizes public housing’s failure. The boarded-up windows are imprinted with burn marks and graffiti, and an uninviting chain link fence surrounds the site. The remaining Cabrini-Green building represents a political and social experiment gone wrong (Figure 3). The financial demise of the Chicago Housing Authority (CHA), disappearance of jobs in the “black ghettos,” and drug trafficking caused the environment to quickly become uncontrollable and chaotic.<sup>9</sup> The predominantly African American residents of Cabrini-Green have long fought for control over this space, which was described as a “national disgrace” following the execution of a 7-year-old boy there in 1992.<sup>10</sup> Possibly motivated by the 1973 “Chicago 21” redevelopment plan, which sought to revitalize Chicago by attracting white, young professionals from the suburbs,<sup>11</sup> the city opted to demolish the Cabrini-Green projects as part of the Chicago Housing Authority’s (CHA) “Plan for Transformation.” With demolition imminent, a period of struggle developed between the City and Cabrini-Green residents, culminating in a court case, settled in 2000, which alleged that the CHA violated the 1968 Fair Housing Act and the 1964 Civil Rights Act.<sup>12</sup> On December 10, 2010, the last Cabrini-Green residents vacated the remaining building.<sup>13</sup>

The tensions between the City of Chicago and residents of Cabrini-Green signify the transition from public to private interests. Currently, Chicago is endorsing “mixed income housing.” In theory, public housing residents are to live among the middle and upper class. Despite initial research indicating that “mixed income housing” is successful, the Plan for Transformation’s rapid demolition rate coupled with the exclusive markets associated with more desirable neighborhoods like Lincoln Park,<sup>14</sup> have prevented public

**FIGURE 3**

Situated at the corner of Division and Halsted, the last of the Cabrini Green developments stands as a symbol of “urban decay” and poverty.



housing residents from relocating to the area. In effect, City of Chicago policies now seem to be fueling gentrification, effectively relocating the poor elsewhere in the city.

### **The Intersection Today**

The increasingly consumer-driven policies of Chicago, adopted in response to the failure of public housing, demonstrate the past’s effect on the future. Now scheduled for demolition, the weathered and tired Cabrini-Green public housing building stands amid expensive lofts. Its physical deterioration represents both past and contemporary tensions of racial and economic segregation (Figure 4). Almost on all sides, save for the west, warehouse-converted lofts surround Cabrini-Green. High in the distance, an Apple advertisement reigns supreme, appealing to upper middle class residents. Commercial centers like North and Clybourn, created under the North Branch Tax Increment Financing (TIF) initiative, serve to attract young professionals to live in the city.<sup>15</sup> These commercial areas replicate the strip malls of the suburbs, making urban living more attractive. Other proposals, like the 2002 Central Area Plan,<sup>16</sup> urge developers to integrate the Loop with central area neighborhoods, making the Halsted-Division intersection a target for economic revitalization. New development will eliminate the last industrial and public

**FIGURE 4**

Standing on Kingsbury, looking east, Cabrini Green stands in sharp contrast, with the lofts which extend further North and surround the site.



housing uses of the space. Residential and commercial property can then, to use Burgess’ language, “invade” the area, solidifying private business’ control over the intersection.

The movements to attract residential and commercial developers are already successful. Chicago’s skyline is clearly visible from the Halsted-Division intersection (Figure 5) and new loft high-rises border the river (Figure 6). With the elimination of Cabrini-Green, such views attract real estate companies and small businesses. Further, repurposing existing manufacturing buildings as residential properties allows real estate companies to retrofit warehouses into luxury condominiums. Photographic evidence shows that such spaces are already on the market around the intersection (Figure 7.1 and 7.2).

Despite these location-based incentives for residential development, the area is still technically zoned for industrial use. The Chicago Zoning Ordinance labels the intersection as either “M” for Manufacturing or “PD” for Planned Development (Figure 8). “M” “districts are intended to accommodate manufacturing, warehousing, wholesale and industrial uses outside the Central Area.”<sup>17</sup> These regulations prohibit residential development and are intended to “promote economic viability of industry and



**FIGURE 5**

From the west, looking at the North Branch Chicago River Lakefront, one can already see development on the water's edge. Moving from the left (north), loft skyscrapers and warehouse renovations seem to be creeping into the central space.



**FIGURE 6**

Looking south on Halsted one can see the Chicago skyline. Coupled with the riverfront, this makes the cross section Division and Halsted a real estate target for redevelopment. sharp contrast, with the lofts which extend further North and surround the site.



employment.”<sup>18</sup> The number following “M” indicates the intensity of manufacturing use. “PD” indicates a specific agreement between the developer and the City of Chicago, so long as the developer complies with the regulations in the agreement.<sup>19</sup> Both developments designated PD on the north and south of Division are currently for sale or are being demolished.

**FIGURE 7.1**

Just a block north of Division and Halsted, signs displaying rehabilitated lofts, and “new city” advertisements, indicate the recent growth of redevelopment.



**FIGURE 7.2**

Just a block north of Division and Halsted, signs displaying rehabilitated lofts and “new city” advertisements indicate the recent growth of redevelopment.



The land north of Division, zoned M3-3 to “accommodate high-impact manufacturing and industrial uses, including extractive and waste-related use” is currently vacant (figure 9.1 and 9.2).<sup>20</sup> Littered with garbage, the space appears neglected. A concrete wasteland, identified as a coal yard on the 1906 map,<sup>21</sup> the M3-3 site is located in a highly desirable area, and it is no longer being used

**FIGURE 8**

This is the cross-section Division and Halsted from a Zoning point of view, from the City of Chicago Zoning Ordinance website.



to “[promote] economic viability and employment of industry.” I speculate that this space will soon be rezoned in favor of residential or commercial developers. Figure 10 shows the space zoned M2-3, intended for “moderate-impact manufacturing, wholesaling, warehousing and distribution uses.”<sup>22</sup> Visual evidence reveals that such a definition has been somewhat loosely interpreted; there is a Dunkin’ Donuts and a gas station. The only area currently being used for its intended purpose is the Towing Co. and Lumberyard south of Division. Although the area is designated M3-3, it is my opinion that the continued push for gentrification will drive these businesses further into the Industrial Corridor.

Another indicator of the future transition of the space is the present use of the Halsted and Division intersection. Widened in the early 20th century for the efficiency and the safety of industrial work, Halsted and Division is now a route for luxury car commuters traveling to and from the Loop (Figure 11.1 and 11.2). The presence of manufacturing still exists, but instead of being the primary use of the space, the ongoing transformation of the surrounding area makes industrial production seem out of place. Halsted and Division will be altered again, and white, middle class consumer interests will likely dictate its use.

**FIGURES 9.1 AND 9.2**

According to the City of Chicago Zoning Ordinance, this area north of Division and to the west of Halsted is marked M3-3. Currently, it stands abandoned, but high-rises and warehouse renovations indicate surrounding trends in favor of private development.



**FIGURE 10**

The commercial center which according to the City of Chicago Zoning Ordinance is marked M2-3, for “moderate-impact manufacturing, wholesaling, warehousing and distribution uses.”



## FIGURE 11.1 AND 11.2

The use of the intersections at Kingsbury and Halsted and Division indicates a change in road use.



## Conclusion

The Halsted and Division intersection has long served the needs of Chicago's ever-changing urban infrastructure. Developers will have to gain zoning changes for the land around the intersection in order to repurpose the space.

As photographic evidence shows, the space is already transitioning. Presently, the current wave of gentrification and redevelopment removes the public housing and industrial uses of the past. And while redevelopment and mixed income housing aims to improve living conditions for all, reality, as seen through the specific space of Halsted and Division, favors the overwhelming power of the consumer, a force to be reckoned with. Such dynamic change, as seen through physical infrastructure, demonstrates further transitions of land use and is indicative of subsequent tensions between different socio-economic groups, which manifest themselves when the city favors private over public investment. Hence, specifically at Halsted and Division, the connections and tensions between architecture and societal trends can be investigated by analyzing the use of urban space over the past 100 years.

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Ross Hoppe | *State Road 701* | Digital Photography

# THE OCCURRENCE OF SLEEP PARALYSIS IN A COLLEGE SAMPLE

Natalie Hengstebeck\*

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**ABSTRACT** Sleep paralysis is the inability to move upon falling asleep or awakening; in the present study, it was found to affect 40.7% of the sample. The few studies that examined the relationship between sleep paralysis and personality, found only a relationship between the experience and Neuroticism. Earlier studies found that sleep paralysis may be associated with individual differences including sex, age, depression and anxiety levels, and sleep irregularities. The present study examined the relationships between sleep paralysis and sleep habits, demographics, and personality factors. The results showed that people who experience sleep paralysis tend to sleep less and score higher for Openness to Experience.

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Sleep paralysis is a phenomenon in which people find themselves unable to move upon falling asleep or waking up and may be paired with hallucinations and a feeling of intense fear. Researchers have found varying frequencies of sleep paralysis ranging from 6% (Ohayon, Zulley, Guilleminault, & Smirne, 1999) to 62% (Ness, 1978, as cited in Spanos, McNulty, DuBreuil, Pires, & Burgess, 1995) in their samples. Many people experience sleep paralysis, yet relatively little is known about what individual differences are related to its occurrence. The present study sought to examine the prevalence of sleep paralysis and its relation to personality, demographics, and sleep patterns.

Despite the many paranormal explanations often attributed to sleep paralysis, there is a biological explanation; the onset of sleep paralysis is associated with REM (rapid eye movement) sleep. As a person falls asleep, the physiological activity of the body slows (Pinel, 2009) and an individual may hallucinate feelings of falling or floating—sometimes jerking to “save themselves” (Myers, 2007). About every 90 minutes, we progress from Non-REM sleep, i.e. light and deep sleep, to REM sleep (Pinel,

2009). Upon entering REM sleep, the activity of the brain increases to a level near wakefulness. In addition, blood pressure, heart rate, and breathing increase; major muscle groups become paralyzed; the body becomes sexually aroused; and the person dreams (Pinel, 2009).

Sleep paralysis is the result of a person becoming consciously aware of their experience and surroundings while in REM sleep, while they are still paralyzed, sexually aroused, and dreaming. This can occur when a person is falling asleep or waking up (it is a symptom of narcolepsy; Cheyne, Rueffer, & Newby-Clark, 1999). During REM sleep, the amygdala—like other parts of the brain—is in a heightened state of alertness, which may cause the person to perceive ambiguous aspects of the environment as threatening (LeDoux, 1998, as cited in French & Santomauro, 2007). During sleep paralysis, people sometimes sense a presence (i.e., have the feeling that a being of some kind was present). Their attempt to figure out what is happening to them may influence the course of their dream and content of their hallucinations (Cheyne et al., 1999). During the experience a person may feel pressure on their chest, back, or throat, and may feel like they are being choked or smothered (Cheyne et al., 1999). When combined with the previously mentioned

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experiences, the sexual arousal may even convince them that they are being sexually assaulted or raped (French & Santomauro, 2007). The physiological changes associated with REM sleep, when combined with social and cultural beliefs and personality attributes, seem to account for the frightening experience of sleep paralysis.

Research examining the relationship between sleep paralysis and personality traits has been limited. To measure personality, the current study employed the Big Five Inventory (BFI), a commonly used five-factor measure of personality consisting of Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (John, Naumann, & Soto, 2008). People who score high for Openness are imaginative, open-minded, and unconventional. Conscientious people are organized, dependable, and self-disciplined. Extraverted people are outgoing and enthusiastic. Agreeable people tend to be sympathetic and accepting. People who score high for Neuroticism are emotionally unstable, anxious, and easily upset (Gosling, Rentfrow, & Swann, 2003). Previous research has found that participants who experience sleep paralysis score significantly higher for Neuroticism than those who have never had the experience (Fukuda, Inamatsu, Kuroiwa, & Miyasita, 1991). Of the other BFI personality traits, only Extraversion has been studied (Spanos et al., 1995) but there were no significant results. However, studies have found that Openness is related to belief in the paranormal (Rose, Blackmore, & French, 2002) and that paranormal beliefs are related to sleep paralysis (Ramsawh, Raffa, White, & Barlow, 2008). Consequently, we predicted that Openness would be related to sleep paralysis.

Previous studies have examined the relationship between sleep paralysis and depression, anxiety, and panic attacks. In one study, highly depressed people were much more likely to have experienced sleep paralysis (Szklo-Coxe, Young, Finn, & Mignot, 2007). People who experienced sleep paralysis with a sensed presence were found to be more socially anxious and depressed than people who experienced sleep paralysis without a sensed presence

(Simard & Nielsen, 2005). Other researchers found a relationship between sleep paralysis and anxiety (Paradis et al., 2009; Ramsawh et al., 2008), panic attacks, stress, and fear of future sleep paralysis experiences (Paradis et al., 2009; Szklo-Coxe et al., 2007). Participants in one sample who had at least one panic attack were more likely to experience sleep paralysis than those who had not (Paradis et al., 2009). In sum, there appears to be a relationship between sleep paralysis and Neuroticism, anxiety, and depression.

Researchers have also examined the relationship among sleep paralysis, sex, and age. Several studies have found that women are significantly more likely than men to experience sleep paralysis (Kotorii et al., 2001; Fukuda, Miyasita, Inugami, & Ishihara, 1987). In contrast, Ness (1978, as cited in Spanos et al., 1995) found that men were more likely to experience sleep paralysis than women, but Spanos et al. (1995) pointed out that the “Nefoundlandic” male participants in Ness’ small sample might have been more likely to experience sleep paralysis because their jobs were associated with greater sleep deprivation than were women’s jobs. With regard to age, several studies have found that sleep paralysis begins in adolescence (Spanos et al., 2005; Paradis et al., 2009; Kotorii et al., 2001; Fukuda et al., 1987). One study found that sleep paralysis decreases with age, which may be the result of inconsistent sleep habits among younger people (Kotorii et al., 2001). Fukuda et al. (1987) found that females tended to have their first sleep paralysis experience around age 15—on average, two years earlier than males. Within their sample, the mean age was 19.6 years, which gave women almost twice the amount of time to experience sleep paralysis at some point before the study (perhaps explaining the higher prevalence in women). Fukuda et al. (1987) implicated biological development and situational stress (i.e. high stress and disrupted sleep schedules) as key factors in the occurrence of sleep paralysis.

Studies have also found a relationship between sleep paralysis and irregular sleep patterns (Paradis et al., 2009; Kotorii et al., 2001; Fukuda et al., 1987; Bell, Dixie-Bell, &

Thompson, 1986). In particular, going to sleep or waking up late, shift work schedules (Kotorii et al., 2001), work schedule changes, emotional experiences, and life changes (Paradis et al., 2009; Ramsawh et al., 2008) were related to sleep paralysis. In addition, 50.4% of the participants who experienced sleep paralysis in a Japanese sample (Fukuda et al., 1987) reported that it occurred under unusual circumstances: they had been tired (36%), under psychological stress (19%), experiencing an irregular life pattern (12%; i.e., “a disturbed sleep and wakefulness cycle,” p. 285), or had experienced sleep loss (10%). Thus, lifestyle changes, including physical, psychological, and emotional stress (Paradis et al., 2009; Ramsawh et al., 2008; Fukuda et al., 1987), and irregular sleep patterns (Paradis et al., 2009; Kotorii et al., 2001; Fukuda et al., 1987; Bell et al., 1986) appear to increase a person’s likelihood of experiencing sleep paralysis.

The present study examined the relationship between sleep paralysis and several individual difference factors, including the Big Five Inventory (John, Donahue, & Kentle, 1991, as cited in John et al., 2008). We hypothesized that people who have experienced sleep paralysis would score higher for Neuroticism (Fukuda et al., 1991) and Openness to Experience (Rose et al., 2002; Ramsawh et al., 2008) but would not differ from people who have not experienced sleep paralysis with regard to Extraversion, Agreeableness, and Conscientiousness. We expected sleep paralysis to be more prevalent when participants slept more or less than the recommended 7 to 9 hours per day because of the relationship between irregular sleep patterns and increased sleep paralysis (Fukuda et al., 1987; Kotorii et al., 2001). We also predicted a higher prevalence of sleep paralysis in women (Kotorii et al., 2001; Fukuda et al., 1987) than in men.

### Method

Two hundred thirty-seven DePaul University undergraduates participated in the current study (two were removed due to missing data). Participants’ ages ranged from 17 to 38, with a mean age of 20.25 (nine participants

did not answer). 158 women and 77 men participated in the study (one participant did not answer). Participants were students in Introductory Psychology courses and received partial course credit for their participation.

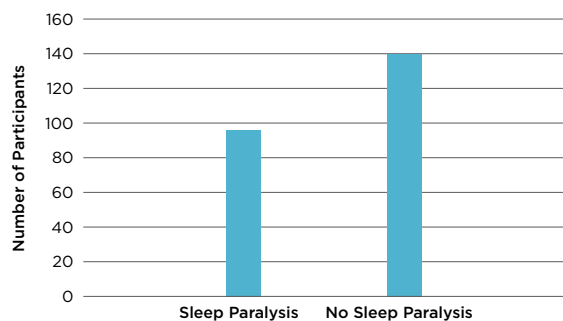
The online study was anonymous and took approximately fifteen minutes to complete. First, participants answered questions about their sex, age, race/ethnicity, zip code, education level, sleep habits, and religious attendance. Then, all participants completed the Ten Item Personality Inventory (TIPI; Gosling et al., 2003) and the Big Five Inventory (John et al., 1991, as cited in John et al., 2008). Participants who experienced sleep paralysis also answered questions about the frequency of the experience, details of the experience, and explanations for why it occurred. The sleep paralysis questionnaire used in this study was based on the work of Rose et al. (2002), Paradis et al. (2009), Cheyne (2002), Fukuda et al. (1991), and Watson (2001). Finally, the participants who experienced sleep paralysis also completed the Revised Paranormal Belief Scale (Tobacyk, 2004).

### Results

In this sample, 40.7% of participants experienced sleep paralysis at least once (See Figure 1). There was no significant difference between the percentage of men (35.1%) and women (43.7%) who experienced sleep paralysis.

**FIGURE 1**

*Prevalance of Sleep Paralysis in the Current Sample.* This figure shows the number of participants who experienced sleep paralysis versus those who did not.



An independent samples t-test showed that people who have experienced sleep paralysis tend to sleep less daily ( $M=3.50$ ,  $SD=0.78$ ) than people who have never had the experience ( $M=3.73$ ,  $SD=0.71$ ),  $t(234)= 2.34$ ,  $p=0.02$  (See Figure 2). The means were based on a six-point scale in which three represented 5 to 7 hours of sleep, and four represented 7 to 9 hours of sleep. 43% of the participants who slept between 5 and 7 hours per night and 71.4% of the participants who slept only 3 to 5 hours per night experienced sleep paralysis at least once compared to 36.2% of people who slept 7 hours or more. In addition, people who have experienced sleep paralysis scored higher for Openness to Experience ( $M=3.83$ ,  $SD=0.57$ ) than those who have not ( $M=3.68$ ,  $SD=0.61$ ),  $t(234)= -1.96$ ,  $p=0.05$  (See Figure 3). No significant differences were found for the other BFI traits.

### Discussion

The hypothesis that amount of sleep is related to the experience of sleep paralysis was supported. In addition, we found that Openness was related to the occurrence of sleep paralysis. There were no other statistically significant relationships. The relationship between Openness and sleep paralysis in this study supports our hypothesis that there may be an indirect connection between paranormal

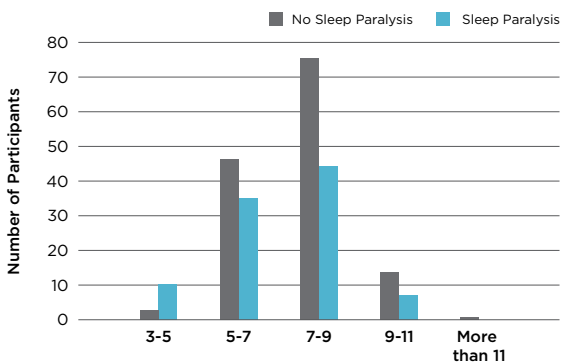
beliefs and sleep paralysis (Ramsawh et al., 2008) and paranormal beliefs and Openness (Rose et al., 2002).

A connection between sleep paralysis and irregular sleep patterns has been found in several studies (Paradis et al., 2009; Kotorii et al., 2001; Fukuda, et al., 1987; Bell et al., 1986). One might imagine that going to sleep or waking up late (Kotorii et al., 2001), fluctuating work schedules and life changes (e.g., ending a relationship or starting a new job; Paradis et al., 2009; Ramsawh et al., 2008), and tiredness, psychological stress, and irregular routines (e.g., studying late or working overtime) would be particularly common in college students. Specifically, the present study adds that sleeping less is associated with the occurrence of sleep paralysis.

The high incidence rate of sleep paralysis in this sample (40.7%) was comparable to the rates found in two Japanese studies, 43% (Fukuda et al., 1987) and 40% (Kotorii et al., 2001). Interestingly, the incidence rate in the present study was higher than the rate found in one American study, 25% (Paradis et al., 2009), and two Canadian studies, 21% (Spanos et al., 1995) and 29% (Cheyne et al., 1999). The two Canadian studies included larger university samples, 1,798 participants (Spanos et al., 1995) and 870 participants

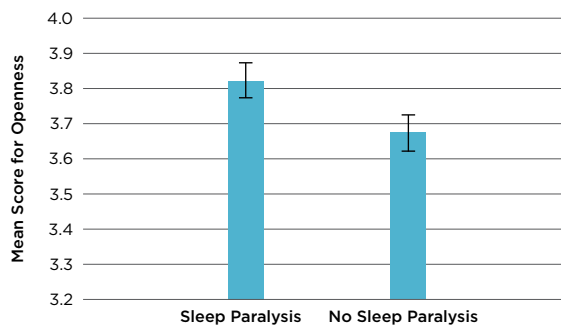
**FIGURE 2**

*Prevalance of Sleep Paralysis and Hours of Sleep.* This figure illustrates how people who sleep less tend to experience sleep paralysis more frequently.



**FIGURE 3**

*Mean Openness Scores for Participants With and Without Sleep Paralysis.* This figure illustrates the openness scores for participants based on whether or not they have experienced sleep paralysis. Error bars represent the standard error of the mean





(Cheyne et al., 1999), than the present study. One limitation of the current research was that the sample consisted entirely of college students. We are trying to overcome this limitation by distributing our materials to a non-university sample. Participants in the current sample experienced sleep paralysis more than expected and our data revealed two relationships that were previously undiscovered.

People frequently make excuses for why they do not get a sufficient amount of sleep; perhaps a fear of sleep paralysis will add to the list of reasons to get a full night's rest. This study provides evidence that highly open people should be

especially wary of their sleep habits. Sleeping about eight hours per day, avoiding extreme stress (Paradis et al., 2009; Ramsawh et al., 2008; Fukuda et al., 1987), and sleeping in a position other than on one's back (Cheyne, 2002) tend to decrease the likelihood of having a sleep paralysis experience. Sleep paralysis can be very scary, especially for people who have never had it. College students, who are probably more open-minded and less likely to sleep regularly, should be aware of the scientific explanations for sleep paralysis and factors that increase the likelihood of the experience to be better able to avoid sleep paralysis in the future.

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Renee Perrino | *Untitled* | Silver-Gelatin

# PARASITE-RELATED SUPPRESSION OF MATING BEHAVIOR IN STREAM CRUSTACEANS: EFFECTS OF HOST ENERGY LEVELS

Sara Caddigan\*

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**ABSTRACT** The crustacean isopod, *Caecidotea intermedius*, is common in Midwestern streams where it is infected by the acanthocephalan parasite, *Acanthocephalus dirus*. Parasite infection correlates with suppression of mating behavior, but little is known about the mechanisms underlying this suppression. I examined the potential significance of host energy levels for this relationship, specifically testing the prediction that males in poor physiological condition would be more likely to experience suppression than males in good condition. Using a combination of field-based behavioral experiments and lab-based biochemical assays, I showed that host energy reserves (glycogen, lipid) did not correlate with suppression of mating behavior.

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## Introduction

Acanthocephalans are trophically-transmitted parasites that infect arthropods as intermediate hosts and vertebrates as definitive hosts (Crompton & Nickol, 1985). In many cases, acanthocephalan infection correlates with changes in both the antipredator behavior and color pattern of the intermediate host, which increases conspicuousness to predatory definitive hosts (e.g., Moore, 2002). In some cases, acanthocephalan infection also correlates with changes in mating behavior (Zohar & Holmes, 1998; Bollache et al., 2001; Sparkes et al., 2006). Although examples of this type of modification are common, relatively little is known about the proximate mechanisms underlying these changes. This study examined the potential significance of host energy reserves to parasite-related suppression of mating behavior in the intermediate host (*Caecidotea intermedius*, Isopoda), infected by the acanthocephalan parasite *Acanthocephalus dirus*.

The freshwater detritivore, *C. intermedius*, is a common host of the acanthocephalan *A. dirus* in the Midwestern

region of the United States (Camp & Huizinga, 1979; Bierbower & Sparkes, 2007). Typically, infection correlates with changes in both antipredator behavior and body pigmentation, which increases conspicuousness to visually-hunting definitive hosts (Camp & Huizinga, 1979). Additionally, some infected *C. intermedius* males undergo suppression of mating behavior (Bierbower & Sparkes, 2007). Mating behavior for *C. intermedius* involves males walking around on the stream bed searching for reproductive females. Once the males have encountered a female, a mating contest commences with males grabbing on to the female and wrestling with her. If the female accepts the male as a mate, the male will then guard the female from other potential male rivals. This mate-guarding behavior entails the male carrying the female underneath his body for a period of 1-4 days, after which the female molts and copulation can occur (Bierbower & Sparkes, 2007).

To determine whether suppression of mating behavior could be mediated by changes in the physiological condition of the host, I quantified energy levels (glycogen, lipid) of infected males that varied in mating behavior. Specifically, I tested the prediction that mating-suppressed

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males are in poorer physiological condition than males that are mating.

## Methods

### Mating Response

Mating response trials were run in the field by staging contests between males and females on the stream bank. Small, plastic containers were filled with stream water and set on a level platform. Paired isopods were collected from the stream using hand nets. The females were gently separated from the males and placed into the containers (5 per container). Unpaired males were collected from the stream and placed individually into a container with females. Mating interactions were observed for up to 20 minutes. Each time the male made contact with a female there were two possible outcomes: the contact was either recorded as a negative mating response if it was brief and the male continued moving around the container or the contact was recorded as a positive mating response if the male and female began a mating contest. Once the male and female began struggling, the trial ended and that encounter was recorded as a positive mating response. Each male was allowed to make contact ten times without initiating a mating response before that male was considered to have an overall negative mating response. Once the mating response was determined, the males were removed from the container, placed into a labeled eppendorf tube, and put immediately into a cooler of dry ice. By freezing the isopods in the ultra freezer at -70°C, their current energy levels were preserved to later determine if a correlation between energy and mating response existed.

### Glycogen Content

The Glycogen content of isopods was quantified using a modified version of a procedure outlined in Van Handel (1985a). Individual isopods were first placed onto a pre-cut piece of aluminum foil, approximately 2 x 1 cm, and body length was recorded using a dissecting microscope (Leica, MZ 12). Each isopod was then dissected to determine infection status. If the isopod contained parasites, it was

deemed infected: if the isopod had no parasites, it was deemed uninfected. For infected isopods parasites were removed, the body of the isopod was placed in a test tube with 2% sodium sulfate, and was ground to a consistent texture with a glass stirring rod. The foil and glass rods were washed with 1.5 ml of 3:2 methanol:chloroform mixture into the test tubes so that all contents would remain in the samples. The test tubes were vortexed, centrifuged for 5 minutes, and the supernatant containing lipids was poured into pre-labeled test tubes for later analysis. The remaining pellets were evaporated in a 70°C dry bath until they had a moist appearance. Next, 0.5 ml of 30% potassium hydroxide was added to each sample and gently vortexed. The samples were concentrated in a dry bath at 100°C for 10 minutes. Once concentrated, 1.0 ml of 100% ethanol was added to the samples, vortexed, and then centrifuged for 5 minutes. The ethanol was poured off and 0.8 ml of deionized water was added to the samples. After vortexing, pellets were allowed to settle for 10 minutes before being centrifuged for an additional 5 minutes.

At this time, 0.5 ml of the supernatant containing the glycogen was carefully removed from the samples with a pipette tip (so as not to disturb the pellet) and placed into clean, labeled test tubes. Each sample was then filled to 5.0 ml with anthrone-sulfuric acid color reagent. Samples were allowed to react with the anthrone reagent in a 90°C water bath for 17 minutes. A set of 6 test tubes containing 0, 10, 25, 50, 75, and 100 micrograms of glycogen were also filled to 5.0 ml with anthrone reagent and incubated along with the samples. These samples were used to generate a standard curve. After incubation, all tubes were cooled to room temperature in an ice slurry and their optical densities were measured at 625 nm using a spectrophotometer.

### Lipid Content

The Lipid content of isopods was quantified using a modified version of a procedure outlined in Van Handel (1985b). Once the lipid content of the isopods had been extracted as a supernatant liquid, the solvent was

evaporated at room temperature or a 70°C dry bath until only a solid residue remained on the bottom of the test tubes. Next, 0.2 ml of concentrated sulfuric acid was added to each sample, as well as to a set of 4 test tubes containing 0, 50, 100, and 200 micrograms of lipid that would be used to generate a standard curve. The samples and standards were then vortexed and incubated in a 90°C water bath for 20 minutes. After cooling to room temperature in an ice slurry, both samples and standards were filled to 5.0 ml with vanillin-phosphoric acid color reagent. Afterwards, every tube was vortexed and allowed to sit at room temperature for 5 minutes. Then, optical densities were measured at 490 nm using a spectrophotometer. Dissected parasites were later retrieved from the ultra-freezer in which they had been stored since being removed from their hosts. Their lipid content was then determined using the same procedure as above.

## Results

The analysis of glycogen and lipid in relation to mating behavior is shown in Table 1.

Infected males were less responsive to females than uninfected males (G-test:  $G_1 = 5.5$ ,  $p < 0.05$ ). Infected males also contained more glycogen and lipid than uninfected males [t-test: Glycogen (logtransformed) -  $t_{118} = 2.2$ ,  $p = 0.04$ ; Lipid -  $t_{118} = 4.7$ ,  $p < 0.001$ ]. There was no difference in energy content between infected males that were responsive to females and infected males that were not responsive to females [t-test: Glycogen (logtransformed) -  $t_{103} = 0.9$ ,  $p = 0.4$ ; Lipid -  $t_{103} = 1.0$ ,  $p = 0.3$ ].

## Discussion

Infection of male *C. intermedius* by *A. dirus* parasites correlated with suppression of mating behavior and an increase in both glycogen and lipid content. This pattern is consistent with previous studies on this parasite-host relationship (Bierbower & Sparkes, 2007; Korkofigas, 2007). However, comparison of the glycogen and lipid content of infected males that differed in mating response revealed that there was no detectable difference in energy

**TABLE 1**

Relationship among male-mating behavior, infection status, and energy reserves for male *Caecidotea intermedius* ( $n = 120$ ). MR + indicates infected males that were responsive to females, MR - indicates infected males that were not responsive to females. Standard error values are shown in parentheses. \* indicates  $p < 0.05$ , \*\*\* indicates  $p < 0.001$ . NS indicates no statistical difference between groups.

Variable	Uninfected	Infected	p-value
Positive Mating Response	78	45	*
Glycogen (micrograms)	61 (10.4)	120 (10.4)	*
Lipid (micrograms)	421 (51.1)	895 (41.0)	***

Variable	Uninfected MR+	Infected MR-	p-value
Glycogen (micrograms)	61 (10.4)	120 (10.4)	NS
Lipid (micrograms)	421 (51.1)	895 (41.0)	NS

stores between responsive and non-responsive males. Thus, variation in parasite-related mating suppression did not appear to be mediated by host-energy reserves. These results provide insights into the mechanisms of host modification by directing future studies towards alternative mechanisms (e.g., parasite physiological state, host neurobiology).

Several studies on parasite-host relationships have shown that parasite infection correlates with an increase in energy storage (e.g., Thompson, 1990; Plaistow et al., 2001; Korkofigas, 2007). The mechanisms underlying this pattern are not understood, but several factors could contribute to this relationship. For example, several parasites manipulate their hosts in ways that increase the probability of transmission to final hosts. This type of manipulation often involves shifts in behavior and a parasite-related reallocation of energy stores could potentially fuel this type of behavior. An alternative explanation for the increase in energy stores in infected

males is that it could increase the energy value of the isopod as a prey item for predatory final hosts. Future studies will examine alternative mechanisms that could explain the difference in energy stores between infected and uninfected males in *C. intermedius*.

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Ross Hoppe | *Atonement* | Digital Photography



Ross Hoppe | *Hollywood Towers* | Digital Photography



# PALEOECOLOGY OF THE LATE CRETACEOUS CARDABIODONTID LAMNIFORM SHARK (*CARDABIODON VENATOR*) FROM KANSAS

Ashley Dickerson\*

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**ABSTRACT** This study investigates the 93-million-year-old remains of an extinct lamniform shark, *Cardabiodon venator*, from Kansas. The remains consist of 53 teeth, numerous placoid scales, and pieces of calcified cartilages. Based on the attempted reconstruction of the specimen's dentition, it is estimated to have measured 2.5 meters in total length. The study includes the first record of placoid scales for *Cardabiodon*. The morphology of the scales suggest that this shark was capable of using its ability to swim quickly to live an active lifestyle as one of the top predators in its oceanic habitat.

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## Introduction

Paleoecology is the ecological study of prehistoric organisms that considers interactions among contemporaneous extinct taxa and, more importantly, helps to deliver clues as to how the Earth has evolved over time. In this paper, I infer the paleoecology of a 93-million-year-old fossilized shark remain, a *Cardabiodon venator* (Lamniforms: Cardabiodontidae) from Kansas, based upon a specimen catalogued as FHSM VP- 425 at the Sternberg Museum of Natural History in Hays, Kansas. *Cardabiodon* is known from both Australia and North America (Cook et al., 2010), and FHSM VP- 425 is significant because of its uncommon preservation within the fossil record of sharks, as it contains a set of teeth with cartilaginous elements from one individual specimen. Until this investigation, the fossil had remained unstudied. The goals of this research are to describe the morphology of anatomical elements preserved in this specimen and to infer the paleoecological role of *Cardabiodon* in its ancient ocean. Top-down predators maintain healthy ecosystems; therefore, this research is an important reminder of the fascinating nature of sharks and their extraordinary significance on Earth.

## Materials and Methods

FHSM VP- 425 is a limestone slab with a set of teeth and pieces of calcified cartilage.

I carefully mapped out the distribution of the teeth that reside in the rock by direct observation, as well as by examination of computer-tomographic images of the specimen that were generated and supplied by the Children's Memorial Hospital in Chicago.

Each tooth was identified with a numbered sticker for record-keeping purposes. After each was labeled and mapped, the rock was rotated and angled to a specific point-of-view that would allow for drawing the outline of individual teeth, showing their shape, size, and inclination. The drawings of the teeth were displayed on a single page in rows organized by tooth-size, ranging from the smallest to the largest. Based on the dental pattern in modern lamniform sharks, as well as in other Late-Cretaceous lamniform sharks (Shimada, 2002, 2007), I attempted to identify the type of each tooth and reconstruct the arrangement of teeth for the *Cardabiodon* specimen.

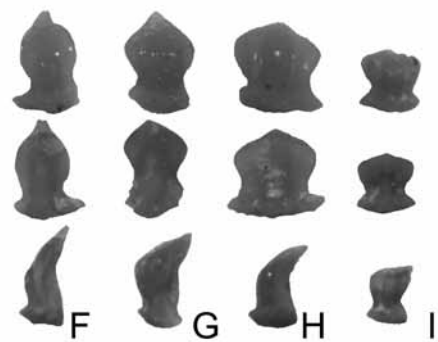
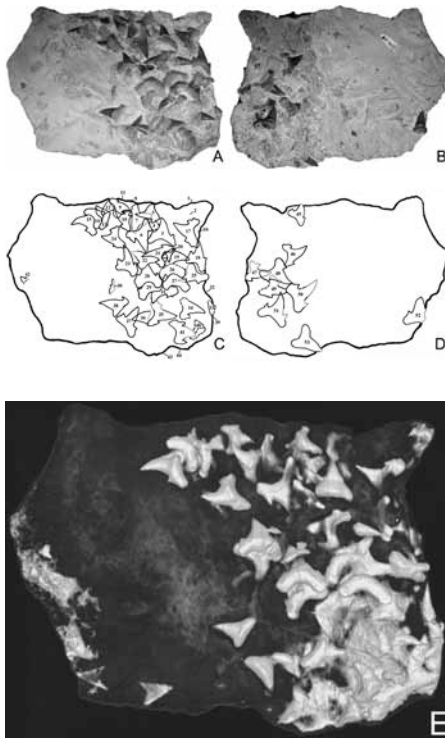
Careful observation revealed that FHSM VP- 425 also contained numerous placoid scales. Some scale samples

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**FIGURE 1**

Associated teeth and placoid scales of *Cardabiodon enator* (FHSM VP-425). A, photograph of one side ('Sid of specimen; B, photograph of other side ('Side B') o specimen; C, distribution of teeth on Side A; D, distribution of teeth on Side B; E, computer tomographic image of specimen (cf. Fig. 1A); F-I, four examples of placoid scales (top,anterior view; middle, posterior view; bottom, profile view)Scale bars: A-E = 5 cm; F-I = 1 mm.



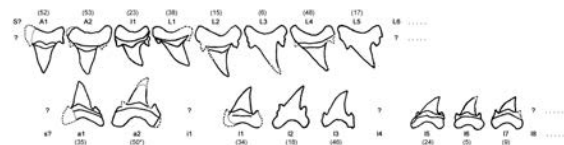
were extracted by chipping off small pieces of matrix and dissolving the limestone pieces in a 5% acetic-acid solution. A dissecting microscope was used to examine and photograph the placoid scales after rinsing them with tap water and allowing them to dry.

**Results**

The examination of FHSM VP- 425 showed that the specimen preserved upwards of 53 teeth (Fig. 1C, 1D), including many replacement teeth and several teeth that are represented only by their casts (i.e., actual missing teeth). The teeth vary in size and morphology, suggesting that the dentition of the shark showed heterodonty. There are 37 well-developed (functional or near-functional) teeth, 16 of which are well-preserved and were used to reconstruct the dentition of the shark

**FIGURE 2**

Tentative reconstruction of upper (top) and lower (bottom) dentitions of *Cardabiodon venator* based on FHSM VP-425 (symphysis to the left; number in parentheses represents tooth numbers shown in Fig. 1C and 1D; asterisk indicates tooth in which image is reversed; for size of teeth, see Fig. 1). Abbreviations: A and a, anterior teeth; I and i, intermediate teeth; L and l, lateral teeth; S and s, symphyisal teeth (see Shimada, 2002).



Of the teeth identified in the specimen with a complete or nearly complete crown, the main cusp of about 12 teeth point to the left, 17 teeth point to the right, and 3 teeth are symmetrical and erect when all teeth were arranged in the crown-up and root-down orientation.

Pieces of calcified cartilage preserved in FHSM VP- 425 are tabular and consist of fused calcified cartilage prisms. Since most pieces are flat and wide, they likely represent pieces of the lower jaws, but they are too fragmentary for accurate identification. On the other hand, placoid

scales offer more anatomical details. Each scale, ranging from 0.3 mm to 0.7 mm in maximum dimension, consists of a teardrop-shaped enameloid crown and a laterally-extended root, generally with one nutritive foramen at its base. The external crown surface of each scale shows 6-8 parallel grooves with keels.

### Discussion

Siverson (1999), described *Cardabiodon ricki* from Australia, followed by Siverson and Lindgren (2005), who described the second species of *Cardabiodon*, *C. venator*, from Montana. *Cardabiodon ricki* possesses a robust root, relative to *C. venator*, and *C. venator* has slightly broader roots with shorter crowns than what is observed in *C. ricki*. The teeth in FHSM VP-425 are more similar to *C. venator* than to *C. ricki*, and thus, FHSM VP-425 is tentatively identified as *C. venator*.

Figure 2 shows the tentative reconstructed upper and lower-left dentitions of *Cardabiodon* in lingual view based on FHSM VP-425, which are thought to consist of at least 8 upper-tooth rows and 10 lower-tooth rows (there were likely as many as 15 tooth rows in each dentition). This reconstruction is based on the reconstructed dentition of another Late-Cretaceous shark, *Cretalamna appendiculata* (Shimada, 2007), as well as from a common trend seen in modern lamniform sharks where the crown of upper-teeth are often narrower than the crown of lower counterparts (e.g., Shimada, 2002). This model differs from Siverson's (1999) reconstructed dentition of *Cardabiodon ricki* based on an associated tooth set from Australia where he arranged wider teeth into the lower dentition and narrower teeth into the upper dentitions, respectively. As both the Australian *C. ricki* specimen and FHSM VP-425 are represented by disarticulated teeth, Siverson's (1999) reconstructed dentitions and my own should be considered working hypotheses that can be tested by the discovery of an articulated dentition.

Another massive Late-Cretaceous lamniform shark is *Cretoxyrhina mantelli*, which Shimada (2008) used

to create an equation that would allow an estimate to be made of the total length (TL, in cm), from the crown height (CH, in mm), of anterior teeth, or  $TL = 12.5CH$ . In FHSM VP-425, the tallest, well-preserved anterior tooth has a crown height of 20 mm (Tooth 53, Fig. 2). If the proportion of the body and the relationship between tooth height and total length are assumed to be similar between *Cretoxyrhina* and *Cardabiodon*, the CH of 20 mm would suggest that the specimen was approximately 250 cm TL in life. This is smaller than the remains of *Cardabiodon ricki* from Australia, described by Siverson (1999) that possibly measured about 500 cm TL (based on the vertebral centra recovered from the specimen), but comparable to the *Cardabiodon venator* from Montana described by Siverson and Lindgren (2005), in which the CH of the tallest tooth is about 20 mm.

The morphology of placoid scales often reflects the swimming efficiency of the shark (e.g., Shimada, 1997). The scales in FHSM VP-425 show 6-8 shallow, parallel grooves bounded by keels that are very similar to scales of *Cretoxyrhina mantelli* (Shimada, 1997). The grooved scales indicate that, like *Cretoxyrhina mantelli*, *Cardabiodon* was capable of fast swimming and an active lifestyle.

### Conclusion

With the teeth of *Cardabiodon* being both large and robust, with pronounced cutting edges, it is reasonable to assert that the taxon was a predaceous shark. My study suggests that, although the *Cardabiodon* specimen represented by FHSM VP-425 was relatively small, 2.5 m in total length, the taxon was able to swim quickly, which may indicate that the shark was able to actively pursue lively prey. Like the contemporaneous lamniform shark, *Cretoxyrhina mantelli* (Shimada 2008), the lifestyle of *Cardabiodon venator* may have been comparable to the modern great white shark, *Carcharodon carcharias*. This inference is important towards understanding the ecology and evolution of marine ecosystems over time.

## Acknowledgments

My sincere thanks to Dr. R. J. Zakrzewski (FHSM), who loaned FHSM VP-425 to Dr. K. Shimada, who, in turn, allowed me to examine the specimen. I would also like to thank C. K. Rigsby, K. Gray, B. Karl, J. Hickey and B. Reilly at the Children's Memorial Hospital in Chicago, for generating computer-tomographic images of the specimen. Additional thanks to Dr. K. Shimada for his guidance in this project, and the Environmental Science Program and College of Liberal Arts and Sciences at DePaul University, Chicago for their financial support.

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# ***RHAMNUS CATHARTICA* (EUROPEAN BUCKTHORN) SEED GERMINATION AND SEEDLING GROWTH IN MULCH-AMENDED SOILS: IMPLICATIONS FOR RESTORATION**

Meaghan Kern\*

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**ABSTRACT** *Rhamnus cathartica* (European buckthorn) is an invasive shrub likely to reinvade due to elevated nitrogen (N) in soils. The addition of Carbon (C) has been shown to decrease available N in soils and reduce reinvasion in the field, but little is known about the impacts of C-addition on growth of targeted invasive species. Our experiment tests the effects of mulch on *R. cathartica* reinvasion in the field, and seed germination and growth in a greenhouse. We hypothesize that reinvasion, germination, and growth will be reduced with buckthorn mulch. In the field and the greenhouse, *R. cathartica* growth was inhibited. We suggest mulch-addition can enhance the restoration process by delaying reinvasion.

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## **Introduction**

Ecological restoration is a vital methodology because anthropogenic stresses have severely degraded ecosystems, causing a reduction in biodiversity (Heneghan et al., 2009). In fact, invasive species are the second largest cause of biodiversity loss; the first is habitat destruction (Soulé, 1990). Invasive species not only jeopardize biodiversity, but also natural ecosystem processes (Liao et al., 2007). Therefore, ecological restoration efforts are imperative to preserve global biodiversity and natural ecosystem functionality.

*R. cathartica* is an invasive species that has spread significantly throughout the Midwest. This shrubby tree was brought over from Europe in the 18th century and was commonly used as a hedge. Upon invasion, *R. cathartica*, strong invader of woodlands, savannahs, and prairies, shifts the ecosystem state above and below ground, an alternative state that remains despite removal attempts. These alterations of the ecosystem processes hinder restoration success and facilitate invasion. Studies

on buckthorn suggest that immobilization of N by the soil's microbial community may be responsible, along with elevated inputs of organic matter that contribute to the accumulation of N (Heneghan et al., 2006). High N availability could explain why common restoration efforts of mechanical and chemical applications are unsuccessful.

There have been successful studies where C-addition (saw dust) was used to induce N-immobilization, which reduced invasive grasses and weeds (Blumenthal et al. 2003). However, there have not been any studies on the effects of C-addition to buckthorn-invaded ecosystems. The primary objective of this study was to see if the practical application of mulch-addition could reduce reinvasion and quantify the effect of mulch-addition on *R. cathartica* in the field and in the greenhouse. Our hypothesis was that *R. cathartica* reinvasion, germination, and growth would be reduced in mulch-amended soils.

## **Methods**

### **Field Methods**

The field site for this experiment is Whipoorwill Farm, a 7-acre abandoned horse pasture. *R. cathartica* began to establish itself in the late 1980's. Restoration on the

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site began in 2007 and 5 replicate plots (52 m<sup>2</sup>) were created using traditional cutting and herbicide methods. Commercial mulch, purchased from Home Depot, and cut *R. cathartica* trees were mulched on-site, roto-tilled into the soil, and each treatment was followed by a broadcast of over 25 native grasses and forbs. For two growing seasons, reinvasion was evaluated in each treatment by counting the number of seedlings and re-sprouts in 3 randomly-placed quadrats (0.25m<sup>2</sup>).

### Greenhouse Methods

In the fall of 2008, 128 *R. cathartica* seedlings were collected from Lake County, IL. The seeds were cold-stratified for 6 months and planted into flats of 3 different treatments: no-mulch, commercial-mulch, and Buckthorn-mulch. The soil was collected from Whippoorwill Farm and sand from the hardware store was mixed in a soil-to-sand ratio of 3:2. The mulch amendments were mixed into the sand-soil mixture in a 3:1 ratio. The exact same soil treatment was prepared and mixed using a cement mixer. Seedlings that germinated with 2 or more true leaves were transferred into larger pots of the exact same treatment. Before the seedlings were transferred, initial biomass was obtained. The pots were organized, alternating into 2 flats and placed in a growth chamber for 4 months, where they were watered every day. While in the growth chamber, the stem height and leaf number were recorded. Stem height was recorded by tying together a string and a large sewing needle, which was used as a measuring stick to record the length of the stem at the soil to the tip of the stem.

## Results

### Field

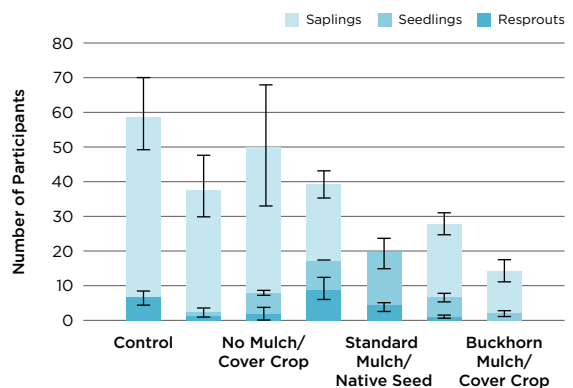
Figure 1 shows the results from the field reinvasion data collected during summer 2009. Specifically comparing no mulch/native seed to the mulch/native seed plots, the buckthorn mulch had the greatest reduction of re-sprouts, seedlings and saplings.

### Greenhouse

Table 1 shows how many seeds germinated out of a total

**FIGURE 1**

*R. cathartica* Seedling and Sapling Reinvasion following Soil Amendment in 2009.



**TABLE 1**

Germination of *R. cathartica* Seeds and Saplings planted

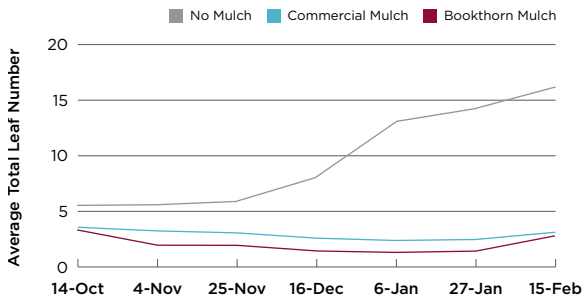
Treatment	Total Seedlings Germinated out of 96	Percent Germinated (%)	Saplings
No Mulch	88	54	52
Commercial Mulch	88	42	40
Buckthorn	31	32	30

of 288 seedlings, 96 in each treatment. 54% of seeds germinated in no-mulch soil. In mulch-amended soils, the percentage germinated in commercial and buckthorn mulch were 42% and 32%, respectively. The least amount of *R. cathartica* seedlings germinated in buckthorn mulch. The saplings transplanted from the seeds germinated are also shown in Table 1.

Figures 2 and 3 show the average number of leaves and height during the 3 months studied. Saplings with no mulch had an average leaf gain of 10.5 leaves. The average leaf change for commercial mulch and buckthorn mulch was negative. Commercial mulch and buckthorn mulch, on average, lost approximately -0.175 and -0.400 leaves, respectively. Areas treated with no mulch grew in height, and overall, had an average height addition of 3.44 cm. However, commercial mulch had an average height gain

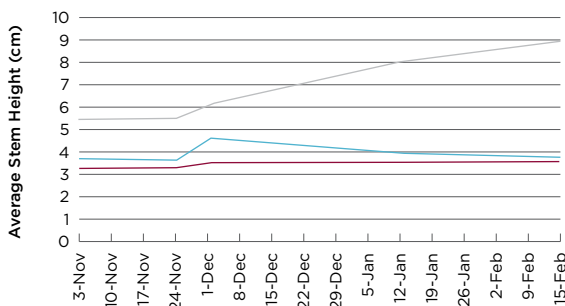
**FIGURE 2**

Average Number of leaves from October 2009–February 2010



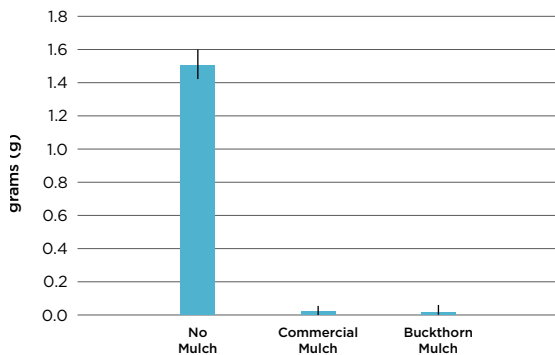
**FIGURE 3**

Average Height from October 2009–February 2010



**FIGURE 4**

Change in Biomass: October 2009–February 2010



of 0.258 cm and buckthorn mulch had a negative height change of -0.037 cm. Also, the graphs clearly show a transition period of 1 month where no change occurred throughout the 3 treatments.

The average change in biomass of saplings in no mulch was a gain of 1.52 g. Sapling biomass gain for commercial mulch was 0.015 g and for commercial-mulch saplings, 0.003 g.

### Discussion

The amount of seeds germinated in soils with mulch was reduced relative to seeds germinated in no mulch. More specifically, the least amount of seeds germinated in buckthorn mulch. No-mulch grew significantly, compared to saplings in mulch-amended soils. However, it was unexpected to see that there was no significant growth difference between commercial and buckthorn mulch. *R. cathartica* seedlings appeared to be happy, healthy, and green. However, a majority of the seedlings in commercial mulch appeared to have a yellowish-tint. This could potentially indicate a phosphorus deficiency. The addition of mulch in buckthorn-invaded areas can inhibit, but not completely deter the growth of buckthorn. It appears that in the field, the mulch just buried the seeds, and although it took them longer, they were still able to invade. Although mulch may not be able to completely deter an invasion, it can delay it.

### Acknowledgements

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# THE RELATIONSHIP BETWEEN INVASIVE EARTHWORM BIOMASS AND HABITAT DEGRADATION IN THE CHICAGO REGION: IMPLICATIONS FOR RESTORATION

Beth Kosson\*

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**ABSTRACT** Invasive earthworms have become a concern for ecological restoration projects as they are capable of changing ecosystem processes in a way that impedes restoration goals. We investigated the impact of restoration management on earthworm communities in Chicago woodlands. Sites were selected in several management categories (control, early-management, intermediate-management, and reference site). We asked: What are the relationships between restoration efforts designed to increase plant diversity and the reduction of invasive earthworm populations? Though abundance was lower in the reference sites, as opposed to the unmanaged, there was no significant difference in earthworm abundance between early (<5 years) and intermediate (10+ years) management.

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## Introduction

Invasive species are an increasing threat to the biodiversity of an ecosystem. Earthworm invasion has only recently been investigated as a major factor in so-called “invasional meltdowns”. An invasional meltdown is the process where one invasion of a species facilitates the invasion of others (Belote and Jones, 2009). Consequently, the rate of loss of ecological health can greatly accelerate as one invasive species makes way for additional ones. Developing a better understanding of this process should allow us to design more effective ecological restoration management strategies. For instance, targeting plant species that facilitate the invasional meltdown may be an effective management technique (Madritch and Lindroth 2009). Changes to the plant community can impact the state of soil processes. In turn, soil ecosystem processes can dictate the health and resilience (capacity to resist disturbance) of the community (Pavao-Zuckerman, 2008). This is because the soil plays a key role in nutrient and hydrological cycling.

A study conducted by Lee E. Frelich et al. (2006) claims

earthworms, “can be considered a keystone class of organisms that exert control over many aspects of ecosystem structure and function, including the primary producers” (Frelich et al., 2006, p.1236). Earthworms are invading much of the North American continent. Recent research provides evidence that they have been colonizing the cold-temperate region of North America since the days of European settlement. Their invasion of the woodlands has caused declines in diversity and abundance of native-understory plants (Hale et al., 2005; Frelich et al., 2006). The native earthworms of this region were most likely annihilated by the Wisconsin glaciation, approximately 12,000 y.b.p. (Madritch & Lindroth, 2009). This open niche was filled when the European earthworms were brought over with settlement and trade. Earthworms have negatively impacted the ecosystems that they have invaded. Appropriately termed, “ecosystem engineers,” they have a great ability to modify habitats and change community species composition (Belote & Jones, 2009). They are thought to be responsible for the reduction of the thickness in the organic layers (exposing mineral soil), increasing soil-bulk densities, and increasing nutrient-cycling rates which leads to an overall decrease in essential nutrient availability such as N (nitrogen)

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and P (phosphorous), impacting seedling survival, and the disruption of plant hyphal networks (Frelich et al., 2006; Belote & Jones, 2009; Hale et al., 2005; Madritch & Lindroth, 2009).

The Midwestern region is of particular importance in the study of invasive earthworms. Much of this region was previously without earthworms and the impact of invasive earthworms has been pronounced. It has been reported that the invasion of earthworms in the northern forests of Minnesota has caused significant declines in the diversity and cover of herbaceous plants and abundance of seedlings (Frelich et al., 2006). The northern hardwood forests may have been prime targets for invasion because they were without native earthworms for so long. In their un-invaded state, these woodlands developed thick forest floors and microbes to control the rate of nutrient recycling and availability in the soil (Hale et al., 2006). After invasion, the organic matter in the forest floor was reduced and species were lost. Additionally, there is a relationship between invasive earthworms and some invasive shrubs. Earthworms increase the availability of nitrogen in the soil and this, in turn, may facilitate the invasion of more earthworms. Heneghan et al. (2007) proposed that the impact of earthworms on litter breakdown creates conditions that promote and sustain invasion by the invasive shrub, *Rhamnus cathartica* (European Buckthorn). A study by Madritch and Lindroth (2009) found that removing the invasive shrubs in an area, “had a direct negative effect on earthworm abundance”. This result provided some supportive evidence for this study’s hypothesis. We speculate here that management directed at invasive shrubs may also reduce invasion by earthworms.

We investigated patterns of invasion as part of The Chicago Wilderness Land Management Research Program, otherwise known as “The 100 Sites for 100 Years.” This program was developed to gain a better knowledge of the impact restoration management has had on the Chicago region’s woodland and prairie ecosystems. In the summers of 2009 and 2010, I was part of a team of

research interns who traveled to approximately 100 different prairie and woodland sites to assess invasion, plant community compositions, and their responses to restoration efforts (which typically included removing the European buckthorn first). A variety of ecological data were collected to assess these sites. Earthworms were collected at the woodland sites to provide some insight on the scale of the invasion and the above-ground impact they have had on the woodlands. Overall, we evaluated the pattern of distribution of invasive earthworms and tested the hypothesis that there was a positive relation between habitat degradation and earthworm biomass.

### Methods

Woodlands in the Chicago region were selected and grouped into 4 management categories: control, identified as W0; early management <5years, identified as W1; intermediate management >10 years, identified as W2; and high-quality reference woodlands, identified as W3. In total, we sampled 5 control sites, 2 early-management sites, 4 intermediate sites, and 2 high-quality reference sites.

Earthworms were sampled in each of 4, 0.25m<sup>2</sup> circular plots placed 10m from the center point of a 1 hectare (100x100m) plot identified within each woodland. The 4 samples were taken in each cardinal direction. A mustard expulsion solution of ground, Hot Oriental Mustard Seed, *Brassica juncea* (Frontier Natural Products Co-Op), and tap water (381g/L) was prepared 12-24 hrs prior to extraction. The solution was then diluted into 5L of tap water in the field and poured incrementally into the plot. The worms were collected using insect forceps, placed into containers with moist paper towels, and transported to the lab in a cooler. The worms were brought to the lab to be identified, counted, weighed, and dried. Adult worms were identified to genus using a ventral-view of the clitellum, pigmentation, length, and shape of tail. Further identification of species was only employed on the *Lumbricus* spp. Non-pigmented juvenile earthworms were combined into one category and *Lumbricus* spp. juveniles were identified by their pigmentation, size, and tail morphology. The categories for species identification were: *Lumbricus*

*terrestris*, *Lumbricus rubellus*, *Lumbricus* spp. juvenile, *Aporrectodea* spp., *Octolasion* spp., and unidentified juvenile.

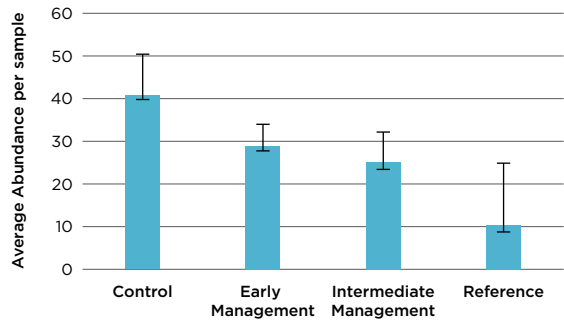
### Results

Earthworm total abundance and biomass was analyzed statistically using Analysis-of-Variance. The results are as follows for count,  $F= 3.17$   $p = 0.0780$ ; for wet,  $F=1.96$   $p= 0.1900$ ; and for dry,  $F=1.74$   $p=0.2276$ . The results from this study show that there is no significant impact in earthworm populations in different management categories. Table 1 shows the data from earthworm collection

The column of category refers to the level of management at the woodland sites, the total count is the average abundance per site, wet mass refers to the mass taken before the worms were dried, and the dry mass was taken after the worms were dried. Figures 1 and 2 show the average earthworm biomass and earthworm abundance per each management category.

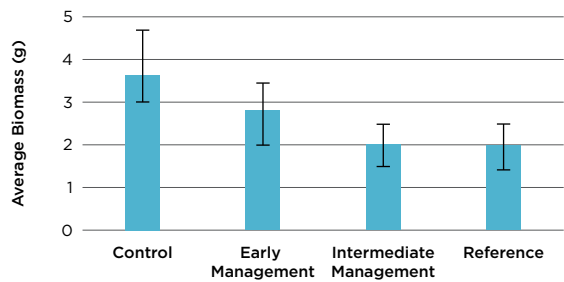
**FIGURE 1**

Earthworm Abundance Graph



**FIGURE 2**

Graph of Earthworm Biomass



**TABLE 1**

Earthworm Data

Woodland Site	Category	Total Count	Wet Mass (g)	Dry Mass (g)
WFG Northgate	W0	74.75	13.3028	2.5075
Winfield Mounds	W0	15	14.7593	2.62875
Conkey	W0	33.75	11.2185	2.394
GP E Sladkey	W0	34.4	35.0138	6.48525
Old School	W0	44.25	25.8683	5.22
West DuPage Woods	W1	23.5	9.75575	1.98725
Old School	W1	34	16.1148	3.5555
GP W Sladkey	W2	17.95	8.47792	2.18868
WFG Old Glen	W2	18.5	4.99825	1.03925
T. Stone	W2	19.3167	8.60135	1.58985
Macarthur	W2	45.75	17.2038	3.2945
Middlefork	W3	10.25	9.087	1.65275
Housiers	W3	11	12.205	2.31

Although there is a trend of decreasing abundance and biomass as management continues, that is, as the quality of the site increases, the overall earthworm population decreases. However, the statistical analysis showed that there is no significant difference in the earthworm abundance and biomass across different levels of management at the woodland sites (Figures 1 and 2).

## Discussion

Based upon prior work, I framed my research in the context of an invasional meltdown involving non-native earthworms and European buckthorn, where the invasion of one taxonomic group facilitated the spread of the other. I hypothesized that management targeting buckthorn would then have an impact on the earthworm populations. However, the results in our study show that restoration conducted on a fairly large scale within the Chicago wilderness region does not have a significant impact on earthworm populations. Further replication will be useful to examine if the management techniques that are currently employed are effective at decreasing the below-ground earthworm invasion. The results do not indicate that the invasions of buckthorn and earthworms are unrelated. Other studies conducted in this region show correlations between invasive shrubs and earthworm abundance (Heneghan et al., 2007). It is likely the case that even after buckthorn is removed, the conditions optimal for earthworms will still persist in the soil. Furthermore, it is still possible that the changes earthworms cause to the soil may facilitate re-invasion after restoration management.

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The results reported here are part of a larger body of research. The “100 Sites for 100 Years” project is examining a large number of specific sites across the Chicago region. Ultimately, earthworms will be collected from an even wider range of sites. However, this is a laborious procedure, and collection success is affected by soil moisture, which includes rainfall, temperature, and season.

Although there was no significant difference in the earthworm populations across the various management types in this study, these results are still a substantial contribution to the body of research that already exists. They demonstrate that restoration ecology cannot proceed without first acknowledging soil as an important factor in management. Many existing strategies target relatively few taxa and ecosystem processes (usually the above-ground components of ecosystems). New strategies are needed in order to target both the above and below-ground invasion.

## Acknowledgments

I would like to thank my advisors, Lauren Umek and Liam Heneghan, for their guidance. Also, the collection of data used in the study would not be possible without the interns: Liz Baylis, Jackie Beard, Lauren Miller, Phil Rothrock, Courtney Gill, Meghan Kern, and Krista Elhert. Thanks also to Professor David Wise from UIC, co-director of the “100 Sites” project. Finally, I would also like to thank the Gaylord and Dorothy Donnelley Foundation and the Gutsell Foundation, without their funding this research would not have been possible.

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# EXAMINATION OF THE INHIBITORY CHEMICAL AILANTHONE IN *AILANTHUS ALTISSIMA*

Samantha Sasnow\*

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**ABSTRACT** Ailanthone is a known inhibitory chemical of plant growth and seed germination produced by *Ailanthus altissima*. The objective of this project was to show the inhibitory effects of ailanthone in *Ailanthus* leaves with biological and chemical assays; this required creating a method to assay plant material. A successful bioassay that used minimum plant material was created along with a corresponding chemical assay. Ailanthone was then tested for allelopathic properties with a density experiment measuring radish growth at varying densities with different soil treatments. The results show that the growth of the radish plants in soil treated with ailanthone was most likely influenced by inhibitory chemicals.

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## Introduction

Urban biodiversity is an important issue for large cities like Chicago where non-native invasive species can threaten native plants. Many invasive species evolve allelopathic chemicals, biochemical “weapons” that can inhibit native plants that have not evolved ways to defend against these chemicals (Callaway et al., 2004). These chemical weapons allow invasive species to outcompete other plants and may ultimately decrease plant biodiversity in native ecosystems.

*Ailanthus altissima* is a native plant from Asia containing chemicals that inhibit plant growth and germination of seeds (Heisey, 1990). One of these chemicals, ailanthone, has been shown to inhibit seed germination in laboratory conditions, but its impact in nature is not fully understood. *Ailanthus* trees thrive in unlikely places and grow rapidly, which could positively affect the biodiversity in urban areas with less than optimal growing conditions. However, the negative inhibitory effects ailanthone has shown in a research environment could have the opposite effect on urban biodiversity. It is necessary to study ailanthone and

its possible allelopathic properties to better understand the role of *Ailanthus* in biodiversity. Ailanthone has been isolated as one of the inhibitory chemicals produced by *A. altissima*, but other chemicals may contribute to its inhibitory effects (Heisey, 1996). Not much is known about the production, movement, and breakdown of ailanthone or how *A. altissima* avoids auto toxicity. All of these are relevant subjects for questions when assessing the ecological impact of chemical weapons (Callaway et al., 2004).

The first purpose of this study was to develop a better way to evaluate the chemical activity of *Ailanthus* with biological and chemical assays and test ailanthone for allelopathic properties. Existing bioassays use large amounts of plant material, requiring the entire seedling to be destroyed. One goal of this project was to establish a bioassay using leaves and minimal plant material so future experiments could examine environmental influences on variations in ailanthone within the same plant.

Another goal of this project was to assess the impact of *Ailanthus* on the growth of other plants. Although it is generally difficult to separate chemical inhibition from competitive interaction, allelopathic chemicals have

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been shown to yield a larger plant size at an intermediate density, with a reduced size at high and low densities (Weidenhammer, 2006). This trend of plants exposed to allelopathic chemicals does not follow the normal trend of declining individual biomass with increasing plant density. The second part of this study set up an experiment to test the hypothesis that plants grown in pretreated *Ailanthus* soil will have an increased biomass or development at intermediate plant density levels in contrast to decreasing plant size with increasing density. This outcome is expected under resource competition.

## Methods

### Biological and Chemical Assays

*Ailanthus* plants grown from seeds found in a local greenhouse last spring were used to develop a biological assay to measure allelopathic properties without destroying the plant. Leaflets that were fully developed and found in the same location on each plant were used for the assays. Six leaf discs were hole-punched from each of four different plants and frozen at -17 C° for one hour. Biological assays using radish seeds were set up in a Petri dish with 90 mm filter paper and 5 mL of water. Each dish had three leaf discs along with three water controls interspersed between the leaf discs. One radish seed was placed on top of each leaf disc and in the water control spots with no disc, directly on the filter paper. A drop of water was placed on each seed twice a day for four days, and the primary root (radicle) was measured on the fourth day.

Chemical assays were prepared using a single leaf disc from each of the same four plants. A leaf disc was frozen for one hour and soaked in 1 mL of methanol for thirty minutes. For each leaf disc, 10 µL of the methanol solution were analyzed with a Waters Acuity high performance liquid chromatography (HPLC) with a 2.1x100 mm ACQUITY column BEH C18 1.7µm with a gradient of 0.1% trifluoroacetic acid (TFA) and acetonitrile. The ailanthone peak was identified by UV spectrum, and the peak area was recorded.

### Allelopathic Properties of Ailanthone

An experiment was set up to compare radish growth at different plant densities grown in soil either preconditioned or not preconditioned with *Ailanthus*. The soil from plants 1 and 3 from the first part of this project were used for this experiment; both of these plants contained the highest amount of ailanthone in their leaf disc when analyzed with HPLC (Table 1). Eight trays each containing four planting cells were used to grow radishes from seed. The four cells of four trays were filled with 40 cm<sup>3</sup> of the *Ailanthus* soil mixed with 40 cm<sup>3</sup> of Metromix soil. The four cells of four additional trays were filled with 80 cm<sup>3</sup> of Metromix. Equal amounts of *Ailanthus* and Metromix soil were used for the experimental trays to provide more replicates for the experiment. Within each tray, densities of one, two, three, and four radish seeds were placed in each separate cell and given 20 mL of water once a day, five days a week. The radish plants were harvested once they reached maturity after twenty days. The biomass of the radish plant above the soil was measured and bulb development was noted. Bulb development of each radish was noted on a scale: 1- no development, 2- beginnings of bulb development, 3- bulb developed.

**TABLE 1**

*Radicle Length with Standard Deviation and Amount of Ailanthone in Greenhouse Plants*

Greenhouse <i>Ailanthus</i> Plant	Bioassay Radicle Length Averages for Six Radish Seeds (mm)	Chemical Assay Area of Ailanthone Peak for 1 Leaf Disc (µV/sec)
1	0	147,717
2	0	124,921
3	0	196,387
4	0	66,357
Water Control	30.9±13.9	—

### Results

For the first part of the project, all four greenhouse *Ailanthus* plants showed biological activity and contained a measurable amount of ailanthone. Table 1 shows that the water control had a considerable growth of primary root

(radicle), while each radish seed on an *Ailanthus* leaf disc was completely inhibited from germinating. In the HPLC, the peak for ailanthone had a retention time of 2.33 minutes and an absorbance at 244.6 nm. However, the spectrum for each leaf disc contained an interfering peak at the same absorbance as ailanthone, which could possibly distort the recorded area of each peak. Because none of the radishes grew, it was not possible to correlate chemical activity (ailanthone peak) with biological activity to ensure that they are measuring the same attribute.

The results of the radish density experiment on *Ailanthus* pre-treated and control soils are shown in Table 2.

**TABLE 2**

*Average Biomass Measured for each Radish Plant Density*

Radish Plant Number	Central Biomass Averages from Four Trays	Ailanthus (1) Pretreated Soil Biomass Averages from Four Trays (g)	Ailanthus (2) Pretreated Soil Biomass Averages from Four Trays (g)
1	2.19±0.58	0.97±0.08	0.94±0.60
2	1.33±0.20	0.82±0.43	0.77±0.16
3	0.78±0.06	0.47±0.07	0.44±0.09
4	0.64±0.21	0.50±0.06	0.44±0.05

For each density treatment, the radishes grown in the soil from *Ailanthus* plants had a significantly smaller biomass than the radishes grown in pure Metromix. The difference in growth was greatest at the lower density treatments (Figure 1). Figure 2 shows the response of bulb development to soil treatment. The variation in bulb development is dependent on size, and size is determined by the soil and density treatment.

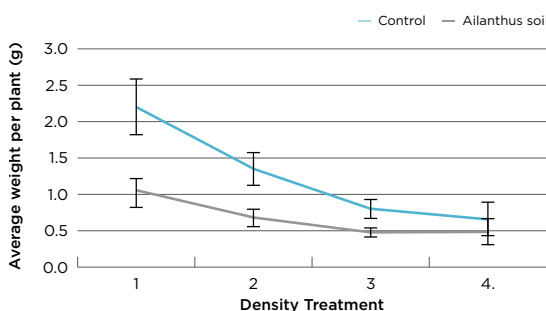
### Discussion

The first part of this project successfully created a way to assess the level of ailanthone in *Ailanthus* leaves using both chemical and biological assays. Prior to that, a biological assay of a plant required the whole plant to be destroyed, but the process of using single leaf discs

**FIGURE 1**

*Density and Soil Treatment vs. Average Weight per Plant*

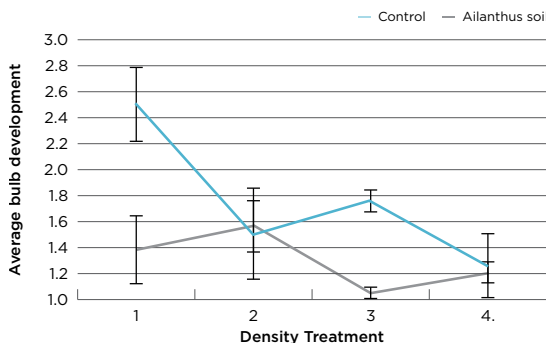
Effect of Soil Treatment on Radish Growth



**FIGURE 2**

*Density and Soil Treatment vs. Bulb Development*

Effect of Soil Treatment on Bulb Development



allows the plant to remain intact so that further assays can be taken. The experiment comparing activity in biological and chemical assays needs to be run again so that an association between these two assays can be confirmed. If confirmed, then it is known that both assays are measuring ailanthone activity, allowing the chemical assay to be used as a proxy for biological activity. The next step in this process is to create a method of separating interfering peaks found in the HPLC analysis. A purification process before performing the chemical assay would permit ailanthone to be quantified accurately in a single leaf disc. This would let further experiments test the possible antiherbivory and allelopathic effects of ailanthone. Determining the biological function of ailanthone will allow for further assessment of its impact on urban plants.

The experiment for the second part of this project suggests that chemical activity in the treated soil could explain the variation in plant weight and size. There was a slight increase from density treatment 1 to 2 for the bulbs of plants grown in *Ailanthus* soil. This supports the observation that allelopathy causes a reversal of normal plant size and density trends and so can be used to separate the direct effects of allelopathy from competition (Weidenhammer, 2006). At a density treatment of one, a radish plant is absorbing the entire inhibitory chemical. When there are two radish plants, they equally share the ailanthone, absorbing less per plant than the single radish plant. Plant densities at three and four will experience competitive interaction in addition to the chemical inhibition, so they tend to grow less than at a plant density of two. While the results support the idea that ailanthone is an allelopathic chemical, another possible explanation is that nutrient levels in the two different sets of soils varied. The *Ailanthus* plants

previously in the soil could have depleted it of nutrients that were preset in the fresh Metromix used for the control. Further experiments are needed to rule out nutrient deficiency as a possible cause for this variation.

There is currently no answer to whether *Ailanthus* has a positive or negative effect on urban ecosystems. This research suggests that ailanthone is allelopathic, but Reid Gustafson's research last year on the breakdown of ailanthone in soil suggests that it may be anti-herbivore (Gustafson, 2010). Allelopathy would suggest that *Ailanthus* has a negative impact on urban ecosystems by limiting the growth of competitive plants, while antiherbivory prevents animal damage, supporting a positive impact. This new methodology for assaying smaller samples of *Ailanthus* plants without damaging them entirely will allow future experiments to assess the role of *Ailanthus* in urban biodiversity.

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# P-N CAGE LIGANDS FORM 2-D COORDINATION NETWORKS WITH SOLVENT-FILLED CHANNELS

Kelly Pickering\*

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**ABSTRACT** The reaction of  $P_4(NCH_3)_6$  ligand and cuprous chloride forms a new compound with a two-dimensional structure made of “ruffled” sheets held together by the bonds between phosphorus and copper. The large pores formed between adjacent sheets are capable of holding solvent or other guest molecules. This information can be applied to the study of metal-organic frameworks and has implications for gas storage studies as well. Furthermore, this research is significant because it examines the reactivity of cuprous chloride with phosphorous atoms, atoms that have not previously received much attention in the application of gas and solvent storage.

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## Introduction

The identification of new metal-organic frameworks that are effective in storing gas and exploring the application of energy efficient technology, the synthesis of coordination polymers with gas storage ability would be a great asset to the advancement of alternative fuels, including hydrogen, which could ultimately lead to better environmental conservation. The vast majority of coordination networks and polymers studied for this application are based on coordination bonds between metal ions and molecules containing N and O atoms. Our studies introduced a new variety of coordination networks that would provide a different set of chemical properties. This research explored the capability of cuprous chloride and the  $P_4(NCH_3)_6$  cage ligand to form crystalline coordination networks with pores capable of effectively storing solvent particles. Future experiments will determine whether the trapped solvents can be removed, and the voids used to accommodate other “guest molecules” such as hydrogen.

## Experimental

All reactions were performed inside a glovebox with a

purified nitrogen atmosphere. Anhydrous benzonitrile was purchased from Sigma-Aldrich and used as purchased after storing over molecular sieves.

## $P_4(NCH_3)_6$ Ligand Preparation

Crude ligand was prepared according to the procedure of Holmes and Forstner (1966). Methylamine for the procedure was distilled from a 40% in-water aqueous solution through a column packed with glass beads; nitrogen gas was used to aid it in its journey through the distillation setup (Wolff et al., 1973). The gas was dried once more by passing it through a 1-foot column of potassium hydroxide pellets. The anhydrous methylamine was then condensed into the reaction vessel at  $-78^\circ\text{C}$ . Phosphorus trichloride was added while stirring the mixture with a mechanical stirrer. After warming over 4 days, the reaction mixture was extracted with dry hexanes, filtered, and evaporated to yield crude product. Vacuum sublimation at  $85\text{--}100^\circ\text{C}$  yielded pure ligand.

## Synthesis of $P_4(NCH_3)_6\text{CuCl}$ crystals in benzonitrile

A solution of  $\text{CuCl}$  in benzonitrile was created by dissolving 0.099g (0.10M) of cuprous chloride in 10 mL of benzonitrile; a magnetic stir bar was used to mix the solution for 10 minutes. Similarly, a batch of  $P_4(NCH_3)_6$

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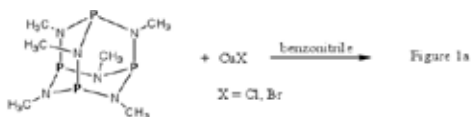
cage ligand solution was made by dissolving 0.301g (0.10M) of  $P_4(NCH_3)_6$  in 10 mL of benzonitrile. The two solutions were mixed in varying ratios of ligand to metal in separate 10 mL vials which were allowed to sit, undisturbed, for 2 days. Upon dropwise addition of the metal solution into vials containing more ligand than metal, each vial produced a flaky white precipitate that dissolved after being shaken, a good indication of future crystal formation.

### Synthesis of larger batch of 2:1 crystals

To perform characteristic analysis on the 2:1 ligand-to-metal ratio crystals, a larger volume of the two solutions was mixed in the hope of harvesting a more significant sample of crystals. Larger volumes of the two solutions were mixed in the same 2:1 ratio in two different 25 mL round-bottom flasks. The flasks were allowed to sit for one week in the nitrogen-atmosphere glove box. After one week, the crystals were harvested via vacuum filtration and washed twice. The precipitate was allowed to dry on the filter for 15 minutes and then the solid was transferred to a vial. The total yield of 2:1 crystals was 0.529g.

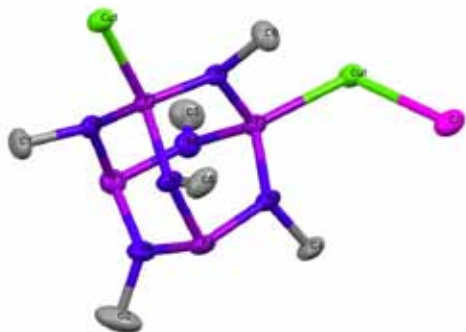
### REACTION 1

The reaction of tetradentate non-chelating ligand  $P_4(NCH_3)_6$  ligand with cuprous chloride in benzonitrile.



### FIGURE 1A

Asymmetric unit of  $P_4(NCH_3)_6CuCl$  in benzonitrile



### X-ray crystallography

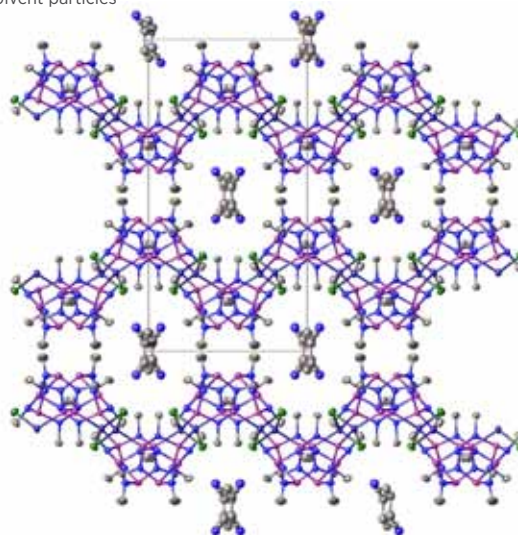
Crystals were handled under UV-curable adhesive and individually secured to the end of a small pin. The sample was then inserted into the SMART X2S benchtop diffractometer on loan from Bruker AXS. Information from the x-ray diffraction pattern, including estimated unit cell and orientation matrix, was interpreted by using XSHELL and the APEX2 computer software suite.

### Results and Discussion

By reacting  $P_4(NCH_3)_6$  cage ligand with cuprous chloride in benzonitrile, we found that a compound with large solvent channels and a 2-D, sheet-like structure, could be synthesized. The material was distinct in its structure compared to other solids isolated from the same reaction in different solvents (Wolff et al., 1973). For example, the reaction of the ligand-metal solution in acetonitrile produced three different structures depending on the ligand-to-metal ratio (Leser et al., 2010). In this experiment, the structure of the compound remained constant despite variations in the ratio of ligand-to-metal, as long as there was more ligand than metal. Crystals selected from a

### FIGURE 2

The 2-D, sheet-like structure of compound 1 with visible pores for solvent particles



sample of 2:1 ligand-to-metal ratio produced the same unit cell as those selected from the reaction of a 6:1 ligand-to-metal solution. This experiment was the first in our study. It suggests that the structure of the product can be manipulated by changing the solvent with less regard given to the ratio of ligand-to-metal, as observed in previous experiments.

**FIGURE 1A**

Asymmetric unit of  $P_4(NCH_3)_6CuCl$  in benzonitrile

Compound	6:1 Structure
Formula	$P_4(NCH_3)_6CuCl$
Fw	412.45
space group	C12/c1
a, Å	22.631(4)
b, Å	11.2610(18)
c, Å	14.052(2)
a, deg	90
b, deg	101.359(5)
g, deg	90
V, Å <sup>3</sup>	3511.0(10)
Z	8
$\rho_{calc}$ , g/cm <sup>3</sup>	1.561
$F_{000}$	1680
$\lambda$ , Å	0.71073
temp, °C°	300
$R$ ; $wR$	0.0524; 0.1878
GOOF	1.1

### Discussion of crystalline structure

The structure of the asymmetric unit was determined by analysis using a Bruker Smart X2S single-crystal benchtop diffractometer and the APEX2 computer software suite. Through refinement performed with the aid of APEX2, the structure of the compound was determined to have the molecular formula  $P_4(NCH_3)_6CuCl$  and a 2-D network of ligands and  $(MX)_2$  dimers. These compounds combined to form a “ruffled sheet” structure which contained bends in the sheet that prevented it from “nesting” together. An arrangement such as this contains open channels

that are partially occupied by solvent molecules. Single-crystal analysis allows an estimation of 0.15 solvent molecules for every copper ion present in the structure. This new structure is unique because it was synthesized from reactions with varying ratios of metal-to-ligand, a property unseen in our previous research. Furthermore, the findings highlight the important influence of solvents on the formation of coordination networks. Unlike the same reaction in acetonitrile, this reaction in benzonitrile always formed the same structure, even if different ratios of metal and ligand were used. This experiment is significant because it has introduced a new factor into the search for desirable metal-organic frameworks. Synthesizing a compound that can be formed in a 2:1 L:M ratio, instead of a 6:1 or 8:1, is helpful for conserving reagents. It also sheds light onto how these reagents interact and can be manipulated for the formation of porous materials with interesting (material) properties.

### Acknowledgement

I would like to thank Bruker Analytical X-ray Systems (Bruker AXS) for the loan of a SMART-X2S benchtop diffractometer to complete this work.

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# FITTING GAUSSIAN CURVES TO MASER PROFILES FROM THE W3(OH) STAR-FORMING REGION

Thomas C. Akers II\*

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**ABSTRACT** The reaction of P4(NCH3)6 ligand and cuprous chloride forms a new compound with a two-dimensional structure made of “ruffled” sheets held together by the bonds between phosphorus and copper. The large pores formed between adjacent sheets are capable of holding solvent or other guest molecules. This information can be applied to the study of metal-organic frameworks and has implications for gas storage studies as well. Furthermore, this research is significant because it examines the reactivity of cuprous chloride with phosphorous atoms, atoms that have not previously received much attention in the application of gas and solvent storage.

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## Introduction

Knowledge about the birth of high-mass stars is crucial for understanding the origin and future of our universe. These stars provide the material for everything that happens in the universe, from the birth of galaxies and other stars, to the basic building blocks needed for life. Currently, there is a basic understanding of how low-mass stars, those similar in size to our Sun, form but the formation of high-mass stars is still hotly debated. With this research, we hope to further our understanding of how these high-mass stars form and shed some light on the actual mechanics of the process.

Stars form when the material in a molecular cloud collapses on itself due to its own gravity. As the material flows inward, a protostar is formed, the first step in the creation of a star. In high-mass stars, these protostars are very large and emit large amounts of radiation, which pushes against the inflowing material. Previous theories assert that this high-radiation pressure would be enough to prevent additional material from flowing into the protostar, and stars would not grow much larger than our sun. High-mass

stars have been observed, however, and therefore must exist. Consequently, theorists were challenged to develop scenarios that would allow such stars to form. At present, there are many competing theories, but more observations are required to get to the bottom of this mystery.

## Methods

To observe high-mass, star-forming regions, radio telescopes are needed. Star-forming regions are filled with gas and dust, absorbing optical and other short-wavelength radiation. In contrast, the longer wavelength radio waves are not blocked by gas and dust in the region and make it possible to obtain clear images of the stellar nurseries. By studying the electromagnetic radiation emitted at radio wavelengths, we can further our understanding of these high-mass, star-forming regions. Large telescopes such as the Very Large Array (VLA) and the VLBA are important because they allow astronomers to obtain high-resolution images of these regions, much like a sharply focused picture, in contrast to a blurry one. One way to study high-mass, star-forming regions is by observing masers, common in such areas. Masers are very similar to the lasers that are seen in everyday life except they propagate at microwave (radio) wavelengths. Masers

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are bright, compact sources of light that are easy to detect and study with large telescopes such as the VLA and the VLBA. Masers reveal information on the motions of high-density gas near protostars and on magnetic fields at densities that are not accessible by any other means.

The W3 (OH) star-forming region studied for this project is located further out in the galaxy than our solar system and is currently a hotbed for high-mass star formation. Since it is located farther away from the Galactic Center than our solar system, it has a higher orbit velocity than our solar system, which is taken into account by measuring its systemic velocity (difference in the velocity of the region and our solar system) at -49.1 km/s.

The masers observed for this study come from a specific location in the star-forming region. The data for each maser is represented by maser intensity along the y-axis as a function of velocity along the x-axis. Intensity refers to the strength of the maser, whereas velocity refers to the line-of-sight velocity of the maser, indicating whether it is moving toward or away from the observer on average compared to the systemic velocity of the region. The goal of the project was to fit Gaussian curves to these profiles to determine the center velocity, the velocity line width, and the maximum intensity of the maser. These values are all coefficients in the equation for a Gaussian curve. A Gaussian curve is usually represented as

$$f(x) = Ae^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

where  $A$  is the maximum amplitude of the curve,  $\mu$  is the point on the x-axis where the maximum amplitude is located, and  $\sigma$  is the width of the curve related to the full-width-at-half-maximum of the velocity that we seek. The full-width-at-half-maximum is the width of the curve at half of the maximum intensity. Each coefficient was calculated from the data, so that the curves would fit properly. Residuals were calculated to see how accurate the fits were to the data by subtracting the value of the curve at a given point by the value of the actual data at the same

point; the difference tells us how close the two values are to each other.

To plot these Gaussian curves, the computer program MATLAB was used. Many scientists use MATLAB as it allows for the creation of individual functions to perform specific actions desired by the user. For the purposes of this project, MATLAB was used to read the data from files, plot out those points as a continuous graph, determine the maximum intensity of the curve, the location of the maximum, and the width of the curve at half of the maximum. To find the maximum intensity, the program was told to find the highest value on the graph and assign it to the  $A$  coefficient in Equation 1. The location of the maximum was the same, in terms of coding, as in the location on the x-axis as to where the maximum of the y-axis is located. Calculation of the width coefficient required determination of the standard deviation of the points located in the curve, the space between all the points in the x-axis, then dividing this value by the square root of the natural log of the values located in the curve. Each coefficient needed to be moved slightly by making adjustments to find the most accurate fit possible. In the process of making these fits, sometimes there would be profiles that were actually two masers very close together. These cases called for fitting multiple Gaussians to a single curve. This was done by making two Gaussian curves and adjusting them until their summation fit the data properly. Many of the profiles in the data required multiple Gaussians in order to get a proper fit. Figures 1 and 2 show representative profiles.

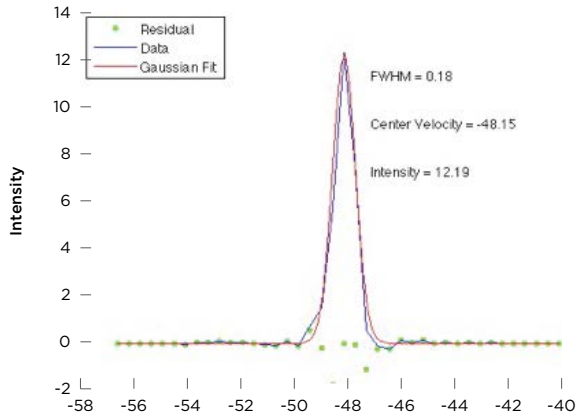
## Results

We fit Gaussian profiles to 32 masers, 19 of which were fit by single components as in Figure 1, 10 masers required two profiles as in Figure 2, and the rest required three or more profiles.

The fitted center velocities ranged from -45.10 km/s to -51.10 km/s. As we obtained values both greater and less

**FIGURE 1**

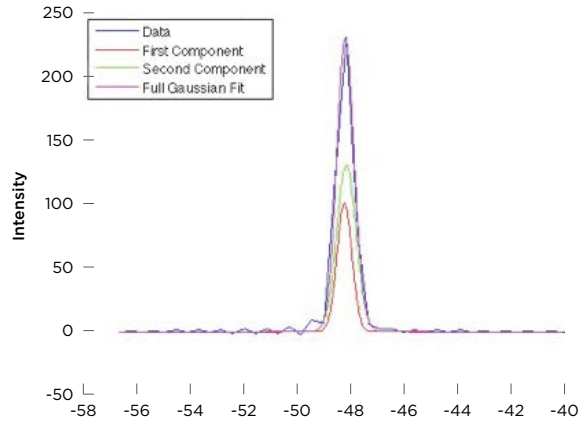
Graph of a simple Gaussian fit to a maser profile. The numbers at the top provide the location of the maser (first digit is the overall field, the next three are the x-axis location in that field, and the last three are the y-axis location in that field). The values displayed on the graph are the full-width-at-half-maximum, the center velocity (location of the max intensity), and the maximum intensity of the graph.



than the systemic velocity of -49.1 km/s, it is clear that some masers are moving toward us and some away from us along the line-of-sight. The full-width-at-half-maximum velocity line widths that we fitted, range from .026 km/s to .327 km/s, expected for these kinds of masers. Finally, the fitted amplitudes ranged from 5.24 to 217.24 Jy (Jansky). These values will serve as inputs to global studies of the movement of material in the W<sub>3</sub> (OH) star-forming region.

**FIGURE 2**

Graph showing a Gaussian fit requiring multiple Gaussians to make the fit. This type of curve required two curves added up to achieve a proper fit.



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Tony Diaz | *Dreams of La Habana* | 35mm Film



# EXAMINING THE FRACTAL DIMENSION OF GALAXY DISTRIBUTION

Jason Luce\*

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**ABSTRACT** According to Einstein's field equations, the geometry of the universe (size, shape, and expansion) is related to the amount of stuff in the universe (matter and energy). However, Einstein's field equations are difficult to solve, which necessitates finding other methods for understanding the underlying dynamics of the universe. The goal of this research was to determine if fractal geometry could be a useful tool towards these ends. The results show that the use of fractal geometry does show tentative promise as a method for obtaining an understanding of the evolution of the universe.

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A solid understanding of the distribution of matter in the universe is of great interest to cosmologists as the fundamental physics of the universe is encoded within. In particular, Einstein's field equations describe how the stuff in the universe (i.e. ordinary matter, dark matter, and dark energy) affects the geometry of the universe. The equation:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + g_{\mu\nu}\Lambda = \frac{8\pi G}{c^4}T_{\mu\nu}$$

describes this relationship, where (in broad terms) the left-hand side describes the geometry of the universe and the right-hand side describes the matter/energy content of the universe. The details of this formula are outside of the scope of this project, but the underlying idea behind it is not. In essence, Equation 1 says that matter shapes space and space affects matter. Unfortunately, this equation is extremely difficult to solve, as it requires information on initial conditions that is nigh impossible to determine. Solving it properly would require knowledge of the position of every single atom at the beginning of the universe! However, one way we can get clues about the initial conditions of the universe, as well as specifics about the matter/energy content of the universe, is by using statistical/geometric techniques. These techniques

are less dependent on knowledge of initial conditions, and instead focus on predicting average behavior for the matter and shape of the universe. Specifically, the use of the *fractal dimension* is a statistical/geometric technique that is seeing increased use in the scientific community.

Fractals were of particular interest to our project because the nature of Equation 1 is such that it becomes increasingly non-linear (more complicated) as time passes, and the dynamics of non-linear systems often display fractal properties. A fractal is a mathematical object that is self-similar (looks roughly the same) at all scales, and has non-integer dimensions. An example of a non-integer dimension is as follows: a straight line would have a fractal dimension of 1, while a jagged line might have a fractal dimension of 1.2 or 1.6 (any number greater than 1 but less than 2), depending upon the nature of its jaggedness. In short, the fractal dimension is used to measure the roughness and/or smoothness of a surface, structure, or distribution. The specific purpose of this project was to study how the fractal geometry of a given matter distribution (as described by its fractal dimension) would change over time. This was done to determine if the use of fractal geometry would be a beneficial tool for better understanding the evolution of the universe on both cosmological and local scales.

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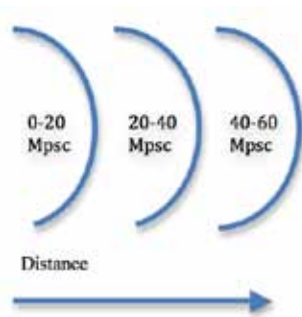
\* Advisor: Jesus Pando, Department of Physics. Summer 2010.  
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A natural way to track matter distribution in the universe is to examine galaxy distributions, as most matter is thought to reside in galaxies. However, to properly study galaxy distributions a large data set was needed in order to obtain valid results. To that end, we used the New York University –Value Added Galaxy Catalogue (NYU-VAGC). This collection of galaxy information draws heavily from the Sloan Digital Sky Survey (SDSS). The SDSS has obtained images covering more than a quarter of the sky and has created a sky map containing more than 930,000 galaxies.

Because we were interested in the evolution of the fractal dimension over time, we divided the NYU-VAGC data into a series of spherical shells centered on the earth, as shown in Figure 1 below. Each shell was set to the same thickness, and then stacked on top of each other. In this example, the blue arcs represented the first three shells in a series where the thickness was set to 20 Mpsc (Mpsc is short for megaparsec, or one million parsecs, where 1 parsec is approximately 3.26 light years). In this project, galaxy data was organized into shells with thicknesses of 20, 40, 60, 80, and 100 Mpsc, with an initial phase-shift of 0,5,10, or 15 Mpsc increments for each thickness. In other words, four data sets were created for each value of shell thickness, with the leading edge of the first shell for each data set beginning 0,5,10, or 15 Mpsc from the earth.

**FIGURE 1**

*Example of a series of spherical shells*



It should be clarified at this point that stacking these shells by distance is the equivalent to stacking them by time. This is because the light from the galaxies arrives at the earth at approximately the same time (simultaneous when viewed from a cosmological time frame). Since the speed of light is constant in all reference frames, the light that comes from a galaxy that is farther away from the earth than its neighbors is also light that comes from a galaxy that is older than its neighbors.

The distance of each galaxy from the earth was found by using their red-shift data, which was also available from the NYU-VAGC. Red-shift is a phenomenon that occurs because the universe is expanding, the end result of which is that light from distant sources is shifted into the red end of the spectrum (this is the visual equivalent of the Doppler Effect, which occurs when listening to a moving sound source). This distance is calculated using the following formula:

$$d_p = \chi(z) = \frac{c}{H_0} \int_{a(z)}^{a_0} \frac{da}{a - (\Omega_m + \Omega_\Lambda - 1) + \Omega_\Lambda a^{-(1+w)}}$$

where  $d_p$  is the calculated distance,  $z$  is the observed red-shift,  $c$  is the speed of light,  $H_0$  is the Hubble constant,  $a$  is a scale factor (i.e. a measure of the size of the universe),  $\Omega_m$  is the ratio of matter density to critical density (critical density is a value related to the expansion of the universe),  $\Omega_\Lambda$  is the ratio of dark energy to critical density, and  $w$  is the quintessence parameter (which is related to the *kind* of dark energy believed to be in the universe).

After creating these shells the data were pixilated by converting the azimuth and declination coordinates used to record galaxy position by the NYU-VAGC into a matrix of numbers representing galaxy densities. This process was required to apply the mathematical methods used to determine each shell’s fractal dimension. Pixilation was done using a program called SDSSPix (adapted by the author from C++ into MATLAB), which was specifically designed for this purpose.

From here we pared these pixelated shells into square matrices and used a mathematical method known as the discrete wavelet transform on each shell (wavelet transforms work best on square matrices). Wavelets were relevant to this project because they are mathematical objects that are inherently self-similar, in the same way that a fractal is self-similar. In essence, the discrete wavelet transform acted like a ‘mathematical microscope’ that examined each galaxy distribution on a scale by scale basis. As such, the use of the wavelet transform was an effective way to extract the fractal nature of the galaxy distributions contained in each pixelated shell.

The fractal dimension of each shell was determined by finding the slope of the power spectrum  $P_j$ :

$$P_j = \frac{1}{2^j} \sum \zeta_{j,l}^2$$

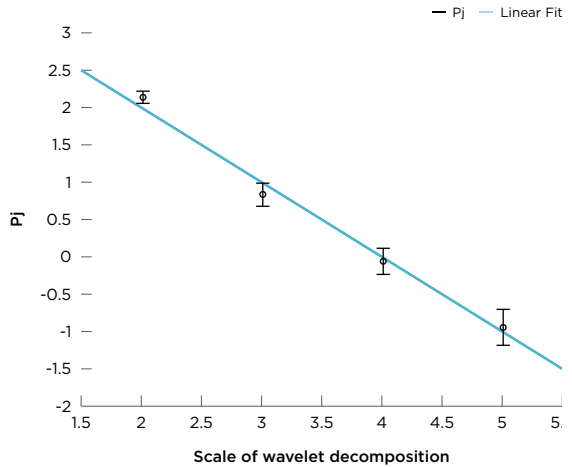
where  $\zeta_{j,l}$  is the wavelet coefficient. Wavelet coefficients are an important set of numbers that arise from a wavelet transform, examining these numbers told us how self-similar the values of a data set were. There were  $2^j$  wavelet coefficients at each scale, where  $j$  is the scale of the wavelet decomposition. Figure 2 shows an example of the process of using wavelet coefficients to determine the fractal dimension of a data set;  $P_j$  for each decomposition level of the wavelet transform was plotted against the scale of each decomposition level. The fractal dimension was the slope of the fitted line, and the error bars are one standard deviation of  $\zeta_{j,l}$  from the average value of the wavelet coefficients at that scale.

Figure 3 shows a sample plot of the fractal dimension vs. distance (in Mpsc) for a composite data set created from three adjacent and overlapping sections of the sky. The shells used in this sample were 40 Mpsc thick, with an initial offset of 5 Mpsc, and ignored all shells that had less than 1000 galaxies in them (data analysis showed that shells that were sparsely populated produced very large margins of error in the calculation of the fractal dimension; however, this was rarely an issue until shells were more than 1800 Mpsc from the earth). An initial analysis of this

plot suggested three distinct regions where the slope of fractal dimension vs. distance undergoes a large change. These three regions appeared to be from 5-200 Mpsc, 200-1200 Mpsc, and 1200 -1800 Mpsc.

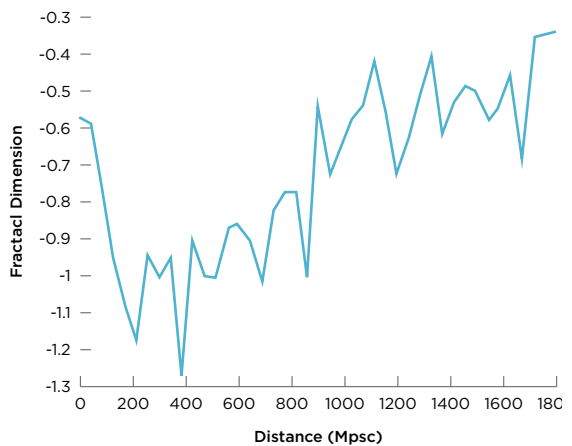
**FIGURE 2**

Example of a wavelet transform, where the fractal dimension is the slope of the linear fit.



**FIGURE 3**

Plot of fractal dimension vs. distance.



**FIGURE 4**

*Three-point-rolling average of fractal dimension vs. distance.*

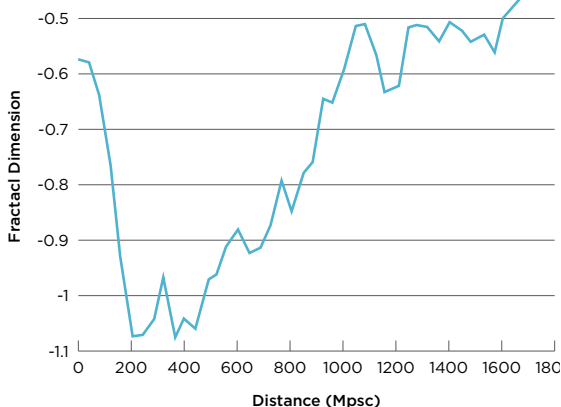


Figure 4 is the three-point-rolling average of the data from Figure 3. This technique was used to smooth out short-term fluctuations and highlight long-term trends. Applying this method to our data supported our initial conjecture that there are three distinct regions where the slope of fractal dimension vs. distance undergoes a significant change.

The region between 1800 Mpsc and 1200 Mpsc corresponds to an earlier time in the development of the universe, when the solutions to Equation 1 are still fairly linear and the change in the fractal dimension is relatively flat. The region between 1200 Mpsc and 200 Mpsc roughly corresponds to when it is believed that dark energy becomes the dominant force on the right side of Equation 1, representing a shift in the dynamics that define the shape of the universe. The region also refers to a time when the solutions to Equation 1 become quasi-linear (neither linear nor fully non-linear), and shows a sharp change in the fractal dimension over time. Finally, there is a sharp change in the direction of the slope of the fractal dimension in the region between 200 Mpsc and 5 Mpsc. This is representative of the present-day universe, where the solutions of Equation 1 have become fully non-linear, and is often referred to in physics as the

‘fully non-linear regime’. As mentioned previously, after 1800 Mpsc, galaxy density begins to steadily decline in the NYU-VAGC data set, meaning wavelet analysis becomes problematic or highly prone to error.

Finally, a Kolmogorov-Smirnov Goodness-of-Fit test was performed on the full collection of galaxy shells. This simple test is designed to determine whether the distribution function in one data set is related to the distribution function of a second data set (it doesn’t describe the nature of the distribution functions, just if they are likely to be different). In almost all cases, this test showed a change in the distribution function between the left and right side of the plot of the fractal dimension. This result suggests a change in the underlying dynamics between these two time frames.

While no definitive conclusion can be drawn from the results above, using the discrete wavelet transform to determine the change in the fractal dimension of galaxy distribution showed tentative evidence of a qualitative shift in the fractal geometry of the universe over distance, or time. In particular, the change in the slope of the graph of fractal dimension vs. distance at 1200 Mpsc could correspond to the time frame wherein dark energy is believed to become the dominant force in right hand side of Equation 1. Also, the turning point in the slope of the fractal dimension at 200 Mpsc could be related to the universe’s transition into the fully non-linear regime of the present day. In either case, the change in slope of the fractal dimension could be indicative of underlying changes in the dynamics of Equation 1. This conclusion is supported by the Kolmogorov-Smirnov test, which suggests a change in the distribution function that describes the fractal dimension of galaxy distribution over time. Based on these results, the use of fractal geometry in future studies to examine the change of galaxy distribution over time shows promise as a viable method for learning more about the evolution of the universe.

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Anna Papuga | *Green Desert* | Digital Photography

# MAPPING OF COSMIC-RAY RADIATION

Richard Whittmore\*

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**ABSTRACT** Cosmic rays are charged particles that travel from their point of origin through space. Along the way they interact with magnetic fields. As a result, they are constantly scattered throughout space. We expect, then, to see cosmic rays bombard the Earth from every direction. To determine if they do, we constructed a balloon-borne cosmic ray detector. We found that cosmic rays do indeed bombard the Earth from every direction, with a greater number of cosmic rays coming from the direction of the Sun.

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## Introduction

First discovered in the early 20th century, cosmic rays are energetic atomic nuclei or electrons that constantly bombard the Earth. Some originate in the nearby energetic processes of our sun, others from the cataclysmic events of supernovae, while others come from unknown events. As they travel from their origin, they encounter magnetic fields that extend throughout space. Because the particles are charged, they interact with these fields. As a result, their trajectories are constantly altered. This has the effect of scattering the particles in every direction possible. Hence, we expected the Earth to be bombarded from every direction.

## Methods

An instrument was constructed with the ability to detect cosmic rays high in the atmosphere since this is where they begin to collide with air molecules. It was developed with a number of subsystems to support its operation. These included the actual detector itself; an array of electronics to amplify, digitize, and store the data; orientation sensors; radio and GPS transponders; and a weather balloon to carry it into near space.

The detector was constructed from scintillator material and a photodiode. The scintillator material is a block of

clear plastic that has the special ability to emit a flash of light in response to a collision. The photodiode is a semi-conductor device with the ability to convert light into a current. Thus, when a single cosmic ray strikes the scintillator material, the particle imparts its energy to the molecules in the material, and the material then re-emits the energy in the form of a small flash of light. The light is converted into a current by the photodiode. This current is digitized and registered as a single count after it has gone through signal processing.

The current must go through signal processing because it is extremely weak; it is on the level of nano-amps ( $1 \times 10^{-9}$  amps). If one were to power a typical 60-watt light bulb that requires 0.5 amps, it would need 500 million nano-amps to get the job done. As a result, naturally occurring electrical noise that has the same amplitude as cosmic ray signals has the potential to act as a source of false positives. To prevent false positives, the scintillator material was wrapped in black electrical tape. This reduced the amount of electrical noise, which is created by light.

To amplify the current, we built a circuit with an operational amplifier and comparator. Figure 1 illustrates the layout. Located on the upper left, the photodiode sends the converted current to the OPA 380, an operational amplifier. Here, the current is amplified and converted to a voltage. This voltage is sent to the LM339N, a comparator. Based on a threshold voltage the signal is digitized here.

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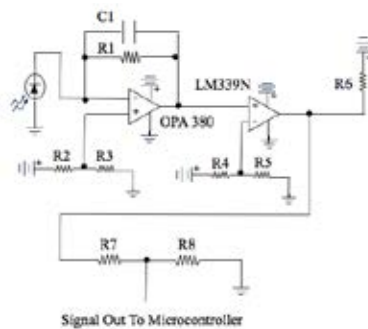
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The microcontroller then receives the digitized signal. Here, it is processed and written to an onboard flash drive. The code to collect, process, and interface with the flash drive was written by us.

**FIGURE 1**

A layout of the electrical circuit. On the upper left hand side of the diagram, the photodiode detects a signal, which it then converts to a current that is sent to the amplifier, OPA 380, and then to the comparator, LM339N, to be digitized. In the picture, the amplifier is located on the left and the comparator on the right.



In addition to receiving detector data, the microcontroller also receives orientation data. The orientation is needed because as the instrument is taken into near space, it is subjected to a great amount of turbulence. As a result, we would not know from which direction our detected cosmic ray originated. The sensor we used employed three accelerometers, three gyroscopes, and three magnetometers. From this, we determined the three-dimensional orientation of the instrument.

We constructed an array of detectors. These were positioned on a slant in an octagonal pattern with two placed in the center looking upward. This required 10 separate detectors, each with their own scintillator material, photodiode, and amplifier circuit.

The array of detectors, the orientation sensor, the microcontroller, and their respective power supplies were mounted on a rigid structure capable of surviving the trip to near space multiple times. Figure 2 illustrates

the arrangement. The structure was constructed out of polystyrene foam insulation material. Built with two levels, the array was mounted on top, and the remaining components were placed underneath. For protection, it was placed within a big box, not seen here, made of the same material.

**FIGURE 2**

On the left is an image of the structure with the array of detectors sitting on top. Notice how the individual detectors are mounted with Velcro. On the right is a side view that shows the microcontroller, the orientation sensor, and power supplies beneath the array.



### Data Collection

The instrument was attached to a weather balloon that, on average, reached heights of approximately 20 miles. Also attached were a long train of cargo that consisted of a parachute, some cameras similarly encased in foam boxes, and radio and GPS transponders. The transponders were included because without them we would not be able to retrieve our data. To guarantee retrieval, we included two in case one was to malfunction.

We needed a rural environment, such as a large open field, to launch the balloon. Therefore, we launched from the Koerner Aviation field in Kankakee, Illinois. To further guarantee retrieval, our team was split into two groups. One group stayed at the aviation field until the balloon was launched and all necessary equipment was put away. The other left slightly before the launch and travelled in the direction of the projected landing area. We did this because as the balloon ascends, it passes through the jet stream where it is hurled at speeds of roughly 100 mph. As a result, it travels very quickly, and within a short amount of time it can travel past the horizon, at which point we would lose contact with the transponders.



We conducted two launches without experiencing any major difficulties. The flights lasted approximately an hour to an hour and a half, and the cargo landed 60 miles away from the launch site, on average. The retrieval time, on the other hand, lasted anywhere from several minutes if the cargo landed in an open field to several hours if it landed in a tree or a cornfield.

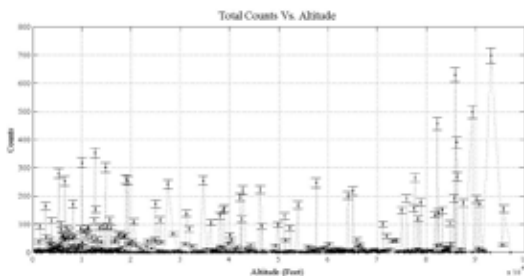
### Results

We used MatLab, a computing platform with data analysis and visualization capabilities, to analyze all of the data. We removed data collected prior to and after the flight as well as any outlying data points that were the result of severe ringing in the amplifier circuit and/or mechanical stress.

By combining the data from all of the detectors on the first flight, we found that the number of counts increases as altitude increases. This is illustrated in Figure 3. The graph displays the sum of the counts detected as a function of altitude in feet. It also displays the error in our measurements, which was calculated by assuming standard error. As can be seen, there was a marked increase in counts above 70,000 feet with activity peaking around 90,000 feet.

**FIGURE 3**

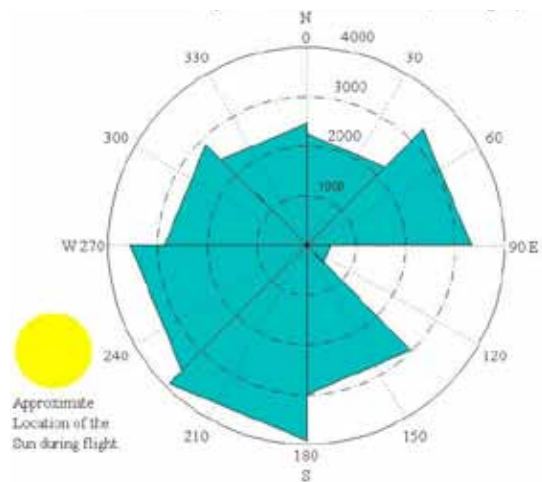
A graph of all the counts detected in our first flight by all ten cosmic-ray sensors as a function of altitude. Standard error was assumed. Note how counts begin to increase near 70,000 ft. and peak near 90,000 ft.



By plotting the number of counts as a function of orientation, we found that the Earth is bombarded from every direction. Figure 4 illustrates the data for the first flight. It is a rose plot, where the total counts are displayed as a function of the azimuthal direction. To help better visualize the orientation, we included the approximate location of the Sun. As can be seen, counts above 3000 were recorded from the southwestern and northeastern parts of the sky. In all other directions, the counts were slightly close or well below that figure.

**FIGURE 4**

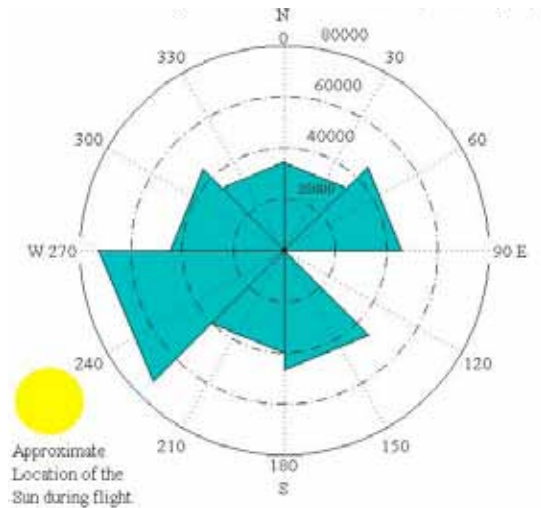
Total Counts by Azimuthal Direction (1st Flight): The sum of the counts detected by the eight directional sensors as a function of orientation at the time of detection for our first balloon flight. Also shown is the approximate position of the sun at the time of the flight. Notice that most of the cosmic rays originate from the direction of the sun.



Likewise, we found a similar pattern in the second flight, as can be seen in Figure 5. We found, once again, that most cosmic rays bombard the Earth from the southwestern and northeastern parts of the sky. The only significant difference was that no counts were detected from the southeastern direction. We do not know why this is the case. More flights are needed to determine the cause.

**FIGURE 5**

Total Counts by Azimuthal Direction (2nd Flight): The sum of the counts detected by the eight directional sensors as a function of orientation at the time of detection for our second balloon flight. Also shown is the approximate position of the Sun at the time of the flight. Notice that most of the cosmic rays originate from the direction of the Sun.



### Discussion & Conclusion

As expected, we found that the Earth is bombarded by cosmic rays from every direction. In both flights, a significant amount of counts were detected from the southwestern portion of the sky. The most likely explanation for this observation is that these cosmic rays originated from the Sun. After all, the Sun was located in that direction at the time of the observations, and it is the closest creator of cosmic rays to Earth. However, what was not expected was the low count of cosmic rays in the southeastern portion of the sky. As of yet, we do not know why this is the case. .

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### Acknowledgements

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# THE VERMICELLI HANDLING TEST: A NEW BEHAVIORAL TEST TO EXAMINE MANUAL DEXTERITY FOLLOWING TRAUMATIC BRAIN INJURY (TBI) IN THE RAT

Kevin E. McDonough\*

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**ABSTRACT** The Vermicelli Test examines manual dexterity while eating pasta in animal models of stroke.

This study used the Vermicelli Test in an animal model of traumatic brain injury (TBI) during a 42-day testing period. Videos of animals eating pasta were analyzed for total eating time, paw adjustments while eating, and abnormal behaviors. The results showed that a TBI results in deficits in the Vermicelli Test; a decrease in adjustments of the impaired paw and an increase in abnormal behaviors while eating the pasta. These findings suggest that this test could be a useful tool to examine forelimb function and recovery following TBI.

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## Introduction

In rat models of stroke that affect one side of the brain and produce deficits in one forelimb, and models of Parkinson's disease, motor dexterity and impairment of the affected forelimb can be measured using a variety of different tasks. One new task recently developed to assess dexterity of both forelimbs is called the "Vermicelli Test" (Allred et al., 2008). It involves allowing the animal to eat dried vermicelli pasta and videotaping the behavior. The videotapes are then slowed down and watched to count the number of forelimb adjustments and abnormal eating behaviors performed by the animal during eating (Allred et al., 2008).

Animals without a deficit grasp the piece of pasta with both paws and make a near equal number of adjustments with both paws while eating. An *adjustment* is defined as any movement of the paw in which the animal releases its grasp on the piece by removing the digits of the paw from the pasta and then grasping the piece again. This test was previously performed on models of ischemic stroke (stroke

due to a lack of oxygen) in the forelimb sensorimotor cortex (FL-SMC), an overlap area of the brain that controls the movement and sensation of the forelimb. It was also performed on models in which there is significant cell degeneration due to blockage of the medial cerebral artery and in models in which there is damage to the nigrostriatal axons in the medial forebrain bundle, creating Parkinsonian-like symptoms. In animal models of ischemic stroke and Parkinson's disease, animals typically have one forelimb (the impaired forelimb) that is affected and has significant deficits, and one forelimb (the unimpaired forelimb) that compensates for the deficits (Allred et al., 2008). In the Vermicelli Test, adjustments of the impaired forelimb were reduced following injury and remain decreased over the 28-day testing period. Additionally, abnormal pasta-handling behaviors were observed to be increased following injury. In the Parkinson's model, not only was there a decrease in impaired limb adjustments, but adjustments of the unimpaired paw were increased as a compensatory mechanism and the time to eat the vermicelli piece also increased. This test, though, has never been performed in animal models of traumatic brain injury (TBI).

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The TBI model used in this study injures the FL-SMC and, as seen in other models, it was expected that animals that receive an injury to this area will have a decreased number of adjustments of the impaired paw and an increased number of adjustments of the unimpaired paw. It was also expected that there would be an increased number of abnormalities observed during the test.

## Methods

**Animals:** Male Hooded-Long Evans Rats (250-350g) were randomly assigned to receive a controlled cortical injury (CCI) to the forelimb sensorimotor cortex (CCI group n=8) or no injury (sham group n=6). All procedures were approved by the Institutional Animal Care and Use Committee (IACUC) and the Animal Care and Use Review Office of the Department of Defense (ACURO).

**Controlled Cortical Impact to the FL-SMC:** Once animals were anesthetized using Equithesin, a CCI to one side of the brain was administered over the FL-SMC by the Benchmark Impactor (4mm craniotomy, skull removal) at coordinates: 0.5mm Anterior/Posterior & 4mm Medial/Lateral). Impact was delivered by a flat impactor tip (3mm) perpendicular to the surface of the brain, penetrating 1.7mm Dorsal/Ventral (18o angle; 3.0 m/s). Animals that did not receive the injury (shams) received all procedures up to, but not including, the craniotomy. The side of the injury was determined by the animal's handedness, decided via a different test used as part of a larger rehab study.

**Vermicelli Test:** Prior to testing, animals were exposed to vermicelli pasta for familiarization by leaving pieces in their home cages. Animals were tested on days 0 (baseline) and days 10, 25, and 42 post-injury. The rats were given 7cm pieces of Safeway-brand vermicelli pasta either in their home cage or another familiar enclosure and allowed to eat the pasta. The behavior was videotaped using a Canon XL2 digital-video recorder. The goal was to record rats eating 5 entire pieces of vermicelli pasta. Tapes were later played back at a slow speed for rating.

**Rating of behavior:** Videos were rated in slow motion to allow for more accurate rating. For each piece of pasta, the number of adjustments and abnormalities were recorded.

## FIGURE 1

An example of a right paw adjustment recorded during the vermicelli test. (Images taken from Allred et al., 2008).



Adjustments for each paw were tallied and marked as either left or right. After rating, left and right adjustments were then labeled as either opposite (contralateral) or same side (ipsilateral) to the injured hemisphere. An "Adjustment Score" was obtained by adding up the total number of all the adjustments for all 5 pieces recorded. If the animal did not consume 5 pieces, then the total number of adjustments was divided by a ratio of pieces consumed to 5 pieces.

The "Abnormality Score" was calculated in the same manner as the adjustment score. Abnormalities most commonly observed in this test were failure to contact the piece with a paw during consumption, dropping the vermicelli piece during consumption, changing the grasping hand, placing hands together on a long piece of pasta, and breaking the vermicelli piece during consumption.

The amount of time it took for the rat to eat each piece of pasta was also recorded. Eating time was calculated by taking the total time it took the animal to eat all five pieces recorded. If the animal did not eat 5 pieces, the total time was divided by the ratio of pieces consumed to 5 pieces.

An analysis of variance (ANOVA) was conducted to test for differences between CCI and sham groups as well as between days, where a *p* of less than 0.05 indicates a significant difference between groups. A repeated-measures ANOVA

**FIGURE 2**

Examples of abnormalities exhibited during testing. (A) Paws together when piece is long. (B) Failure to contact piece (arrow). (C) Dropping vermicelli piece. (D) Paws apart when piece is short. (Images taken from Allred et al., 2008).



was used to test for significant difference of groups over testing days.

### Results

Animals that did not receive an injury showed no change in the number of adjustments of either paw throughout

the 42-day testing period. Additionally, there were no differences in the number of abnormalities observed. Sham animals did, however, show a decrease in time to eat throughout the testing period ( $p < 0.0212$ ).

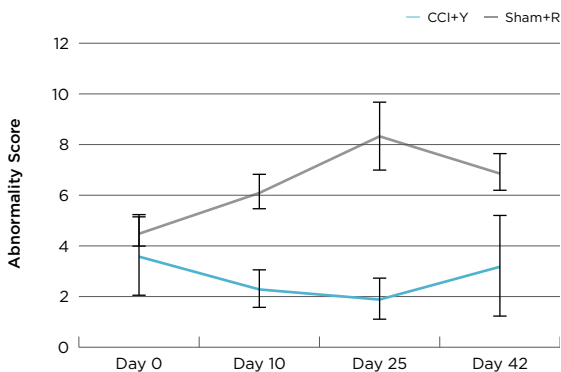
Animals that received an injury to the FL-SMC showed a statistically significant decrease in the amount of adjustments of the impaired forelimb when compared to animals that did not receive any injury ( $p < 0.0005$ )

This decrease remained consistent throughout the 42-day testing period following injury. In post-hoc analysis, CCI animals showed significantly fewer adjustments on the injured side when compared to non-injured animals on each day of testing except for pre-operative day 0. There was not a significant increase to the number of non-injured side adjustments following injury when compared to animals that received no CCI

Furthermore, animals that received an injury showed a significant increase in the amount of abnormal behaviors performed during consumption, which remained elevated throughout the testing period ( $p < 0.0246$ ).

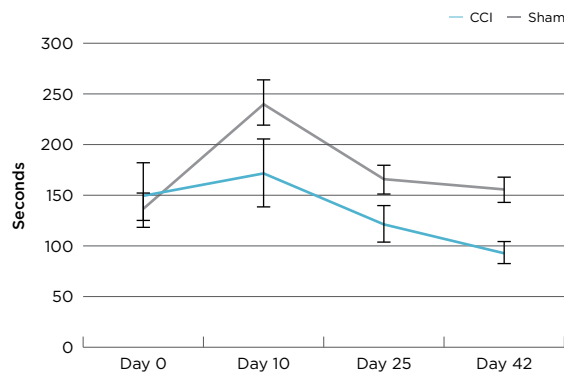
**FIGURE 3**

Rats with CCI (injury) show a decreased number of adjustments with the impaired limb (Contralateral adjustments) compared to those without injury. (\*  $p < 0.0005$  significantly different than Sham)



**FIGURE 4**

Although there is an increase, rats with CCI show no significant differences in the number of non-injured side (ipsilateral) adjustments when compared to the sham group throughout the testing period.



Finally, there was no statistically significant difference in the time taken to eat each piece of pasta between animals that received a CCI and those that did not, though the trend does make it appear as if injured animals take longer to eat

### Discussion

To date, the Allred et al. (2008) study is the only one to have used the Vermicelli Test to assess deficits following neuronal degeneration. The models used in that study were ischemic injuries to the FL-SMC, ischemic injury to the brain following blockage of the medial cerebral artery (MCA), and a Parkinsonian model.

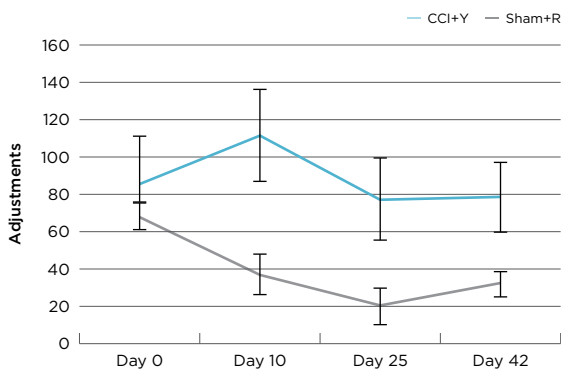
The results of this study show that animals with an injury to the FL-SMC showed a statistically significant decrease of adjustments with the injured paw with no significant increase or decrease of adjustments seen in the non-injured limb. There does appear to be a trend in decreasing number of non-injured adjustments in sham animals and an increase in non-injured adjustments in CCI animals; however, the difference is not significant. These results

remain consistent with the study performed by Allred et.al. (2008) in the model of ischemic stroke to the FL-SMC; there was a deficit seen with impaired limbs, and no increase of non-injured side adjustments. The increase in the amount of abnormalities found in the TBI model also resemble the results of the Allred et al. study for animals that received lesions to the FL-SMC as well as those that received MCA occlusion or damage to the nigrostriatal medial forebrain bundle. In that study, Parkinsonian models also showed an increase in total eating time. This result was not observed in this study. In fact, there was a statistically significant decrease in total eating time by sham animals, which suggests that there is a learning component involved in this test and that the animals are learning to become more efficient while eating. In Parkinson's models, animals receive an injury to a different area of the brain, having a greater effect on motor function than damage to the FL-SMC, which likely leads to the increased eating time not seen in other models of brain injury.

When compared to other behavioral tests, the Vermicelli Test provides a useful method in determining motor deficit because it examines fine motor movements of the

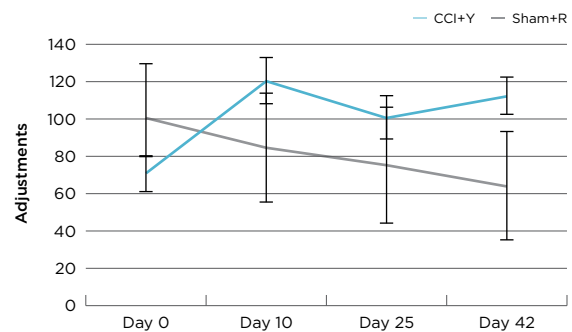
**FIGURE 5**

CCI animals show an increase in abnormal handling behaviors per piece of vermicelli pasta. (\*  $p < 0.0246$  significantly different than Sham)



**FIGURE 6**

CCI (injured) animals showed no significant difference in time to eat when compared to non-injured animals, although there was a trend for injured animals to take slightly longer to eat the pasta post-injury. Sham animals do show a significant decrease in time to eat ( $p < 0.0212$ )



animals' hands and digits while manipulating a symmetric and uniform object. Other tests simply measure gross motor function and motor deficit, but ignore the finer digit and hand movements. Furthermore, the Vermicelli test provides a more detailed method of measuring the negative effects following injury to the motor cortex. In previous studies examining impairments using food items, deficits were measured using generic scales, rating the animal's behavior while manipulating various shapes and sizes of foods. These scales rated the animal's behavior on a four-point scale, observing specific behaviors that the animals exhibited while eating thin pasta, focusing mainly on contact (or lack thereof) to the piece during eating (Wishaw et al., 1995). The scale, however, provided less-detailed data regarding deficits when comparing injured and non-injured limbs. The Vermicelli Test allows for a more quantitative measurement to assess forelimb function following injury, comparing the number of adjustments between paws. Researchers are then able to precisely measure the return of function between test groups.

This test showed a sustained deficit following TBI. Consequently, it can also be useful when used to compare pharmacological treatments. In other measures of deficit,

simple repetition of the test can often increase the animal's ability to perform that test, which may obscure observation of the drug's effectiveness. The sustained deficit allows researchers to measure the return of function due to pharmacological treatment or other manipulations.

The Vermicelli Test is a sensitive test of forelimb deficits which can be used to test neuroprotective agents as well as the effects of motor rehabilitation following a Traumatic Brain Injury. Future applications of this test will be used to measure the effectiveness of various forms of rehabilitation following TBI in conjunction with other tests measuring both fine and gross-motor deficits, something that has not been researched as thoroughly as it has been in models of ischemic injury. The Vermicelli Test will also be implemented in a project studying the effectiveness of mesenchymal stem cell transplants following TBI.

#### **Acknowledgements**

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# REHABILITATION REGIMEN INFLUENCES BEHAVIORAL RECOVERY AND NEUROPROTECTION FOLLOWING A CONTROLLED CORTICAL IMPACT (CCI)

Steve Lance\*

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**ABSTRACT** Effective treatments for those who have experienced a traumatic brain injury (TBI) have remained elusive. This study examined 3 different modes of rehabilitation in the animal model of TBI, the controlled cortical impact (CCI), to determine if rehabilitation can induce recovery. The 3 modes used to assess the effectiveness of the rehabilitation were reach training, exercise, and forelimb constraint. Behavioral recovery was examined using the limb use test and neuroprotection was examined with an analysis of cortical volume. Only those animals that received a combination of all rehabilitative treatments demonstrated an enhanced behavioral recovery and neuroprotection, which was statistically significant when compared to CCI+Yoked animals. Constraint-only animals demonstrated behavioral recovery, but not neuroprotection. These results indicate that a more robust rehabilitation regimen is necessary when compared to stroke animals, in order to induce behavioral recovery and neuroprotection.

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## Introduction

With the increase in combat fighting over the past ten years in Iraq and Afghanistan, instances of traumatic brain injury (TBI) have also seen a drastic increase over the same period (Speziale et al., 2010). Yet many aspects of TBIs remain relatively uncharacterized and poorly understood by the neuroscience community. Individuals suffering from a TBI rarely have the benefit of a medicinal treatment that prevents the death of surrounding injuries following the initial injury. Thus, developing a rehabilitative regimen to treat TBIs becomes an essential component in addressing and treating individuals requiring neurorehabilitation. Modes of rehabilitation have been extensively studied in animal models of stroke (Maldonado et al., 2008; Nudo, 1996), but similar knowledge of neurorehabilitation and plasticity in the injured brain following a TBI is limited. Therefore, it is important to determine whether similar

rehabilitative methods used in stroke can induce recovery in those suffering from a TBI.

In animal models of stroke, tissue surrounding the area of damage undergoes functional and structural plasticity, whereby neuronal pathways are redeveloped. Essentially, pathways that were damaged due to the stroke were able to reform and rewire along new pathways so that functions damaged by the injury could be regained. These areas of plasticity also have been shown to take on functions of the injured area, an essential component in the recovery of behavioral injuries following a stroke (Jones, 2009). Reach training in animals following a stroke has led to improvements in the function of the damaged forelimb, promoting plasticity, and preventing the loss of undamaged tissue located near the site of the damaged tissue (Maldonado, 2008; Hsu & Jones, 2005). The application of these various forms of rehabilitation, alone and in combination, may lead to plasticity and increased function of neuronal pathways damaged by a TBI.

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Recently, it was reported that although a controlled cortical impact (CCI) to the sensorimotor cortex induces behavioral impairments, there is a difference in how the brain tries to repair itself (Liput et al., 2008). Contrary to stroke models, the CCI injury did not induce plasticity, and regrowth of neuronal function was not observed. Thus, it is not clear if rehabilitation of motor behaviors will be as effective following TBI. The current study examined the effectiveness of rehabilitative training, exercise, and forelimb constraint, both alone and in combination, on behavioral recovery following a CCI over the forelimb sensorimotor cortex (FL-SMC). The overall effectiveness of the various rehabilitative measures was assessed following a CCI by examining how animals use their front paws during weight bearing exploratory behavior (through the limb use test), and by measuring the remaining cortical volume. Ultimately, it was predicted that more combinations of rehabilitative procedures would lead to a more robust recovery, resulting in a greater degree of neuroprotection.

## Methods

All protocols were approved by the Institutional Animal Care and Use Committee (IACUC) and The Animal Care and Use Research Office (ACURO) of the Department of Defense.

**Shaping and Delivery of CCI:** Male Hooded Long-Evans rats were used. Prior to the delivery of the CCI, rats were trained on the various rehab tasks and their dominant paw was determined. Following the determination of the dominant paw, rats were randomly placed in a group.

Placement in these groups determined whether or not they would receive a CCI, and the type of rehabilitation they would receive following delivery of the CCI. A CCI was administered over the FL-SMC by the Benchmark Impactor. After animals were anesthetized with Equithesin and a portion of their skull was removed, impact was delivered by a flat impactor tip (3 mm), perpendicular to the surface of the brain. Animals that did not receive a CCI (Shams),

received all procedures up to, but not including, the craniotomy. A unilateral injury to the FL-SMC produced one forelimb that was injured and one that compensated for this injury.

**TABLE 1**

*Rehabilitation Groups:* Rehabilitation groups and the number of rats that completed testing for each respective group. Rats were randomly selected for these groups.

Group	n	Group	n
CCI+Reach+Ex.	9	Sham+Reach Training	6
CCI+Reach+Ex.	11	Sham+Reach+Exercise	6
CCI+Reach+Ex+Forelimb Constraint	9	Sham+Reach+Ex.+Constraint	7
CCI+Reach+Ex.	10	CCI+Reach+Ex.	5
CCI+Reach+Ex.	8	CCI+Reach+Ex.	6

**Neurorehabilitation:** Rats underwent various forms of rehabilitation following delivery of the CCI or sham procedures based upon their designated group placement (Table 1).

**Reach Training:** Prior to surgery, animals were trained on a forelimb-reaching task in order to determine a baseline and preferred forelimb function. The reach-training task required the animals to use their impaired forelimb in the retrieval of pellets from a tray placed outside the container where the rat was situated. Reach training started on day 3, post-CCI, and was administered once a day until the end of the study, day 42.

**Exercise:** Rats placed in exercise groups were given voluntary access to a running wheel 6 hours a day (3 hours in both the light and dark cycle).

Running distance was measured following the completion of the 6 hour exercise period. Exercise started on day 14, post-CCI, and continued until the end of the study on day 42.

**Forelimb Constraint:** On post-CCI day 10, rats were placed into limb-restricting vests (soft, customized rat jackets with tape used to immobilize the less-affected forelimb).

The vests were worn continuously between day 10 and 20, post-CCI.

A yoked control group was also designated for a group of rats that would not receive the various rehabilitation procedures. Non-rehabilitated animals were placed in the reaching chamber and received pellets on the floor at the same rate that reaching rats retrieved them in the tray. Non-exercised rats received access to a locked running wheel during exercise periods. Furthermore, animals not receiving forelimb constraint were fitted with control vests. **Examination of Forelimb Function Post-CCI:** Rats were tested for the use of their forelimbs in weight-bearing movements during exploratory behavior using the Limb Use Test on day 0, pre-injury, and days 3, 7, 10, 14, 21, 25, 29, 35 and 42, post-injury. Rats were placed in a plastic cylinder and videotaped until completing 10 rear-before-wall movements.

A rear-before-wall consisted of the rat rearing and touching the side of the container with its forepaw and returning to the floor of the cylinder. The videotapes were analyzed and instances of left and right forelimb use were assessed. The total number of ipsilateral (to the placement of the CCI) forelimb behaviors was obtained, and a percentage of usage for the ipsilateral (non-injured) forelimb was calculated for each animal on each testing day ((ipsi/total)\*100).

**Histology and Measurement of Contusion Size:** Rats were sacrificed on day 43 post-injury by cardiac perfusion. Brains were removed, cryoprotected, and sliced in 50  $\mu$ m cross sections. Slices were sequentially placed in six wells of cryoprotectant for immunohistochemical analysis, with each 7th slice placed in phosphate buffer for immediate slide-mounting and Nissl staining. Nissl staining, a type

of cell body stain, was used to visualize the anatomy of the brain.

Measurements of the contusion size were obtained by visualizing the Nissl-stained brain sections in the injured area (or comparable area in Shams), using a Leica microscope and CCD camera at 2.5X. The images were analyzed using NeuroLucida (MicroBrightfield; Colchester VT). Sections from approximately 2.7 mm before the injury though 2.7 mm after the injury were chosen. For Shams, a random hemisphere was chosen for analysis. The area of the remaining cortex for each section was obtained; the 8 sections were summed, and termed “the total cortical area per animal”. A total cortical volume was obtained by converting the total cortical area from  $\mu$ m<sup>2</sup> to mm<sup>2</sup> and multiplying this total cortical area by 0.3 mm.

**Statistics:** Behavior was analyzed by Two-Way Repeated Measures ANOVA followed by post-hoc tests (Super ANOVA). Anatomy was analyzed by a One-Way ANOVA for group (Microsoft Excel). P-values represent the likelihood that the results obtained were due to random chance.

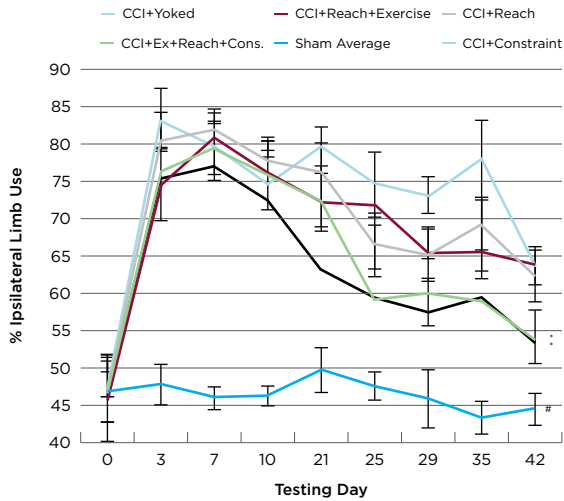
## Results

**Limb Use Test:** The use of forelimbs for support during weight-bearing behavior was assessed by examining limb use data. The percentage of usage for the uninjured forelimb (ipsilateral to the side of the brain that received the CCI) was graphed for each of the testing days.

No statistical difference was observed between the Sham groups when analyzed by a two-way repeated measures ANOVA ( $p=0.2623$ ), and thus all Sham groups were pooled for final comparisons. All CCI groups demonstrated a significant deficit when compared to the Sham groups over the entire 42-day testing period ( $p<0.05$ ). A significant difference was observed on day 42 between the CCI+Yoked and CCI+Constraint ( $p=0.0032$ ) and CCI+Reach+Exercise+Constraint ( $p=0.0136$ ) groups.

**FIGURE 1**

*Percent Ipsilateral Limb Use:* Rats that received either Reach+Exercise+Constraint or Constraint only treatments had a faster recovery on the limb use test when compared to the CCI+Yoked group at day 42, post-injury ( $*p<0.05$ ).

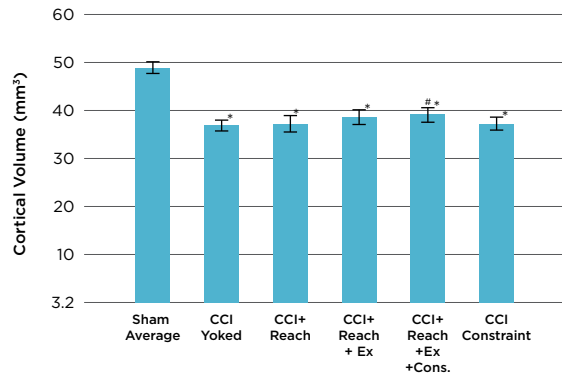


**Contusion Size:** In order to assess the size of the contusion delivered, the remaining cortical area was measured, and from this the remaining cortical volume was determined.

The average cortical volume for each of the testing groups was graphed and differences between the groups were examined. No significant difference was observed between various Sham groups as assessed with a single-factor ANOVA ( $p=0.38$ ). All animals that received a CCI showed a remaining cortical volume that was substantially smaller than the Sham animals ( $p<0.05$ ), indicating that the size of CCI was consistent between groups. However, the CCI+Reach+Exercise+Constraint group showed a cortical volume that was slightly larger than that of the CCI+Yoked group and this value approached statistical significance ( $p=0.0512$ ). Therefore, it may be that a combination of rehabilitation tasks produced a neuroprotective effect.

**FIGURE 2**

*Cortical Volume:* All rats receiving an injury had a smaller volume of remaining cortex (larger injury) compared to Sham groups ( $p<0.05$ ). Rats receiving all 3 rehabilitative treatments showed a larger cortical volume (smaller injury) than rats receiving no rehabilitative treatments. The difference between these two groups approached statistical significance ( $p=0.0512$ ).



## Discussion

The examination of different forms of rehabilitation following a CCI yielded experimentally significant results for both the recovery of behavioral function and neuroprotection. After examining the limb use test, it was observed that the rehab treatment that was received following a CCI greatly influenced the recovery of the animal. Animals that received CCI+Reach+Exercise+Constraint or CCI+Constraint only showed an overall better recovery of function upon completion of the experiment. Overall, these two rehabilitation groups were statistically different from CCI+Yoked animals. These results indicate that rehabilitation does influence behavioral functions following a CCI. Moreover, the use of rehabilitative methods can influence behavioral tasks in order to aid in the recovery of function. These data show that a more extensive rehabilitation regimen is needed to induce a

behavioral response than is needed for animals following a stroke. Previous research has indicated that Reach and Reach+Exercise can significantly enhance behavioral recovery following a stroke to the FL-SMC (Madonado et al, 2008). These data suggest that individuals suffering from a TBI may require a more extensive form of rehabilitation than what is currently used in stroke patients. Receiving some form of rehabilitation is not enough to induce behavioral recovery following a CCI, but rather the extent of rehabilitation received is essential to recovery.

Rehabilitation also influenced the size of the injury. There was a difference in cortical volume between CCI+Yoked and CCI+Reach+Exercise+Constraint groups that approached significance ( $p=0.051$ ). Animals that received all 3 rehabilitative treatments exhibited a slightly smaller injury when compared to the CCI+Yoked group. These data suggest that the type of rehabilitation treatment can influence the extent of neuroprotection following a CCI. Previous studies in stroke animals have indicated that neuroprotection does not occur regardless of the form of rehabilitation that was received (Madonado et al, 2008). Thus, these findings indicate that neuroprotection may be occurring in animals receiving Reach+Exercise+Constraint and that the brain responds differently to stroke than it does to a TBI.

The observed neuroprotection and behavioral recovery should be further investigated in the future to better characterize the type of rearrangement that the brain undergoes following a TBI. This will allow for better characterization of the precise link between rehabilitation and the neuroprotection that it induces. While TBI rehabilitation may need to be more intense than what is currently seen in rehabilitative treatments following a stroke, this study suggests that rehabilitation can induce measurable recovery. The results of this study have numerous ramifications with regard to the clinical treatment of TBIs, and the data suggest that an intense rehabilitative regimen may be able to induce both behavioral recovery and neuroprotection in clinical TBI

patients. Ultimately, the type of rehabilitation received following a CCI does influence both behavioral functions and the amount of neuroprotection observed. Examining the links between the observed recoveries and the coupling of the treatments applied in this study with emerging pharmacological treatments of TBIs will provide essential data on ways in which to treat TBI patients.

### **Acknowledgements**

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# ENHANCING THE CONDUCTIVE PROPERTIES OF ZINC OXIDE

Bryan Hardnacke and Anna Wesolik\*

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**ABSTRACT** This research involved studying zinc oxide (ZnO) as a transparent conducting oxide (TCO).

Commercially viable TCOs must conduct electricity, be optically transparent, and be produced inexpensively. Though pure ZnO is an insulator, its atomic structure can be modified, improving its conductive properties. ZnO can be manufactured less expensively than currently used TCOs. The electrical properties of several ZnO samples, including micron- and nano-grain sizes and those with impurities were tested. These specimens were heated under different oxygen environments to enhance their electrical behavior. The atomic structures were examined using x-ray diffraction. The most promising samples showed a significant increase in electrical properties.

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## Introduction and Theory

TCOs are semiconductors able to easily conduct electricity while maintaining high optical transparency. They are common in many modern-day electronics such as solar panels, touch screens, and liquid crystal displays (Ginley & Bright, 2000). TCOs are in great demand, yet the most commonly used TCO, indium-tin oxide (ITO), is low in supply and expensive to manufacture. Furthermore, ITO is known to be toxic, causing pulmonary diseases in workers at several ITO-producing facilities. ZnO, however, is high in supply, relatively cheap to manufacture, and non-toxic, making it an important candidate for study.

Semiconductors conduct electricity through charged carriers. These carriers can be negatively charged electrons, found in n-type semiconductors, or they can be electron holes, which are positively charged carriers created by the absence of electrons in an atom's structure, resulting in p-type semiconductors. In conductive materials, electrons move almost freely throughout the atomic structure. Good conductors have high carrier concentrations and/or high

charge mobility. Typically, metals have a high carrier concentration, whereas semiconductors rely much more on the internal mobility of the charge carriers. Intrinsic semiconductors are highly pure materials, and the type of carrier depends on the charge of the dominant atomic defect. Extrinsic semiconductors are intentionally modified with controlled impurities in a process called *doping*, which improves the materials' properties. Doping allows samples to be made into either n-type semiconductors through an increase in free electrons, or p-type semiconductors by increasing the concentration of electron holes. Typically, ZnO is found as an n-type semiconductor, and recent efforts have focused on improving the process for p-type semiconductors (Ginley & Bright, 2000). While the mechanism resulting in n-type (or p-type) ZnO is not well understood by the scientific community, it is believed that impurities and inherent defects in the atomic structure of ZnO are responsible for its electrical behavior.

Electric conductivity can be explained by Ohm's Law (Equation 1):

$$V=IR$$

where V is the potential difference, I is the current, and R

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is the resistance. By measuring the potential difference across a sample against different currents, it is possible to find a sample's conductivity using Equation 2:

$$\sigma = \frac{1}{\rho} = \frac{l}{RA}$$

where  $\sigma$  is the conductivity,  $\rho$  is the resistivity,  $l$  is the sample length, and  $A$  is the area of the sample. The conductivity is directly proportional to both the carrier mobility and the carrier concentration.

Thermopower measures the voltage created when carriers experience a temperature gradient in a sample. The Seebeck coefficient,  $Q$ , is given by the equation:

$$Q = -\Delta V/\Delta T$$

where  $DV$  is the potential difference, and  $DT$  is the temperature difference between two sides of a heated sample. In thermopower tests, negative  $Q$  values indicate the abundance of electrons in n-type semiconductors, while positive drops are due to the electron holes present in p-type semiconductors. The magnitude of the thermopower is related to the concentration of carriers, although no information can be gained about the carrier's mobility. The thermopower measurements help determine the cause of any changes in conductivity when used in comparison with the conductivity test previously described.

X-ray diffraction and scanning electron microscopy can be used to study the atomic structure and morphology of ZnO particles. X-ray diffraction shows the arrangement of atoms in the sample. The scanning electron microscope produces magnified images of individual ZnO particles. More details on these techniques can be found in the work of McManus and Hennen (2009).

The initial stages of this research project showed that impurities and processing conditions of the samples had a major effect on the electrical behavior of ZnO (McManus & Hennen, 2009; Hernandez & Slawik, 2009). This study required 13-mm diameter pellets of previously studied

ZnO materials to test the reproducibility of the preliminary results. Furthermore, new ZnO batches were investigated for the first time. The goal was to further examine the effects of the impurities, the processing conditions, and the grain size on the electrical properties of the samples tested. By finding the relationship between certain impurities and their effects on conductivity, we hoped to find the most promising doping scenario for future work on ZnO as an extrinsic semiconductor.

### Procedure

The samples consisted of ZnO powders that differed in purity levels and grain size. Grain sizes varied from 25 nm to a few microns. The samples were classified as *N* for nanometer-sized or *B* for bulk-sized grains (on the order of microns). The samples were labeled according to their purity levels as *B1* (Puratronic, Alfa 99.9995%), *B2* (Acros, 99.999%), *B3* (Alfa, 99.99%), *B4* (Alfa, 99.0%), *B5* (Alfa, 99.5%), *B6* (Alfa, 99.999%), *N2* (Nanotek, 99%), and *N3* (American Elements, 99.5%). The purity levels shown are according to the manufacturers; although from x-ray fluorescence experiments, the purity levels were different (McManus and Hennen). 13-mm diameter pellets of *B1*, *B2*, *B3*, and *N2* were produced, while the *B4*, *B5*, *B6*, and *N3* batches were investigated for the first time using 6 mm pellets.

For each ZnO batch, powder was pressed into 8 pellets using a hydraulic press. The pellets were placed in a crucible with "sacrificial" excess powder of the same sample to prevent contamination of the pellets from the walls of the crucible. The samples were heated in an oven at 1100 °C for 48 hours in order to increase contact between the ZnO particles. For the *N2* and *N3* batches, additional samples were heated to only 500 °C for 48 hours in order to maintain their small grain size (less than 300 nm).

A four-point probe, current source, and digital multimeter were used to test the electrical conductivity of the samples. The resistance of each pellet was determined using Equation 1. Resistivity was used to determine

the conductivity of each sample using Equation 2. Thermopower measurements were performed using gold foils, thermocouples, a heat source, and a digital multimeter. A heat source created a temperature gradient between the top and bottom of the sample to induce a voltage difference. The temperature and voltage difference were used to measure heat transfer and determine the type of carrier and its concentration in the samples. More details on these procedures are found in the work of Hernandez and Slawik (2009).

The four pellets of each batch that showed the most consistent conductivity and thermopower properties

were placed in a furnace to undergo gas reduction with intent to increase conductivity. The samples were placed in a ceramic boat containing excess powder from the annealing process. The boat was placed inside a furnace connected to a forming gas source with a 4 % hydrogen and 96 % nitrogen mixture. The samples were heated to 500 °C for 10 hours in the presence of the forming gas. After this reduction process, the samples were again tested for conductivity and thermopower.

The samples with the most consistent conductivity results were studied using synchrotron x-ray diffraction (XRD) and scanning electron microscopy (SEM) at Argonne

**TABLE 1**

*Average Conductivity of ZnO Samples*

Sample	Average Conductivity Before Reduction (S/cm)	Standard Deviation	Average Conductivity (Post-Reduction) (S/cm)	Standard Deviation
B1	0.00038	0.00013	0.82	0.07
B2	0.24	0.16	0.23	0.08
B3	0.023	0.008	0.56	0.18
B4	0.022	0.006		
B6	0.0019	0.0002		
N2 (1100 C)	0.0093	0.0016	0.1	0.01
N3 (1100 C)	1.5E-04	3.0E-05	1.34	0.34
N2 (500 C)	4.7E-06	5.2E-06	0.26	0.01
N3 (500 C)	4.0E-06	7.0E-07	5.1	0.9

**TABLE 2**

*Average Thermopower of ZnO Samples*

Sample	Average Q Before Reduction ( $\mu\text{V/K}$ )	Standard Deviation	Average Q Post-Reduction ( $\mu\text{V/K}$ )	Standard Deviation
B1	-655	77	-598	66
B2	-865	114	-570	12
B3	-812	100	-641	7
B4	-809	49	-353	47
B6	-548	292	N/A	N/A
N2 (1100 C)	-783	96	-475	35
N3 (1100 C)	-342	11	-273	17
N2 (500 C)	N/A	N/A	-283	40
N3 (500 C)	N/A	N/A	-135	5

National Laboratory and Northwestern University. The XRD data were used to determine crystallographic phases and average sizes of the grains in the specimens. The SEM images provided information on the regularity of grain morphology and particle-size distribution. More details on these techniques are found in the work of McManus and Hennen (2009).

### Results and Discussion

The 13-mm pellets of *B1*, *B2*, and *N2* powders were compared to prior results on 6-mm samples (Hernandez & Slawik). For *B4*, *B5*, and *B6* powders, 6-mm pellets were pressed. The *B5* samples were very fragile and only one pellet survived the testing process, while *B4* and *B6* pellets withstood the initial conductivity testing. Table 1 shows the average and standard deviation values of the conductivity for the most consistent samples.

The thermopower results are found in Table 2.

The grain size of *N2* and *N3* increased with oxidation and reduction at even 500 °C, as shown in the XRD results of Table 3.

Procedural errors during the testing process affected the results. Conductivity data are sensitive to physical imperfections on the pellets, such as chips, uneven surfaces, or discoloration. Therefore, to test the reproducibility of the results, 8 identical pellets of each powder were prepared and measured. Irregular pellets that produced inconsistent conductivity data were not considered when calculating the average conductivity in Table 1. A standard deviation of  $\pm 10\%$  in conductivity and thermopower values fell within experimental error and

further testing will hopefully produce data that also fall within this margin.

Of the samples that were reduced, *B1*, *B3*, *N2*, and *N3* had the greatest increases in conductivity after reduction. The nano-samples *N2* and *N3* had the most dramatic increases (up to 120,000 times) when heated to only 500 °C. The conductivities for reduced *B2* samples did not show any significant changes within experimental error.

The values for thermopower (*Q*) were negative, indicating that the samples were n-type semiconductors. The largest *Q* values correlated to a smaller electron concentration, while smaller *Q* values correlated to larger electron concentrations. In all cases, reduction caused a decrease in the magnitude of thermopower, which indicated that the electron concentration increased. Similarly to conductivity, the most dramatic changes in electron concentration occurred in the small-grain-sized nano-powders *N2* and *N3*. Before the reduction process, the thermopower for these nano-powders could not be measured as it was below the -1000 mV/K resolution of the apparatus (N/A in Table 2). After the reduction, both *N2* and *N3* nano-samples had the best thermopower results. The process affected the *B1* samples the least, with a minimal change in thermopower.

The samples showed increases in conductivity after reduction, except for *B2* powders where the reduction in forming gas increased the carrier concentration, but the conductivity remained the same. The reduction process served to enhance certain structural defects, presumably those most conducive to conductivity, while decreasing or

**TABLE 3**

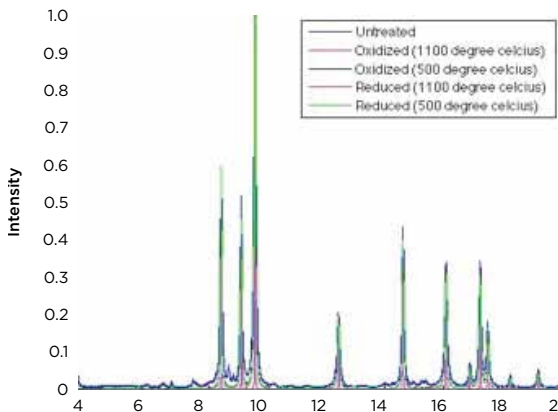
*Grain Size (nm) for N2 and N3 Samples from X-ray Diffraction Data*

Sample	Untreated	Standard Deviation	Before Reduction (500 C)	Standard Deviation	After Reduction (500 C)	Standard Deviation
B1	94	1.5	121	1.3	264	1.6
B2	26	0.6	44	0.3	56	0.3

altogether eliminating other defects. Of the bulk samples, *B1* had the greatest increases in conductivity, but least change in thermopower. This indicated that the carrier became more mobile. The *N3* and *N2* samples had large increases in conductivity after reduction, correlating to a significant decrease in thermopower. It is likely that a larger concentration of electrons improved the conductivity of the samples. The starting *N3* powder had the smallest grain size (Figure 1), but was not phase pure and contained impurities, as seen in the XRD pattern of Figure 1.

**FIGURE 1**

Structural analysis (normalized) of *N3* sample at various points in the procedural process



These impurities were seen as extra diffraction peaks. After heating to 500 oC, the minor secondary phase evolved into the major ZnO phase. Fluorescence measurements showed that the impurities in those samples were mainly silicon and titanium. The impurities may have acted as dopants that caused favorable electrical properties.

The most promising samples were *B1* and *N3*, despite a significant difference in purity levels (0.499) and grain size. It appeared that certain impurities may be more favorable for improving the electrical properties of ZnO. Both nano-sized grain samples significantly increased in conductivity and carrier concentration after reduction, suggesting that smaller grains produce improved electrical behavior.

Further conductivity tests should be carried out to obtain more consistent data. Additionally, further testing will be helpful in identifying stronger correlation between purity of the sample, grain size, and conductivity.

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# GENERATION OF A MUTANT ANTIBODY FOR SINGLE MOLECULE FLUORESCENCE SPECTROSCOPY

Ian Agne\*

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**ABSTRACT** Of the serum antibodies, immunoglobulin G (IgG) is the longest-lived, largely due to interactions of the crystallizable fragment (Fc) with neonatal receptor (FcRn). Modification of the Fc constant heavy (CH) domains of an antibody is associated with variable binding to FcRn. A point mutation changing serine-267 to cysteine in the CH2 domain of the Fc region allows for the attachment of dye molecules (fluorophores) and thus the detection of conformational subpopulations using single molecule Förster Resonance Energy Transfer (FRET) spectroscopy. Comparing the conformational subpopulations of wildtype and mutant IgG Fc regions is useful in studying the mechanism of FcRn affinity.

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## Introduction

In contrast to many Fc receptors, FcRn-IgG interactions are associated with trafficking (cellular movement within an environment) rather than signaling (cellular perception and response within an environment).<sup>1</sup> IgG is shaped like the letter “Y,” and the Fc domain consists of the stem of the “Y.” Variable heavy and light domains and constant heavy domains make up the arms of the “Y.” Transcytosis is the movement of a molecule from one side of a cell to the other side. In utero, FcRn facilitates the transcytosis of maternal IgG across neonatal tissues, conferring immunity to the fetus. In adults, FcRn mediated transcytosis diverts IgG from lysosomes to the cell surface, protecting it from degradation and increasing the half-life of serum IgG.<sup>1</sup> Mutation, the alteration of a DNA sequence, can change a protein’s structure and function by altering its constituent amino acids. The HN mutant changes amino acids histidine-433 to lysine and asparagine-434 to phenylalanine. Wildtype (WT) refers to the typical form of a characteristic as it occurs in nature contrasted by the aforementioned mutations. Binding of the HN mutant to FcRn is 16-fold higher than that of WT human

IgG.<sup>2</sup> Binding affinity for FcRn has important implications in autoimmune disorders, as competition by therapeutic antibodies for FcRn binding could decrease the half-life of endogenous autoimmune IgGs.<sup>3,4</sup> Determining differences in conformational subpopulations between WT and HN mutant Fc regions is potentially useful in the design of these therapeutic antibodies.

FRET involves the attachment of two fluorophores, donor and acceptor, at two different points in the molecule of interest. If the donor fluorophore absorbs light, it can transfer energy to the acceptor fluorophore, which will then give off light. The efficiency of this energy transfer is related to how far apart these two fluorophores are. Hence, by measuring the efficiency of the energy transfer via the light given off, the distance between the two molecules can be calculated. For this reason, FRET is often referred to as a “spectroscopic ruler.”<sup>5</sup> Thiol reactive fluorophores have been examined for use in these FRET experiments. To allow the attachment of fluorophores, serine-267 in the BamHI fragment of the  $\alpha$ lys-28 plasmid was mutated to a cysteine residue. A major advantage of thiol reactive molecules is that native proteins rarely contain surface exposed cysteine residues, as the thiol groups (-SH) exhibit

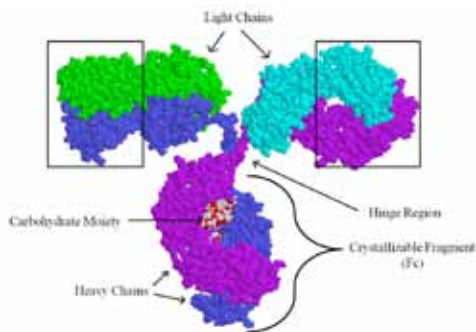
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a tendency to form disulfide bonds (S-S).<sup>6</sup> This increases the selectivity for the cysteine insertion as a site for thiol fluorophore attachment.

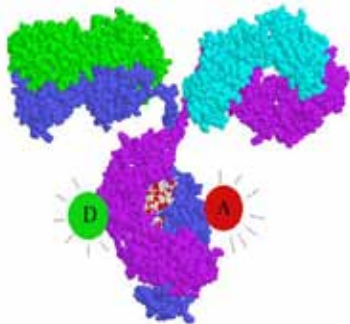
**FIGURE 1**

*Rendering of the structure of an immunoglobulin G molecule.* The antibody is made up of four chains: two light chains and two heavy chains. The regions of the antibody that correspond to the light and heavy chains, the Fc (crystallizable fragment), and the hinge region, are also shown. Additionally, the location of the carbohydrate moieties, which are bound to the Fc fragment, is indicated. Boxed regions indicate portions of the variable regions of the IgG molecule while unboxed portions indicate constant regions. The antibody shown was drawn from the protein data bank file 1IGT.pdb, Harris, L. J.; Larson, S. B.; Hasel, K. W.; McPherson, A. *Biochemistry*, 1997, 36, 1581.



**FIGURE 2**

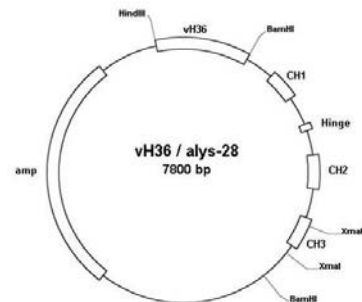
Fluorophores are to be attached to examine the distribution of distances across the Fc region where the carbohydrates are bound. D: donor fluorophore, A: Acceptor fluorophore. The antibody shown was drawn from the protein data bank file 1IGT.pdb, Harris, L. J.; Larson, S. B.; Hasel, K. W.; McPherson, A. *Biochemistry*, 1997, 36, 1581.



DNA for the full length anti-lysozyme IgG1 heavy chain was manipulated in the  $\alpha$ lys-28 plasmid. In addition to the s267c mutation, the XmaI fragment was altered to create a s267c WT Fc plasmid for comparison with the HN Fc mutant.

**FIGURE 3**

$\alpha$ lys-28 plasmid. The  $\alpha$ lys-28 plasmid contains a 800bp heavy chain fragment flanked by HindIII and BamHI cut sites and an 1800bp Fc region flanked by BamHI cut sites. amp = ampicillin resistance gene, vH36 = variable heavy domain, CH1 = constant heavy domain 1, CH2 = constant heavy domain 2, CH3 = constant heavy domain 3.



### Materials and Methods

**$\alpha$ lys-28 Plasmid.** The  $\alpha$ lys-28 plasmid used is described further in reference 1 and was a generous gift from Sally Ward.

**Transformation of  $\alpha$ lys28 Plasmid.** The  $\alpha$ lys28 plasmid was transformed into Promega JM109 Escherichia coli competent cells. Competent cells were mixed with DNA in chilled Falcon™ 2059 polypropylene culture tubes, heat shocked at 42°C for 50s, and grown in SOC media for one hour. Media was plated onto ampicillin-treated LB agar at varying dilutions.

**Mutagenesis of Plasmid DNA.** The s267c and HN to WT mutations were carried out using the Stratagene QuikChange® Lightning Site Directed Mutagenesis Kit. Mutagenesis primers were obtained from Integrated DNA



## Technologies

**Purification of Plasmid DNA.** Plasmid was purified using the Promega PureYield™ Miniprep System.

**Restriction Digests.** Restriction digests were performed using XmaI, HindIII, and BamHI restriction endonucleases procured from New England Biolabs. A restriction endonuclease cleaves a specific DNA sequence, creating predictable DNA fragments in a known sequence.

**Characterization of Plasmid DNA.** Restriction fragments were separated via 1% agarose gel electrophoresis performed in 0.5x TBE buffer. Gels were visualized with 0.5 µg/mL ethidium bromide (EtBr) solution using a KODAK GEL LOGIC 100 Imaging System. Purified plasmid DNA was sent to Macrogen Inc. USA for sequencing. Sequencing primers were obtained from Integrated DNA Technologies.

## Results

EtBr is able to insert itself between DNA base pairs and fluoresces under UV light. DNA is negatively charged and will move towards the positive pole when exposed to an applied current. Movement of DNA through agarose gel is hindered in larger DNA fragments, thus separating the DNA fragments by size when moving under an applied current. Fragment size can be determined by comparing experimental fragments to a ladder, a set of known DNA fragments. Figures 4, 5, and 7 are agarose gels under UV light with separated DNA fragments that have been exposed to EtBr. Prior to sequencing, transformants were screened for the presence of a 350bp XmaI restriction fragment, denoting the presence of the  $\alpha$ lys-28 plasmid. All trials of transformants displayed this restriction fragment. Sequencing results were also consistent with the presence of the  $\alpha$ lys-28 plasmid.

The s267c mutants were screened for the presence of an 800bp BamHI / HindIII restriction fragment. All trials of the s267c mutation displayed this restriction fragment.

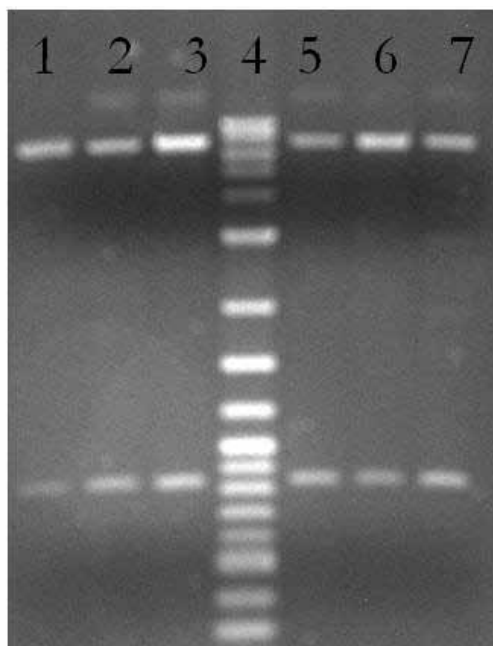
**FIGURE 4**

A restriction endonuclease, XmaI, was used to cleave the plasmid at two cut sites, producing a notable 350bp fragment. Lanes 8-10 represent various trials of  $\alpha$ lys-28 transformants. Lane 1 is the 2-log DNA ladder and lanes 2-7 are unrelated trials.



**FIGURE 5**

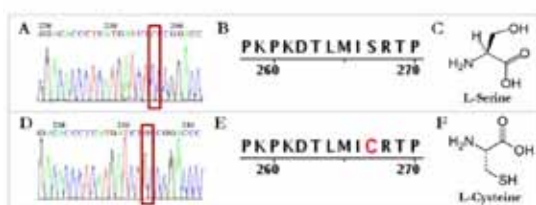
A BamHI / HindIII double digest produced an 800bp fragment representing the variable heavy domain. Lanes 1-3, 5-7 represent trials of the s267c mutants. Lane 4 is a 2-log DNA ladder.



The serine to cysteine mutation was confirmed by the presence of a guanine base at the 267th position in the Fc region sequence, confirming the efficacy of the mutagenesis reaction. Sequencing results for all trials were consistent with the s267c mutation.

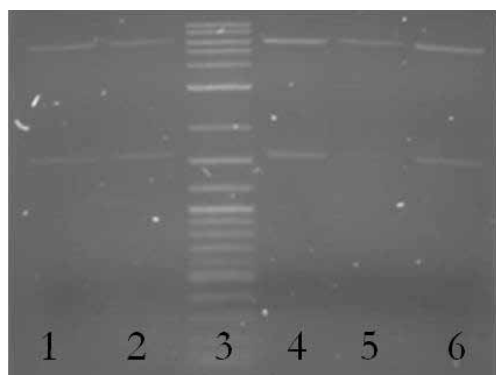
**FIGURE 6**

Sequence changes with s267c mutation. A single point mutation was characterized, indicating the change from serine to cysteine. A: Pre-mutagenesis DNA sequence; B: Pre-mutagenesis protein sequence, C: Structural formula of L-Serine, D: Post-mutagenesis DNA sequence, E: Post-mutagenesis protein sequence, F: Structural formula of L-Cysteine; Red letter denotes deviation from WT.



**FIGURE 7**

A restriction endonuclease, BamHI, was used to cleave the plasmid at two cut sites, producing 1800bp and 6000bp DNA fragments, corresponding to expected fragments from the alys-28 plasmid. Lanes 1-2, 4-6 represent various trials. Lane 3 is a 2-log DNA ladder.

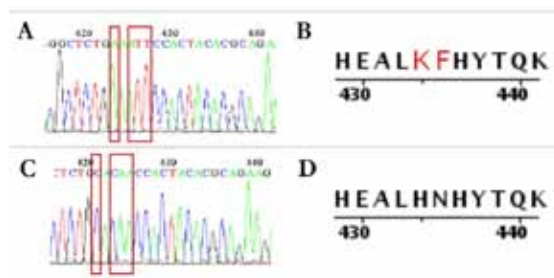


A restriction digest was performed to screen for the presence of an 1800bp BamHI fragment, indicating the presence of the  $\alpha$ lys-28 plasmid. All trials of HN to WT Fc mutants displayed this restriction fragment.

The conversion of the CH3 region from HN to WT was confirmed by a four-nucleotide change identified during sequencing. This change signifies the mutation of lysine-433 to histidine, and phenylalanine-434 to asparagine, as is consistent with the WT Fc region. Sequencing results for all trials were consistent with the HN to Fc mutations.

**FIGURE 8**

Sequence changes with HN to WT Fc mutation. The 4 nucleotide change denotes the change from the HN CH3 to WT CH3. A: Pre-mutagenesis HN DNA sequence, B: Pre-mutagenesis HN protein sequence, C: Post-mutagenesis WT DNA sequence, D: Post-mutagenesis WT protein sequence; Red letters denote deviation from WT.



## Discussion

The results of this project confirmed that our samples contain the DNA desired for future projects. Specifically, with the recombinant DNA for WT and HN Fc regions, it is possible to produce, or express, entire antibodies for use in FRET spectroscopy. Transfection is the process of deliberately introducing foreign DNA into a cell. In order to express the desired mutant IgG1, the mutated Fc plasmid DNA and plasmid containing a variable light chain must be transfected into NS0 cells, a mouse myeloma cell line naturally lacking IgG production. By choosing a cell line

that will not produce IgG on its own, one can be certain that the IgG produced will be the result of the transfection. Transient expression of the mutant IgG1 will produce a sufficient amount of protein for FRET spectroscopy.

The carbohydrate moiety of an IgG molecule has a major impact on the conformation of the antibody's Fc region, which affects the antibody's ability to illicit an immune response via effector molecules.<sup>7,8</sup> An effector is a molecule whose binding to a protein affects the function of that protein. Studying conformational alterations created by removing specific carbohydrates from the moiety (aglycosylation) could discern the mechanism of differential effector function. As IgG effector function has implications in autoimmunity, it is a future area of study for this project.

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Halley Miglietta | *Class Warfare* | Photography

# THE SELECTIVE ATTACHMENT OF FLUORESCENT PROBES TO CATALYTIC ANTIBODIES FOR FÖRSTER RESONANCE ENERGY TRANSFER (FRET) STUDIES

Michael Kelliher\*

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**ABSTRACT** Selective labeling of fluorophores is important in fluorescence spectroscopy experiments.

The goal of this experiment was to verify that a small organic linker molecule (hapten) would bind to the catalytic antibody 38C2 and the fluorescent probe Alexa Fluor 594. Thin Layer Chromatography (TLC) and spectroscopic analysis confirmed binding between the dye and hapten molecule. Spectroscopy was used to calculate binding efficiency of 87.4% for the reaction between the hapten molecule and 38C2. Confirmation of binding ensures that future Förster Resonance Energy Transfer (FRET) experiments can be performed on 38C2 using Alexa Fluor probes.

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## Introduction

Fluorescent molecules are characterized by their ability to absorb light at a particular wavelength and subsequently emit light of a longer wavelength (lower energy). Fluorescence spectroscopy and fluorescence microscopy are experimental techniques that take advantage of the fluorescent properties of molecular systems in order to learn more about them. Because most systems do not fluoresce naturally, fluorescent probes are often attached to molecules of interest. Lipophilic dyes attach to lipid (fat) molecules and may be used to illuminate cells under a microscope. This is referred to as nonspecific labeling because the dye molecules will bind to any lipid molecules present. Hundreds of dye molecules can attach to the surfaces of cells whose membrane is composed of many different lipid molecules. Nonspecific labeling can also occur with sugars, proteins, DNA, and many different molecules. When illuminated with an appropriate light source (one that corresponds to the excitation wavelength of the dye), the probes will fluoresce and can be seen with a microscope.

In some instances, nonspecific labeling is not appropriate to the system being studied. For instance, it may be pertinent to study the diffusion of a bacterial toxin as it passes through the cell membrane. If the toxin is a protein, a nonspecific dye that binds to proteins would not work as there are many proteins scattered throughout the membrane that would also pick up the probe and make it difficult to distinguish the toxin from other proteins. However, many dyes have been synthesized that can be used to selectively label specific molecules based on their chemical structure. In the case of the bacterial toxin, several different color fluorophores (dyes) could be attached to the toxin and known channels that provide transport of materials inside the cell. By monitoring the fluorescence, it would be possible to learn which chemical pathway is traversed by the toxin.

The Förster Resonance Energy Transfer (FRET) is another spectroscopic technique that can give insight into dynamic processes that occur on small scales, such as within a cell. FRET is a distance-dependent non-radiative energy exchange from one fluorophore to another. The technique involves two distinct dye molecules that absorb and emit

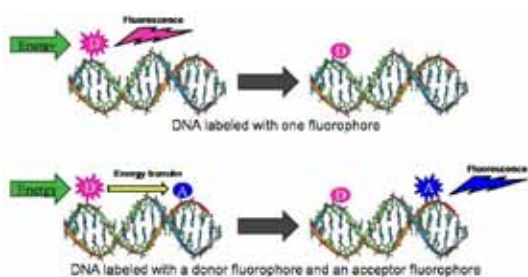
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distinct wavelengths of light. The only caveat is that one molecule (the acceptor) must absorb light at a wavelength emitted by the other (the donor). A laser is often used as the excitation source because it emits light that is absorbed by the donor but not by the acceptor molecule. It is then possible for the absorbed light to be transferred to the acceptor molecule through the FRET process, which can then give off light that is distinct from that given off by the donor molecule (Figure 1). The efficiency of this process can be calculated if the fluorescence of the donor and acceptor are separated, which can be accomplished using specialized mirrors. By observing the efficiency over time, it is then possible to detect movement within or between molecules (depending on whether the acceptor is attached to the same molecule as the donor or a different molecule).

**FIGURE 1**

*FRET Schematic.* The top portion of the image shows normal fluorescence of a dye. The bottom half of the image details how the energy from the donor molecule (D) can be non-radiatively transferred to the acceptor molecule (A) which then fluoresces. The closer the acceptor is to the donor molecule, the more likely the energy is transferred. The green energy arrow represents an outside energy source, such as a laser.

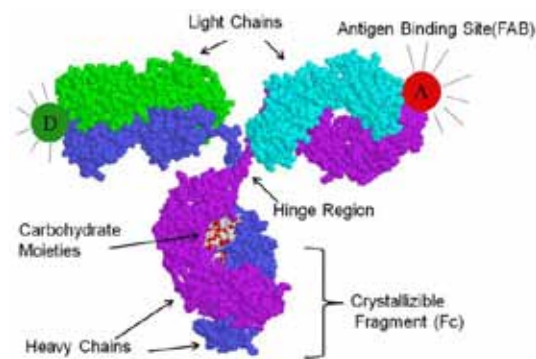


The system of interest in this experiment is the catalytic antibody 38C2 (Figure 2). Catalytic antibodies are antibodies that are able to catalyze chemical reactions. 38C2 is referred to as an aldolase antibody, because it catalyzes the aldol condensation reaction. A unique feature of this antibody is that the catalytic amino acid is an unprotonated lysine. The amino acid lysine ( $\text{NH}_2$ ) is basic and typically removes a proton ( $\text{H}^+$ ) from neighboring

water molecules to become protonated ( $\text{NH}_3^+$ ). 38C2 is unusual as the amine group of lysine is usually protonated at biological pH conditions. As such, amine reactive compounds will not react with other amino acids that make up the antibody because they are in their protonated form. Because the catalytic lysine is sequestered from water molecules, it remains unprotonated (it has not removed a proton from a water molecule) and reactive, even in aqueous solution. In theory, amine reactive dye molecules could be selectively attached to 38C2 at the catalytic lysine residues. If the antibody can be labeled with a donor and acceptor molecule, then FRET can be used to determine conformational changes in the arms of the antibody.

**FIGURE 2**

*Diagram of Antibody 38C2.* The image diagrams the major features of an IgG antibody. The letters 'D' and 'A' correspond to the desired locations of the donor and acceptor molecules for FRET studies (protein image was generated from the protein data bank 1IGT.pdb).

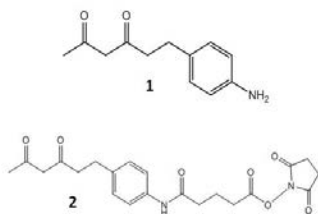


The experiments detailed here involve the attachment of the fluorescent probe Alexa Fluor 594 to the antibody. Previous crystallography experiments have been used to determine that the catalytic lysine, the unprotonated amino acid that catalyzes the condensation reaction, is located in a pocket approximately 10 Å deep. It is formed from folds in the antibody at the antigen binding site and comprises a nonpolar environment that keeps the lysine unprotonated and inaccessible. Because of this, a hapten molecule (Figure 3), a small organic linker molecule, must first be attached to the dye before it can bind to the

antibody. The goals of this experiment are twofold: One is to verify that the chosen hapten will bind to antibody 38C2 while the other is to show that the dye will bind to the chosen hapten. Ultimately, if both reactions are successful, FRET experiments can be performed on the antibody to determine its dynamic nature (or lack thereof).

### FIGURE 3

*Hapten molecules.* The two hapten molecules used in the experiment are shown. The amine hapten (1) was used to verify binding did occur between the antibody and the hapten molecules. The N-hydroxysuccinimide ester (NHS) hapten molecule (2) was reacted with fluorescent probes to provide a long chain capable of reacting with the isolated catalytic lysine.



## Experiment

### Hapten Synthesis:

The amine hapten linker (1) and the N-hydroxysuccinimidyl ester (NHS)-hapten (2) were synthesized according to the procedure detailed by Sinha et al (Figure 3). The product was verified using <sup>1</sup>H NMR spectroscopy and purified by column chromatography. A small amount of NHS-hapten (2) was stored in dry tetrahydrofuran (THF) at a concentration of 1 mg/mL while the remainder was stored in the freezer at -20°C.

### Reaction of Hapten with Antibody 38C2:

20 μL of amine hapten were combined with antibody 38C2 in phosphate buffered saline (PBS) such that the antibody was brought to a final volume of 200 μL at a concentration of 2 mg/mL. The reaction was allowed to incubate at room temperature overnight.

### Verification of Hapten-Antibody Binding:

The reaction mixture was placed in a Millipore Amicon Ultra Centrifugal Filter Unite with a molecular weight cutoff of 10,000 g/mol centrifuged at 14,000 relative centrifugal force (14,000 times the force of gravity) for 4 minutes. The recovered sample was compared to the solution that passed through the filter (flowthrough) using a ThermoScientific NanoDrop 1000 UV-Visible Spectrophotometer.

### Reaction of Dye with Hapten Molecule:

AlexaFluor 594 hydrazide (a compound that reacts with amines) was stored at a concentration of 10mg/mL in dry dimethyl formamide (DMF). 10 μL of the dye were added to excess NHS-hapten (in THF) in a ratio of approximately 1:10 to reach a final volume of 450 μL. The reaction was incubated, with constant stirring, at room temperature overnight. Thin Layer Chromatography (TLC) was used to gauge the extent of the dye-hapten reaction. A solvent system that consisted of a 60:40 methanol:ethyl acetate ratio was observed to give the best separation of reactants from starting materials.

### Column Chromatography:

The dye-hapten reaction product was isolated from the starting materials by filtration through a narrow silica gel column. The column of silica was approximately 3 cm high. Hexanes were used to equilibrate the column and wash unreacted hapten. A solution of 60:40 methanol:ethanol was used to elute the dye-hapten product. The methanol:ethanol solution was added until all of the dye had washed out of the column and fifteen 1 mL fractions were collected as the solution passed out of the column. A ThermoScientific NanoDrop 1000 UV-Visible Spectrophotometer was used to analyze the fractions collected from the column and verify the dye-hapten linkage.

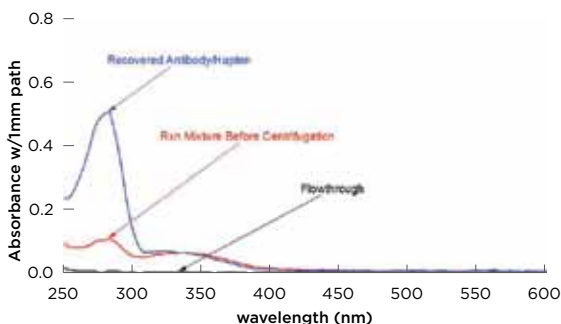
## Results and Discussion

The reaction of the antibody with the amine hapten (1) was assessed using spectroscopic techniques after the sample

had been purified using the centrifugal filters. The filters retain any molecules with a molecular weight larger than 10,000 g/mol while allowing smaller molecules to pass through. Figure 4 displays the spectra of the mixture both before and after centrifugation. The peak for the antibody at 280 nm is seen to increase after filtration, but the peak for the hapten stays approximately the same size but shifts slightly to a lower wavelength. Because the hapten (MW = 205.26 g/mol) is smaller than 10,000 g/mol, it was expected to pass through the filter, and any peak that appears must be a result of hapten that is bound to the antibody. If the hapten did not pass through the filter, it would be expected that the peak would increase in a fashion similar to the antibody. The absence of signal in the flowthrough indicates that free hapten was caught in the filtration and did not pass completely through.

#### FIGURE 4

*Hapten Binding to Antibody 38C2.* Absorbance data are shown for the reaction of the amine hapten and antibody increases after filtration. The peak at ~330 nm is caused by bound haptens as the free hapten would have passed through the 10,000 MWCO filter. The flowthrough shows no absorbance. The ratio of the peak heights (antibody:hapten) corresponds to a binding efficiency of 87.4%

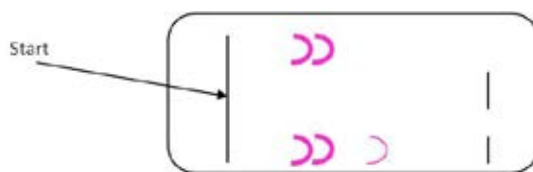


Using the extinction coefficient of 1.35 ml/mg\*cm and a MW of 150,000 g/mol and an absorbance value of 0.51 for the antibody and the Beer-Lambert Law, the concentration of antibody after filtration was determined to be  $2.57 \times 10^{-5}$  M. Similarly, the experimentally determined extinction

coefficient of 17,800 L/mol\*cm for the amine hapten ( $A = 0.08$ ) was used to calculate the hapten concentration after filtration at  $4.49 \times 10^{-5}$  M. Because there are two binding sites for the hapten per antibody molecule, the binding efficiency of the hapten is calculated to be 87.4%. The dye AlexaFluor 594 was combined with the NHS-hapten in order to isolate the dye-hapten conjugate for attachment to the antibody 38C2. After incubation overnight, the products were isolated using TLC in 60:40 methanol:ethyl acetate. The products separated into four distinct bands. A band corresponding to the free hapten travelled with the solvent. The two trailing bands mirrored those travelled by the free dye. The presence of a fourth band at an intermediate distance between the dye and hapten bands supports the presence of the dye-hapten conjugate. Figure 5 is a qualitative illustration of the paths travelled by each substance.

#### FIGURE 5

*TLC of Dye-Hapten Mixture.* The free dye (top) split into several bands while the free hapten (middle) travelled with the solvent (60:40 methanol:ethylacetate). The presence of the faint intermediate band in the lane with the reaction mixture (bottom) likely corresponds to the desired dye-hapten conjugate.



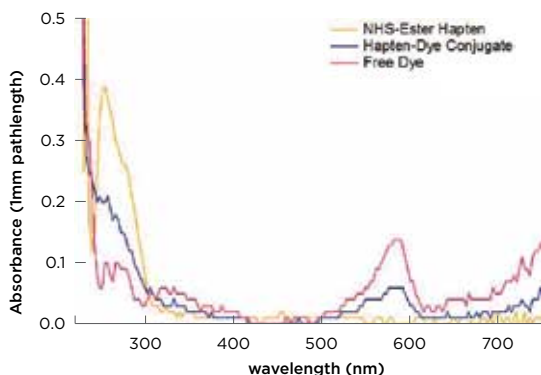
The remaining reaction mixture was run through a silica gel column to isolate the dye-hapten conjugate. A total of 15 fractions were collected, and Figure 6 shows the spectra for the most relevant fractions. The free hapten was collected in the first three fractions (Figure 6, orange line). Fractions 3 and 4 were empty of absorbing species but fraction 5 (Figure 6, blue line) showed peaks at both 250-270 nm and 580-600 nm, which suggests the dye-hapten conjugate lies in this fraction. All remaining samples (6-15) collected showed strong dye



absorbance, but relatively weak absorbance in the range of wavelengths absorbed by the hapten. The presence of the weak absorbance in the 260-280nm range for the free dye is likely due to weak absorbing characteristics in this range.

#### FIGURE 6

*Hapten-Dye Conjugation.* The spectra of three fractions collected during the purification column after the dye-hapten reaction. The orange spectrum is indicative of the first fractions collected, the blue represents the fifth fraction, while the pink spectrum represents the sixth and subsequent fractions collected. The NHS-hapten absorbs strongly at 250-270nm, while the Alexa 594 absorbs strongly in the range of 580-600nm.



#### Conclusions

The results of the hapten-antibody reaction indicate that the amine hapten binds to antibody 38C2 with an 87.4 % binding efficiency. While this reaction showed the successful binding of the amine hapten to 38C2, it is necessary, with future experimentation, to verify that the NHS-hapten also attaches to the antibody as it is the linker that will ultimately serve to attach the dye molecules to the antibody. The attachment of the fluorophore AlexaFluor 594 to the NHS-hapten suggests that the hydrazide dyes bind to the hapten and can be purified using column chromatography.

In the future, the fluorophores AlexaFluor 568 (donor) and Cy5.5 (acceptor) will be attached to NHS-hapten molecules. Once attached, the dye-hapten conjugates will be bound to the antibody to create molecules that are labeled with both donor and acceptor fluorophores. The compound will then be made very dilute such that FRET experiments can be run at the single molecule level in order to determine the conformational nature of individual molecules.

#### Aknowledgements

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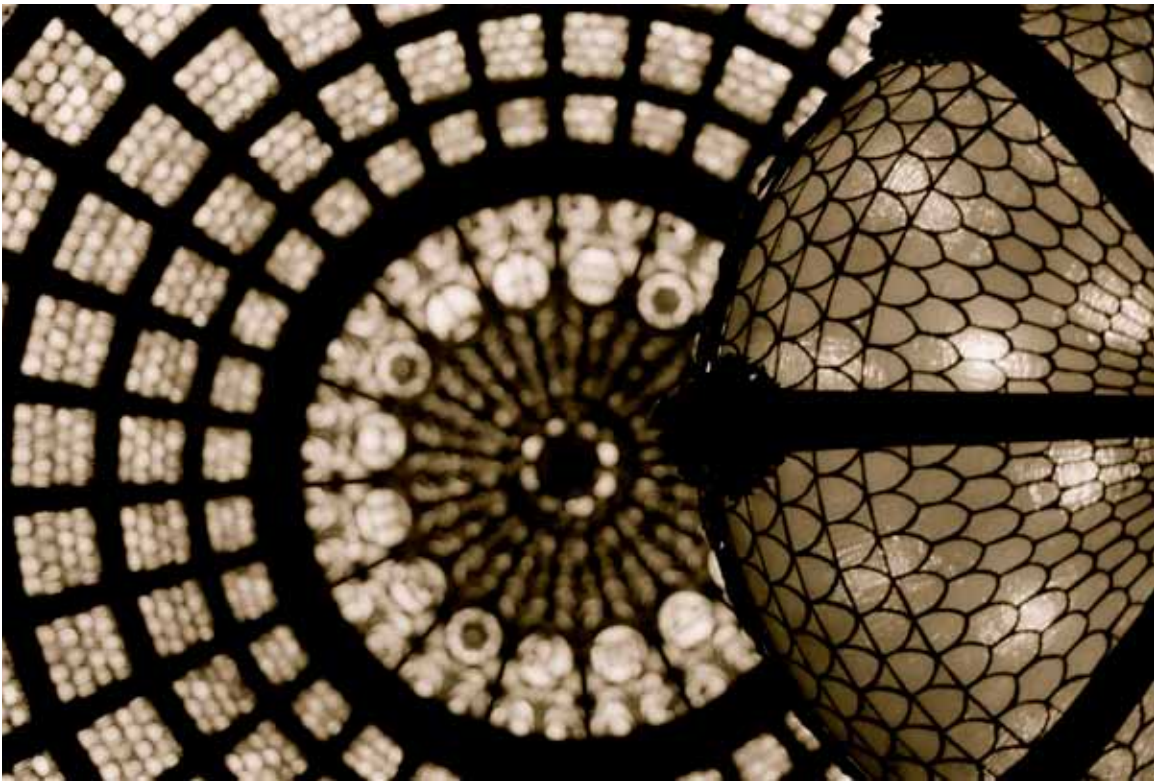
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