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**Creating Knowledge:  
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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. Last year, this eventuated in the publication of the very first volume of *Creating Knowledge: The LA&S Student Research Journal*. Of course, it might be argued that a tradition of such student scholarship and accomplishment can only be truly started if there are follow-up volumes to the “premiere” edition of the journal. And so, I am extremely pleased to be able to introduce the second volume of *Creating Knowledge*. 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 second 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.

Chuck Suchar  
Dean

*This volume of*  
Creating Knowledge: The LA&S Student Research Journal  
*is dedicated to the graduating class of 2009.*



*Untitled*  
*Gerardo Victor*  
*Photo, 2008*

## Daniel H. Burnham in the Philippines: The Architect of Choice for American Politicians

### Abstract

*This year, 2009, Chicago is celebrating the centennial of Daniel H. Burnham's famous 1909 Plan of Chicago, which shaped the city we live in today. Burnham was an architect and urban planner who devoted much of his career to Chicago during the late 19th and early 20th centuries. His work overseas, however, is less widely known. In 1905, during the period when the United States colonized the Philippines, American politicians chose Burnham to plan the capital city of Manila and the summer capital of Baguio. By examining the United States' objectives for the Philippines and Burnham's influences in designing the plan, we can begin to understand why Burnham was selected to redesign two important cities in this new American colony.*

Daniel H. Burnham (1846-1912) was a famous Chicago architect and city planner. He is well-known not only for designing many buildings still standing in the city, but also for preparing the 1909 Plan of Chicago, which shaped the city that we live in today. He was also the lead architect of the legendary World's Columbian Exposition, held in Chicago in 1893.<sup>2</sup> However, while many may be familiar with his work in Chicago, they may be less aware of Burnham's role overseas in designing the Philippine cities of Manila and Baguio. To understand why Burnham received the commission and what influenced his designs, we must look at what American politicians envisioned for the Philippines, along with the ideals of the Progressive Era and the City Beautiful Movement.

For more than three hundred years, the Spanish ruled the Philippines.<sup>3</sup> At the conclusion of the Spanish-American War in 1898, dominance of the Philippines was transferred to the United States. Like Spain, the U.S. utilized the capital city of Manila for its valuable position for international trade. In addition, U.S. Presidents William McKinley and Theodore Roosevelt understood that a strong presence in the Philippines was necessary to strengthen the country's relationship with China.<sup>4</sup>

While many Filipinos wanted their independence and did not want to be controlled by yet another imperial power, the U.S. government did not support the idea of Philippine independence.<sup>5</sup> In fact, American government officials,

including Secretary of War William Howard Taft, believed that the Filipinos were not quite ready to govern themselves and live as citizens of an independent country.<sup>6</sup> Therefore, Taft outlined a comprehensive development plan that he described as "Philippines for the Filipinos" and defined its colonial mission as preparation of the Philippines for eventual independence.

Under Taft, the American government began a campaign to modernize the Philippines. It started by reforming what it considered to be inefficiencies inherited from the Spanish regime, including the former Spanish infrastructure, which was seen as old and out-dated by the American elites. The new progressive administration planned to "uplift" the Filipinos from their current conditions through a series of Progressive reforms.<sup>7</sup> The American government followed the "progressive" planning ideals and standards it implemented in American cities—such as improvements in sanitation, health, education, shelter, transportation, and urban reform—believing that it was appropriate to initiate similar programs in American territories overseas.<sup>8</sup>

Yet, reform and modernization were not just intended for the Filipinos. A growing interest and curiosity about this new foreign territory brought an influx of wealthy Americans traveling to the Philippines. However, American tourists were accustomed to much better living conditions than the islands had to offer. The simple huts native Filipinos lived in did not meet the demands of wealthy Americans. "Americanizing" the islands for U.S. travelers became a goal of governmental officials.

To accomplish its ambitious goals and demonstrate its intentions, Governor Taft quickly realized that America needed to build massive new infrastructures in the Philippines. For American city planners and architects, this offered a golden opportunity. New governmental buildings, schools, hospitals, churches, parks, and even a new summer capital in the city of Baguio (four hundred miles north of Manila) were envisioned.<sup>9</sup>

By 1904, Burnham had established a friendly relationship with President Theodore Roosevelt and U.S. Philippine Commissioner Cameron Forbes. However, what made Burnham a prime candidate for the job was his previous city planning experience in major U.S. metropolitan areas and his commitment to better cities and the lives of the people living in them through parks and road improvements. In addition, unlike many Chicagoans who were anti-imperialists, Burnham supported what the U.S. was doing in the Philippines and believed the Filipinos deserved a better life. Burnham's name and reputation had become world-renowned because of his involvement with the 1893 World's Fair.<sup>10</sup> The fair created a perception of what an ideal city could look like, along with a belief that architecture and

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2 Interestingly enough, Burnham's role in the Chicago fair has become more known to the public through Erik Larson's non-fiction book, *The Devil in the White City*.

3 Donald M. Seekins, "Historical Setting," in Frederica M. Bunge, ed., *Philippines, A Country Study* (Washington, D.C.: Headquarters, Dept. of the Army, 1984), p. 22.

4 Ibid., 7.

5 Ibid., 24.

6 Ibid., 27.

7 Jonathan Best, "Empire Builders: American City Planning in the Philippines," *Arts of Asia* Vol. 28, no. 4 (1998): 99.

8 Thomas Hines, "The Imperial Façade: Daniel H. Burnham and American Architectural Planning in the Philippines," *The Pacific Historical Review* Vol. 41, no. 1 (1972): 40.

9 Best, p. 100.

10 Ibid., 100.

urban planning could solve modern social problems. For all of these reasons, Burnham got the job. From an American politician's perspective, he was the perfect candidate to plan Manila and Baguio. He fit the American government's ideals, goals, and vision for the Philippines.

In December 1904, Burnham and his assistant Pierce Anderson arrived in Manila. They stayed for approximately six weeks, talking to government officials, surveying, sight-seeing, and enjoying Filipino culture. After their short visit, they returned to Chicago and got to work. By June 1905, they sent their plans to Secretary Taft in Washington, D.C. Later that fall, the plans were approved.<sup>11</sup>

The major goals Burnham had proposed in his 1905 Plan of Manila were to update the sanitation system, improve the streets to allow better transportation and communication throughout the city, create a park system with green space, and keep the 16th-Century Spanish wall called *Intramuros*, or “within walls,” as an example of a medieval fortified city.<sup>12</sup> Burnham understood the historical significance of keeping the wall, but he was influenced by Progressive concerns about sanitation when it came to the moat surrounding the wall. On his visit to Manila, he had found it unsanitary with floating debris that he believed could only be a health risk.<sup>13</sup> He suggested that the moat be filled in. Creating a better sewer system would also have improved the city's sanitation. However, because Manila lies barely above sea-level, installing a modern underground sewage system would be difficult.<sup>14</sup>

Ease of transportation was another major Progressive Era concern that Burnham tried to address. He proposed a street system that would leave the old city streets intact except for those crucial to relieve congestion and create a rectangular street system in the outer part of the town. Burnham avoided orienting the streets on a north/south, east/west axis, so that all four sides of houses along the streets would have the advantage of direct sunlight at some point during the day and cross ventilation (both of which would also improve sanitation).<sup>15</sup> This design made every section of the city readily accessible via radial and diagonal roads. In addition, Burnham suggested widening existing roads to improve passage between districts.

Burnham's overall 1905 Plan of Manila was not only based on the ideals of the Progressive Era, but was also inspired by the City Beautiful Movement for the beautification and monumental grandeur in U.S. cities. Like the ideals of the Progressive Era, the American government saw City Beautiful models as adaptable and useful not only in the Philippines but in any territory outside the U.S.<sup>16</sup> The 1893 World's Fair marked the beginning of the movement and Burnham was considered one of its leaders. The goal of this new movement was to beautify cities by incorporating parks

and other green spaces into their design. In the proposed plan, Burnham stated that parks were “an architectural accessory for the modern city with its immense and congested population” that would serve “as breathing places for the people”.<sup>17</sup> He believed that Manila's greatest resources for recreation and refreshment lay along the Pasig River and its ocean bay.<sup>18</sup> In addition, park spaces—in the shapes of plazas, circles, esplanades, and parkway boulevards—were to be laid out to provide every quarter of the city with green space for its residents.<sup>19</sup>

At the summer capital proposed for Baguio, little infrastructure was in place when Burnham visited the site,<sup>20</sup> with only a few huts belonging to the native chief and his family found on the rolling hills of the Corillera Mountain Range in northern Luzon. Burnham virtually had a blank canvas in which to design the new summer capital.<sup>21</sup> However, the topography of the land made this a challenge. Burnham understood the importance of a geometric street system, but had to adapt his design to fit the area's uneven, hilly terrain. The resulting street system of Baguio is not a strict grid as in Manila; it is more curvilinear.<sup>22</sup> Burnham located the business and government centers on approximately level ground, considering this to be “the most convenient way for the transaction of business”. He connected these centers through a network of winding roads.<sup>23</sup> Despite the geographic challenges, Burnham's overall vision for Baguio was influenced by the principles that guided designs for Manila. The City Beautiful-inspired green spaces include a large park facing the summer residence of the governor general on one side and City Hall on the other.<sup>24</sup> The winding streets leading to these buildings were also lined with pine trees, eventually ending at rotundas and smaller parks. This incorporation of government buildings and focus on the natural environment allowed the summer capital at Baguio to function more as a retreat for government officials during the hot summer months in Manila. Nevertheless, it was still an important city during the colonial period.

According to Burnham scholar Thomas Hines, the administrative colonization of the Philippines represented America's “first and last experiment in administrative colonial rule and reflected her new status as a world and Imperial power”.<sup>25</sup> Beginning in 1898 and ending in 1946

17 Moore, 182.

18 Ibid., 180.

19 Ibid., 182.

20 The climate in the Philippines is extremely hot and humid for most of the year, especially Manila. A summer capital was envisioned for the American government to be a place for the high politicians to escape the intense heat. They discovered this “cool-spot” that the ancient Spanish had talked and written about in northern Luzon in a city the locals called Baguio.

21 Compared to the other cities Burnham designed throughout his career, which had existing infrastructure, I argue that Baguio is the only one he designed from scratch. Having a “fresh” start in the Corillera Mountains, Burnham could design the city any way he desired.

22 For illustration of the plan, see Moore, p. 199.

23 Moore, p. 197.

24 Today the park is known as Burnham Park and has become a popular vacation spot in the Philippines.

25 Hines, p. 45.

11 Charles Moore, *Daniel H. Burnham: Architect, Planner of Cities* (New York: Houghton Mifflin Company, 1921), p. 177.

12 For illustration of the plan, see Moore, p. 181.

13 Moore, 178.

14 Ibid., 179.

15 Ibid., 187.

16 Manfredo Tafuri, *Modern Architecture* (New York: Rizzoli International Publications, Inc., 1986), p. 40.

with the country's independence, the American colonial regime lasted less than one hundred years, and America was the last imperial power to control the Philippines. In this short time, the American presence brought about not only fundamental changes in Filipino urban planning, architecture, and ways of life through schools, education, and infrastructure, but also established America as an imperial power. As the architect who shared a vision for the Philippines with the American government, Burnham played an important role in an extremely controversial topic at the beginning of the 20th Century. It is evident that his connections with government officials, his prestigious status as an architect, and his skills as a city planner qualified him for this historic opportunity. By incorporating the ideals of the Progressive Era and City Beautiful Movement into his, Burnham created ideal designs for Manila and Baguio. His vision was clearly what American politicians had in mind for the Philippines and made him their architect of choice.

## The Twilight Renaissance: Jayavarman VII, Mahayana Buddhism, and the End of Angkor

### Abstract

*The architectural record left by Jayavarman VII communicates a complex blend of political authority, religious philosophy, and national history. Understanding how these seemingly separate concepts overlap is crucial to grasping the intricacy of the Khmer mindset and to debunking the notion that the art of the Angkor Thom period is derivative of classical Khmer conventions. At the heart of the artistic revolution of the Angkor Thom period was the integration of Buddhism into the then predominantly Hindu religious culture. Jayavarman VII's efforts to harmonize new religious practices with existing cultural norms resulted in an unmistakable material record.*

To the contemporary mind, history, politics, and religion are distinct concepts with separate functions. While the segregation of these ideas from each other is natural, it is but one possible worldview. In fact, when interpreting the Angkor Thom period of Cambodian history (c. 1181-1215), it is an obstacle to be overcome. To interpret the architectural record from the reign of Jayavarman VII correctly, religion, history, and politics must be understood as fluid concepts that bleed into and influence each other's narratives. Only in grasping this place of overlap can the Khmer mindset be accurately reconstructed. To add another layer of complexity, Jayavarman VII was Buddhist, and was faced with the challenge of integrating a new belief system into Khmer culture. This essay examines how the state-sponsored art of the Angkor Thom period depicts a reinterpretation of Buddhism that presented the religion in an understandable cultural framework, and how that reinvention fits into the overarching political concepts of kingship and imperial authority. This is manifest especially in the Head of a Deva, the arts of the Bayon, and Preah Kahn.

The Bayon style that dominated the 12th and 13th Centuries is typically understood as expressing the last great era of a declining empire. Indeed, the king in Angkor was losing his grip on his subjects by the 12th Century. According to Michael Coe, the Cham people successfully attacked the Angkor Wat complex, resulting in a brief occupation. Jayavarman VII, who resided outside the Khmer empire in voluntary exile, rallied an army outside of the capital. He successfully conquered the city and expelled the invaders, but found it in chaos and disarray. The civilization responsible for the construction of the largest religious structure in the world, Angkor Wat, was crumbling. Jayavarman VII took it upon himself to restore the now diminished glory of the nation by launching a series of large-scale building projects that would come to be the

final demonstration of Khmer monumental architecture.<sup>2</sup> While these projects far surpass any of their predecessors in scale, they are typically viewed as derivative of conventions that date to the Classical Angkor Wat period.<sup>3</sup> Although artists certainly did continue creating familiar motifs and representing the same religious characters, the devotion of Jayavarman VII to Mahayana Buddhism changed the nature of imperial art, as is exhibited in the Head of a Deva (Angkor, 12th or early 13th Century, Cambodia, sandstone). Works of art created under Jayavarman VII exhibit a remarkable and intricate balance between Mahayana Buddhism and the Hinduism of the Khmer people, having classical Angkor motifs alongside an innovative, modern style. In this way, Jayavarman VII showed respect for the ancient lineage of kings, but also communicated his own idiosyncratic personality.

To some degree, Jayavarman VII was compelled by his kingdom's decline in prominence to remold royal art in a way that would persist in a changing world. In comparing Jayavarman VII's building projects to their notable predecessor, the Angkor Wat, it is clear that subjects being portrayed sculpturally were concerned with more realistic, down-to-earth themes. The dimensions of the Angkor Wat are based on the solar calendar, and the sun follows the path of certain causeways on solstices. This then marries the Indian cosmology that involves Mt. Meru<sup>4</sup> to impressively advanced levels of mathematical and astronomical achievement.<sup>5</sup> While the Jayavarman VII's projects dwarf the Angkor Wat projects in scale, they do not reflect the same intricate cosmological concerns. Some of the structures and sculptures in Angkor Thom were altered during their construction, indicating haste, and all are built without regard for the solar calendar.<sup>6</sup> This could signal a lack of overall refinement, but it would be a grave disservice to define the Angkor Thom solely as part of a decline in Classical conventions. The architecture and sculpture of the Angkor Thom represent a complex negotiation between past and present, decline and ascension, and innovation and convention.

Representations of Devas in particular convey this tension. Devas were gods indigenous to the Khmer religion who, under the patronage of Angkor kings, were depicted in a variety of ways. Sometimes called "giants" by Western scholars, devas took on a distinct but varied style from

1 This paper was originally turned in to Elizabeth Lillehoj, Department of the History of Art and Architecture, Autumn Quarter 2008-2009. dritter2@students.depaul.edu.

2 Coe, Michael, *Angkor and the Khmer Civilization*. (New York: Thames and Hudson, 2003) pp. 122-124.

3 Jessup, Helen Ibbitson and Zephir, Thierry, eds., *Sculpture of Angkor and Ancient Cambodia: Millennium of Glory*. (Washington: National Gallery of Art, 1997) p. 297.

4 Mt. Meru is a cosmological concept in Hinduism and Buddhism. It is an enormous peak located center in the center of the universe, and is home to different heavenly realms. At the top resides the principal deity of the religion, be it Shiva in Hinduism or Vairochana in Buddhism. For a concise discussion of Mt. Meru, see Robert E. Fisher, *Buddhist Art and Architecture*. (London: Thames and Hudson, 1993) pp. 22-23.

5 Mannikka, Eleanor. *Angkor Wat: Time, Space, and Kingship*. (Honolulu: University of Hawai'i Press, 1996) pp. 7-21.

6 Jessup, Helen Ibbitson and Zephir, Thierry, eds., *Sculpture of Angkor and Ancient Cambodia: Millennium of Glory*. (Washington: National Gallery of Art, 1997) pp. 297-298.

individual sculptors.<sup>7</sup> Lining the causeway in front of the gopuras in Angkor Thom, colossal devas served as protective attendants. They appear in great numbers; there are fifty-two devas on the West causeway alone. These are accompanied by attendant figures as well. Jayavarman VII allowed the local sculptors a degree of artistic license in royal art. The devas' facial expressions vary from contented smiles to rage-induced contortions.<sup>8</sup> The Head of Deva appears peaceful, calm, and gentle, his mouth curved into a placid smile. He wears kingly symbols of power and prestige, including an ornate crown. His earlobes stretch down to his shoulders and his forehead and neck are adorned with ornate jewelry. Were it still mounted on its colossal body, the piece would have a daunting frontality; the surviving figures that line the causeway stand at stiff attention. As one approached the majestic, towering gopura at the end of the causeway, these emblems of great power and prestige were intended to inspire the viewer with awe.

The features of the deva are idealized to achieve this end. The symmetrical, smooth face gives it a quality of otherworldly perfection. The impossible smoothness and gentle curves of the deva's skin are juxtaposed with the ornate protrusions of its crown. Though just as orderly and symmetrical as the face, the crown is layered in jagged protrusions that rise to a majestic peak above the top of his head. These symbols of power and wealth are drawn from artistic conventions that predate Jayavarman VII. An innovative Buddhist element is the closed eyes, which impart a feeling of meditative inwardness. The deva is clearly at peace in this state, as his mouth is curved into a distinctive smile. This smile is one of the unique characteristics of the Bayon style, and it illustrates the transformative effect Buddhism had on the arts. Devas were incorporated into the catalog of semi-divine beings without profaning either religious tradition.

The devas do not simply represent a distant spirit world. Their identity is also bound to the emperor and to the past. They are manifestations of the imperial influence that allowed Angkor to be retaken militarily. In this way, religion, kingship, and the past are mythologized together into an all-pervasive whole. It is important to note, however, that the king was not worshipped, notwithstanding numerous equations between the king and his god in the arts and his nearly limitless authority over his subjects.

The line between political and religious history is equally blurry in the temple Preah Kahn. The nagas, or auspicious, semi-divine snakes, that appear at the moats around Preah Kahn serve as markers of spiritual landscape. Crossing the boundary of water, one enters a sacred setting. The complex is built on the battlefield where Angkor was recaptured from the Cham king.<sup>9</sup> The equation of religious authority and political authority is evident in that a site of military triumph is also a place of religious significance. The victory of the Khmer army signified religious as well as human action. In a sense, the battlefield was sanctified by military victory.

7 Ibid., 292.

8 Freeman, Michael and Jaques, Claude, eds. *Ancient Angkor*. (Trumbull: Weatherhill Press, 1999) p. 170.

9 Ibid., 172-175.

When the authority of the kingship was exerted successfully, it was also a demonstration of a godly presence. The place in which such phenomena occurred was imbued with both historical and religious meaning. The placement of Preah Kahn illustrates political potency as an expression of a religious presence on earth.

In the Khmer mindset, these two distinct aspects of culture were bound to one another; the king and the god he promoted (typically Siva or Vishnu) were equated with one another.<sup>10</sup> The earlier practice of connecting the king with a god emerged from the practice of sculpting Shiva in the form of a linga. As a linga, Shiva was represented as a phallic stone, sometimes with four images of his face on each side.<sup>11</sup> The earliest known depictions of Shiva in Khmer history represent him as a linga. The linga took on a special meaning for the Khmer kingship. In Khmer tradition, the linga was thought to dually represent the presiding monarch as well as the god. In this way, lingas cemented the identity of the king to that of the god. Once the monarch died, he was believed to unite with the god he worshipped and promoted during life. Thereafter the linga was a testament to the king's time as a universal monarch. The symbolic importance of the linga would endure beyond the rule of Jayavarman VII, but he would not represent himself or his kingship through it.

Although Hinduism and Buddhism coexisted peacefully under Jayavarman VII, the artists Jayavarman employed faced the challenge of determining how to equate the king with divinity without employing the markedly Hindu linga. The answer was responsible for giving the Bayon its most distinctive characteristic. Jayavarman VII chose to represent himself as Avalokiteshvara, the bodhisattva of compassion. The towering faces built into the spires of the Bayon represent both the Bodhisattva and the monarch. Sculptures of Jayavarman VII have virtually the same facial features as the towering faces of the Bayon.<sup>12</sup> Each has closed, inward-looking eyes, characteristic of meditation. The theory that the bodhisattva represents the monarch is further reinforced by the uniformity of the faces on the Bayon. From the varied images of the devas, we can be reasonably sure that Jayavarman VII was not opposed in principle to representing a single being in a wide variety of forms. The lack of diversity of the towering faces of the Bayon, then, indicates that the colossal faces were actual portrayals of Jayavarman VII. Those who witnessed the Bayon's erection would no doubt have seen Jayavarman VII as part of the ancient lineage of chakravartins, as well as the revolutionary champion of a new Buddhist state. This kingdom, however, would barely outlast its founder.

The scale of the public works programs Jayavarman VII undertook does not suggest that he saw himself as the last of a kingly line, and the wall reliefs of Bayon architecture notably reflect values concerned with the affairs of ordinary people. The subject matter deviates from the

10 Mannikka, Eleanor. *Angkor Wat: Time, Space, and Kingship*. (Honolulu: University of Hawai'i Press, 1996) pp. 6-7.

11 Jha, D.N. *Early India: A Concise History*. (New Delhi: Manohar Publishers, 2004) p. 170.

12 Coe, Michael, *Angkor and the Khmer Civilization*. (New York: Thames and Hudson, 2003) p. 124.

high, cosmological concerns that marked the Angkor Wat period, instead illustrating the everyday and the mundane. Ordinary people are pictured going about their daily business alongside sculptures depicting towering devas and nagas.<sup>13</sup> The wall reliefs show that Jayavarman VII was concerned with not only representing the religious web that bound the universe together, but his concerns were also those of the ordinary. This shift in values indicates that the religious art was more a continuation of past conventions than a bold statement about the future. Only the representations of the Buddha are a proud, unprecedented declaration of identity. Buddhist philosophy might have been Jayavarman's response to the condition of his empire. Buddhism stressed inward contemplation as a means to achieve enlightenment. Between civil disorder, dwindling resources, and powerful enemies, notions of an immortal empire were no longer the ruler's primary focus. Although Jayavarman VII succeeded in restoring the empire to its past glory, the notion of kingship had been irreversibly transformed.

The means Jayavarman VII used to promote Buddhism and make a Buddhist ruler accessible are both innovative and complex. The art created during his rule exhibits an intricate relationship between religion, kingship, and history. Accordingly, the Bayon style should not be understood as symptomatic of a period of cultural remission. The art of the late Angkor kingdom does not simply manifest the transformation of a kingdom from international prominence to near obscurity, but also the transformation of the role of the king in a changing world. Acknowledging how this dynamism is conveyed artistically should correct the perception of this period as strictly an era of cultural and political decline.

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Daniel L. Edelstein<sup>1</sup>

## Listening to Consonant and Dissonant Harmony through Music

### Abstract

*Audiences, both individual and group, experience a similar connection with music and with each other. This essay attempts to analyze this relationship through the concept of harmony. Both as consonance and dissonance, harmony represents the unique relationship that listeners have to music. Connected to the music, individuals feel similarly connected to one another. Through a basic understanding of the usage of harmony in music and what this means for philosophy from Nietzsche and Plato, we may come to better understand this unique relationship, but also its place in aesthetics.*

### Introduction

In this paper, I will analyze the concept of harmony, insofar as it is both a musical device and an integral part of the aesthetic experience of music. Such arguments can be verified by an inquiry into the appreciation of music, both from an individual and group audience perspective. It is true that one's listening may greatly vary from another's, but there is a connection for both that harmony seems to be able to describe. So, if harmony occurs between a single listener and a piece of music, then the same is possible for a group, both with music and one another. Therefore, music functions as a way to connect people through a shared experience of harmony.

This will fundamentally be an analysis of harmony that must be defined both as a concept in everyday discourse and a musical device, keeping aware of the various modes of its expression. With harmony defined, we may inquire into experiences of it through music. This investigation is primarily philosophical, so it is important to recognize that no one experience is right and another wrong, but that we merely inquire concerning experience.

Harmony comes, etymologically, from the Greek *harmonia* meaning "joining, joint, or agreement," (OED, sec. 1: etymology). The joining of individuals—some set individual parts, whether it is people, colors, musical notes or other objects—into one unique whole is harmony. The resulting whole is an agreement, because if the previously exclusive parts did not agree with one another, then the whole would not exist as a whole. It is certain that what is assumed with harmony is the completion of the joining, the agreement that is harmony. Harmony may be different to various people. This can be described by its usage in music.

According to Kamien, "Harmony refers to the way chords are constructed and how they follow each other" (51). In defining harmony, Kamien elucidates the nature of harmony that is found in its *construction*, which is the combining of notes for a chord, for example. "A chord is a combination of

three or more tones sounded at once" (Kamien 51). Here it is clear that, even with music, harmony, as a process of joining, and the joining resulting in agreement, remains consistent. However, harmony is integral for music because it adds support and fullness to a melody and makes the feeling of the music unique (Kamien 51).

There are two distinctive modes of harmony: consonance and dissonance. On the one hand, consonance is "considered stable and restful... [Consonance is] a tone combination that is stable" (Kamien 52). So, if a chord is a combination of three or more tones, then it is not only that a chord itself is harmony, but that a chord, when sounded, is consonance when it evokes such feelings, perhaps relaxed or balanced. Harmony as defined above, though, seems to describe harmony as only consonance. Consonance is defined as "points of arrival, rest, and resolution" (52). This seems like agreement, which would make harmony merely consonance. But, some tones may join, whose harmony gives a much different feeling.

On the other hand, harmonious chords may be dissonant. In other words, "A tone combination that is unstable is called a *dissonance*" (Kamien 52). A dissonant harmony does not show itself to be the stable, restful richness that consonance does. Instead, dissonance has a quality of tension, one of instability and with no resolution. This is not to say, however, that dissonance is incomplete. Using dissonance can be very effective in music to give a different feeling than consonance. Dissonant harmonies can be "considered harsh and have been used in music that expresses pain, grief, and conflict" (Kamien 52). Dissonance is appealing; dissonance itself is what captivates the listener sometimes. Perhaps it is because consonance tends to be the norm that we become intrigued more by something that challenges this norm. A whole piece of music may be dissonant, but it is not incomplete. Dissonant harmony is still harmony.

Certainly, a concept, defined as a word, does not necessarily define or even completely explain the concept in experience. Harmony as "joining" does not do justice to experience, like what chocolate is does not define the experience of eating chocolate. For this investigation, it is essential to note that consonance and dissonance are examples of aesthetic terminology. In other words, how the harmony appears in its presentation can be either of the two, depending on the individual's perception of the presentation. To be sure, "a chord considered harsh in one period has later come to seem rather mild" (Kamien 52). Some music is more dissonant, but it depends on the perception of the individual to understand its consonance or dissonance in terms of feeling. One's Mozart is another's Led Zeppelin. Whatever the case, an intimate connection between the music and the audience exists that allows for such conclusions to be made.

We have seen that the listening experience is in fact subjective. In other words, the fact that one piece of music is dissonant to one person does not mean that it will be the same for another. However, both experience harmony in coming to their own conclusion. A certain type of connection for one who feels the comfort of consonance, another for the discomfort of dissonance, occurs. Music brings all

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who listen into harmony, but it is up to the individual to make a conclusion, determining the aesthetic.

The harmony to be analyzed begins with a composer or artist. Nietzsche describes music as a “gospel of universal harmony”, alluding to harmony in hearing music. The Dionysiac drive, which is a force of nature that Nietzsche attributes to the Greek god Dionysos,<sup>2</sup> who influences and inspires the artist, acts like a muse.<sup>3</sup> The artist is brought into a state of intoxication, whereby inspiration, Nietzsche says, “causes subjectivity to vanish to the point of complete self-forgetting, awaken either under the influence of narcotic drink, of which all human beings and peoples who are close to the origin of things speak in their hymns, or at the approach of spring when the whole of nature is pervaded by lust for life” (17). The artist is brought into a state of disarray and dissonance, where the result is the “imageless art of music” that at least attempts to express such a feeling, and perhaps is the necessary result (Nietzsche 14). But the artist is also brought into a state of harmony with the Dionysiac. Let us analyze this further.

With intoxication, we also find a harsh instability, a feeling of disarray, like that of madness. Socrates, in *Phaedrus*, describes three states of madness, one being caused by the Muses. The Muses, possess “a gentle and pure soul, arouse it and inspire it to songs and other poetry, and thus by adorning countless deeds of the ancients educates later generations” (Plato 469). Here we see many similarities between what Nietzsche describes as intoxication from Dionysiac and what Socrates describes as madness from Muses. Another similarity is Nietzsche’s description of the Dionysiac as coming from the “innermost ground of man” and coming with “people who are close to the origin of things” (Nietzsche 17). This shows more of the similarity between the influence of the Dionysiac and the Muses.

The artist, in both cases, joining in harmony with either source, is brought into a state of dissonance, however described, and returns with songs and music that express such inspiration or possession. As Kamien suggests, “*A dissonance has its resolution when it moves to a consonance*” (52). Therefore, harmony shows itself first as dissonance, and then resolves to consonance. In the form of music, it is an attempt to express the intoxication or madness in a balanced way.

So far we have explained the experience of the artist in creating music. The experience of the individual is not so different. Nietzsche describes the artist as the “imitator” of the Dionysiac (Nietzsche 19). Therefore, what the listener hears is the expression of the inspiration of the artist. The listener is in harmony with the experience of the artist. “Musicomania,” from an ancient understanding of music’s impact upon people, was a term commonly used in the 19<sup>th</sup>

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2 Dionysos, the Greek god of wine, “represents not only the intoxicating power of wine, but its social and beneficent influences likewise, so that he is viewed as the promoter of civilization” (Bulfinch 8).

3 The Dionysiac is contrasted with the Apolline, the drive attributed to Apollo, that Nietzsche terms the “art of the image-maker or sculptor” (Nietzsche 14). The Apolline conversely influences structured art, hence an image, as such.

Century and towards the turn of the century, to describe the “powerful psychological and physical effects” of music upon its listeners (Cavicchi 245). “In response to opera, especially, music lovers often expressed visceral ecstasy, imagining music ‘filling their souls to the point of losing composure’” (Cavicchi 241). The experience of the listener is not so dissimilar from that of the artist, also experiencing harmony as a state of dissonance at first. We will soon see how the resolution is also similar.

The harmony that the individual experienced has been concluded to be a feeling of intoxication from expressing pleasure towards the music. It seems that although the artist comes to a state of consonance in composing, the listener is left in dissonance and, in fact, desires to remain there. “Concertgoers often turned to the piano to reproduce the pieces they had heard and amateur performers found themselves drawn, as audience members, to the virtuosity of the professional stage” (Cavicchi 242). The more listeners loved a particular piece of music or performer, the more they tried to recreate the experience through seeing the performance as many times as possible, or even performing the piece themselves. The more someone enjoyed a piece, the more the desire to experience music with other people, therefore establishing the audience harmony in the form of a community. This is also where we find a resolution.

The last analysis is of the community that is created by an audience of individuals who experience the profound feeling of harmony. Once again we find Nietzsche when he says further of the “universal gospel of harmony” that when hearing it “each person feels himself to be not simply united, reconciled, or merged with his neighbor, but quite literally one with him” (Nietzsche 18). This is not to say that the individual is no longer human, somehow changing form. Instead, harmony becomes even more intense when experienced with many other people. Dionysos, as the promoter of civilization, shows community in music to be an almost necessary outcome. Music not only captivates the individual, but also is able to destroy those things that make each individual exclusive, and brings the realization that we are human, all of us. Therefore, through music we are able to create harmony that is more profound than discourse or conversation. Instead, community is the consonance that is resolved from dissonance.

It is true that this harmony seems the intoxication and visceral ecstasy that the individual experiences. However, although harmony makes the individual realize his or her humanity in common with others, the aesthetic experience still allows for the subjectivity of the individual; the individual is human, yet still individual. This creates a balance between the necessary subjectivity of aesthetics and the loss of subjectivity in harmony. Consonance and dissonance require one another to create harmony, and both are harmony, but this also creates a community that is a group of individuals in harmony with one another, gently tapping their feet.

Where this investigation began in dissonance, questioning, it has resolved to the conclusion affirming the statement

that music creates harmony through shared experience. At first, harmony was defined in its construction of individual parts joining to an agreeing whole. Agreement took various forms, from the construction merely of a musical chord, to the composition of a piece, to the experience of the single listener and, finally, to the community of the audience. Basic musical knowledge in the canon of Western thought led us to observations concerning harmony as a way to better understand the aesthetic experience of music. Aesthetics are fundamentally individual; beauty is unique to each individual. This has been concluded more concretely from this inquiry, but we also intend to give way to the opportunity to inquire into such an experience.

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## Architecture, Aesthetics, and Education

### Abstract

*This paper explores the importance of design and aesthetics to university campuses and the educational ethos of students. Using the University of Illinois at Chicago (UIC) as a case study, I explore how the built environment affects student learning. Specifically, I examine the ways in which one can locate educational experience by examining the history and more recent renovation of the UIC campus.*

Education is a journey. As with any voyage, the location sets the mood and experience of the travelers. The built environment of institutions of higher education is crucial for effective teaching and learning as well as for the identity of the university. Consequently, university campuses aim to promote an educational environment that is a stimulating place for students to excel.

My continued interest in campus design morphed from an earlier ethnographic research assignment I completed with three other classmates in the Autumn 2008 quarter for an anthropology course. Using ethnographic research methods, I studied campus culture by examining the design of the UIC campus. I began my research by reading about campus design, then narrowed my focus to literature about specific aspects of design, such as Kowalski's *Planning and Managing School Facilities* (1989), Medd's *School Furniture* (1981), and Sharpe's *The Psychology of Color and Design* (1982). I visited UIC throughout the quarter and kept a field-log of my observations. I also wrote about how the buildings and interior design made me feel. Although design and aesthetics are not exclusive, they have a symbiotic relationship in which each defines the other. There I will briefly discuss both.

Because the built environment is the first visible clue to the school for visitors and prospective students, campus architects focus their design on communicating a particular *campus feel* as well as aiming for a "harmonious interplay of buildings, open space..." (Geller and Corning, 2007: 69). In campus design, a building is not a single entity but rather a unit of the larger campus and the educational environment. Campuses are therefore designed with a sense of unity and university pride, identity, and an ability to accommodate potential structural change. Walkways and signs between buildings are vital for establishing a *feel* and an identity of a particular campus. As Geller and Corning point out, "signs, and other visual cues like plantings and lighting . . . [that] assist visitors with finding their way around are also critical contributors to identity" (2007:69). A campus identity is similarly expressed in how user-friendly and welcoming the campus is for students and visitors (Geller and Corning, 2007:70). Pathways and outdoor gathering spaces affect visitors' first impressions of the campus.

The UIC campus creates a sense of unity through its water-drop design (UIC Walking Tour Webpage). Walter Netsch, head architect in designing UIC's campus, organized the campus "to mimic the concentric rings emanating from a drop of water in a pond, arranging the buildings by function rather than by academic discipline" (Veenstra, 2008). A meeting place, the Circle Forum, stands in the middle of campus with classrooms, offices, laboratories, and athletic buildings making the outer ripples, respectively. The close proximity of the buildings at UIC helps to unite the campus. Although the campus has changed since its original design, the Circle Forum remains a place for students and community members to gather. It is surrounded by cascading stairs, tables, benches, trees, and plants. Students gather here on warm days. At this location I have seen the UIC band performing and community members meeting for *CropWalk*, a fundraiser walk to raise awareness and money to combat world hunger. The Circle Forum space invites UIC and the wider community to come together.

The sense of campus unity is further enhanced by banners naming successful alumni and other points of university pride that hang on the several lampposts and engraved cement benches. While these features help brand the campus and navigate pedestrians, they cause individual buildings to stand out less, making certain lecture halls and buildings difficult for visitors and new students to find. Despite an abundant display of university pride, the lack of signage for some buildings detracts from campus identity.

Campus design ideally reflects the identity of a campus and the specific demographic it caters to. For example, UIC has many commuting students. To accommodate their needs, in 2003 the Office of Campus Learning Environments (OCLE) started turning empty, dismal locations throughout campus into homey student lounges.

Campuses also reflect the social issues prominent at the time of their design. As Kowalski points out, "schools are truly mirrors of society and the shifts in priorities often represent the reactive nature of public education to social, political, and economic dynamics" (Kowalski, 1989: 15). UIC was built during the 1960s, a turbulent time in United States history, a time when the nation was still enjoying the technologies gained following World War II. UIC was one of many "instant campuses" that had popped up across the country. The university began in 1946 as a two-year program for undergraduate students, located in the only available space, Navy Pier (UIC Walking Tour Webpage, Instant Campus). In response to parents who lobbied for a full university in the city, Mayor Richard J. Daley selected the current site of UIC.

The design employed by renowned architect Netsch was Brutalism, a popular style of architecture from the 1950s to the 1970s. "Brutalist architecture avoided polish and elegance. Practicality, economy, and user-friendliness were the principal aims of the stark, rectilinear style. Readily accessible materials such as concrete, brick, and stone were preferred" (UIC Walking Tour, Instant Campus, 2009). Following this style, the buildings of UIC consist mainly of exposed brick and concrete.

Throughout the U.S., interest increased in the new technologies and resources that had emerged from the war, an

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interest reflected in the architecture and materials of UIC. “The campus, as it was designed and built, was surely an expression of the heady post-World War II techno-optimism that celebrated science and new materials” (Kent, 1996:21).

As times have changed, so have the defining social factors that determine school design. UIC continues to make renovations amidst contemporary concerns about global warming, acid rain, pollution, and the green movement toward sustainable design, that is, designing buildings and products that minimize harmful impact on the environment and reduce the necessity for non-renewable resources to build and operate buildings. Sustainability is also more cost-effective and may enhance aesthetic feel.

UIC has endorsed sustainability and several green renovations of campus lecture halls are underway. The most notable project is in geothermal energy designs. The first renovated building, Grant Hall, remains at constant temperatures between 70 and 72 degrees Fahrenheit by means of a geothermal system that works through 14 pipes buried 500 feet underground (Renewable Energy on Campus, 2008). Geothermal heat pumps (GHPs) use the underground temperatures, on average 55 degrees Fahrenheit, to provide constant heating and cooling energy naturally throughout the year. This lowers costs and is environment-friendly, using half the energy of a conventional system (Renewable Energy on Campus, 2008). Given the great benefits of this system, UIC plans to heat and cool other buildings through geothermal energy. Several banners on campus boast about these new geothermal systems. Additional environmental methods implemented on campus include increased windows, recycling, and other innovative and sustainable technologies.

Aesthetic appeal is a crucial but often overlooked aspect of the educational environment. While Susan Klonsky states that aesthetics is “not what drives decision making” in school designs (2007: 33), researchers have noted that attractive rooms invoke a greater sense of well-being and a more invigorating educational experience than less attractive rooms, which may induce fatigue and be less conducive to student learning (Rydeen, 2003:159). Recognizing the importance of campus aesthetics, UIC established the Office of Campus Learning Environments (OCLE) five years ago to enhance aesthetics and create an environment that promotes academic success.

Given that UIC was built in the style of Brutalism, it may feel dark and uninviting. “Without question, the UIC campus was a hard-edged, tough place not easily accessible, intellectually nor esthetically” (Kent, 1996:21). The rooms were dark with exposed brick or grey walls. There was a lack of natural lighting as “windows are often screened by ornate precast concrete that creates an interesting textural effect from the outside but blocks light inside” (Kent, 1996:21) and some classrooms have no windows at all. The campus design seemed to lack a human aspect.

Since the 1970s the university has been revamping the campus to make it more aesthetically and physically appealing to students. Mobile furniture, lighting, and color decisions at UIC are informed by student surveys conducted by the OCLE, which works closely with the student government

to fulfill students’ needs. Surveys can be completed anytime on the OCLE website. Students also have direct involvement in the many renovated spaces that display student artwork. The Stevenson Hall Oasis goes a step further. The entire space was designed and constructed by students of UIC’s School of Architecture. By including students in the design process, UIC is ensuring that students receive the surroundings they desire while uniting the UIC community behind a common goal, to create a pleasurable environment to thrive in.

According to the OCLE’s website, student surveys requested more natural lighting, and the Office responded. The significance of color in daily functioning has been the topic of recent studies as findings suggest that “the effects of light . . . impact beyond the phenomena of vision . . . on mood and behavior” (Kuller, 2006:1497). UIC’s OCLE has tried to improve lighting in two ways: by adding new windows and allowing more natural light into existing windows (OCLE, 2008). Lecture hall renovations include many more windows, beneficial for sustainable building, costs, and student learning. A greater challenge was how to increase natural light in existing spaces. One solution was to replace heavy, dark curtains with lighter window panels that let light in without the distraction of glare and bare windows. The other solution was to put up new fixtures with softer lighting (OCLE, 2008).

The surveys repeatedly called for more color. Color is crucial to a classroom setting; color is emotional and also affects learning, as “too many colors evoke incorrect responses to test questions” (Sharpe, 1974:138). The classroom design guidelines set by the Office of Campus Learning Environments in consultation with other offices within the university community in August 2007 note that color must appeal to the great variety of people who use the rooms and its maintenance must be easy (Classroom Guidelines, 2008)). The result was a backdrop of earthy tones with bright-colored accents. The guidelines also note that “classroom walls should benefit from the well-understood potential for a very little bit of bright color to have a large impact on the overall feeling” (Classroom Guidelines, 2008). This is accomplished through neutral-colored walls with colorful furniture or artwork to brighten the tone of the room. For example, the addition of a colorful mural and furniture described as “brown, orange, and gold – complements the mural’s color palette and provides a comfortable place for students” (Levy, 2008: 1, 5). Student art adorns classroom walls, making places of social interaction more colorful while promoting student involvement. UIC recognizes that color impacts students’ moods and motivation to learn and it has invoked appropriate color schemes in and out of the classroom.

A campus also invokes a sense of well-being through its furniture. The most important aspect of furniture is mobility. To aid learning, furniture “must be easy to move about, giving teachers freedom to use it how and where they want” (Medd, 1981:63). Furniture should also accommodate places of social interaction around campus, and UIC has been actively updating and improving its furniture throughout campus. The OCLE website points to classroom renovations with “flexible seating... [and] multipurpose chairs”. In

larger lecture halls, tablet seats, fixed seats with side tables that can be lifted for writing, have been upgraded. About ten percent are designated for left-handed students. Classrooms have seen the greatest changes in seating, as fixed tablet desks have been replaced with tables and chairs to be more conducive for flexible learning. Outside the classrooms, comfortable armchairs are strategically placed for students to lounge in, and coffee tables have been added for students' multipurpose use. Furniture defines a room and helps dictate how students learn and interact with fellow students.

**Figure 1**  
**Science and Engineering Room 170 Before and After**  
**Figures from the Office of Environmental Learning**



As these photographs demonstrate, aesthetics can transform rooms from drab to fabulous by focusing on furniture, lighting, and color. Rydeen notes that “spaces designed with aesthetic pleasantness, complementary colors in proper furnishings, and galleries . . . that display student artwork contribute to a sense of self-worth and ownership” (2003:160). Aesthetics can complement campus design unity and enhance the educational experience.

Certainly, additional considerations such as safety and technology are necessary for the enhancement of learning. However, a basic understanding of the built environment's impact on learning is important for universities to recognize. While well-designed and pleasing facilities do not guarantee good education, they provide a strong foundation for students to learn and socialize. Student input is crucial to this process. By giving students a voice in the process, UIC shows that renovations based on input from its consumers can make a difference in students' learning and sense of well-being.

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*Untitled*  
*Lisa Armstrong*  
*Cut paper collage, 2008*

Brian Shevenaugh<sup>1</sup>

## America's Strategic Engagement with Africa: An Assessment of AFRICOM

### Abstract

*Officially established in 2008, AFRICOM is the Pentagon's newest Unified Combatant Command. This article employs documents written by analysts of U.S. military policy, as well as interviews that I conducted with senior-level Department of State officials in 2008, to critique the strategic logic undergirding AFRICOM's creation. It begins by briefly outlining the history of U.S. foreign policy towards Africa. It then argues that the creation of AFRICOM represents a long-overdue reprioritization of African affairs. However, it cautions that AFRICOM's integrated command structure and expanded mandate create significant complications. Finally, this article provides policy recommendations aimed at countering these difficulties.*

### Introduction

Officially established as an independent entity on October 1, 2008, United States Africa Command (AFRICOM) is the Pentagon's newest Unified Combatant Command (UCC)<sup>2</sup>. UCCs are organizations within the U.S. military that oversee the "operational control" of all military forces within a major geographic area, known as an Area of Responsibility (AOR). The Unified Command Plan (UCP) is the document that divides the earth's surface into AORs, assigning each one to a UCC<sup>3</sup>. There are currently six regional UCCs: NORTHCOM (AOR: North America); SOUTHCOM (Central/South America); AFRICOM (Africa minus Egypt); EUCOM (Europe); CENTCOM (Egypt/Middle East/Central Asia); and PACOM (Asia-Pacific region).<sup>4</sup>

AFRICOM is the first UCC to be dedicated solely to Africa. Prior to AFRICOM's creation, the African continent was split among three different UCCs—none of which focused primarily on Africa: EUCOM was responsible for most of North, West, Central, and Southern Africa; CENTCOM looked after East Africa; and PACOM monitored Madagascar and a few small island nations in the Indian Ocean (see Figure 1 in the Appendix).

AFRICOM's mandate is also unique. Testifying before the House Subcommittee on Africa and Global Health in late 2007, Deputy Assistant Secretary of Defense for African Affairs Theresa Whelan noted that, whereas existing UCCs are designed for war-fighting, AFRICOM will expand its

mission to focus on war-prevention. This commitment entails enlisting the military not simply to fight battles, but also to help build "crisis response" and "humanitarian relief" capacity.<sup>5</sup> Further differing from existing UCCs, AFRICOM will also incorporate representatives from the Department of State—a non-military governmental agency—into its command structure, forming what is known as an "integrated command structure."<sup>6</sup>

This article employs documents written by analysts of U.S. military policy to scrutinize the strategic logic behind AFRICOM's creation. It also draws on interviews that I conducted with senior-level Department of State officials during the summer of 2008 to illuminate AFRICOM's limitations. It begins by briefly outlining the history of the Unified Command Plan and United States foreign policy as they pertain to Africa. It argues that, in light of this history, the creation of AFRICOM represents a long-overdue reprioritization of African affairs that corrects bureaucratic inefficiencies and responds to current geopolitical realities. However, this article then asserts that AFRICOM's integrated command structure creates significant legal ambiguities. Moreover, it cautions that AFRICOM's expanded mandate could prove counterproductive. Finally, this article proposes a solution to the legal dilemma and suggests a non-military policy alternative for expanding American influence in the region.

### A Change Whose Time Has Come...

The UCP grew out of the joint U.S.-U.K. military arrangements during World War II.<sup>7</sup> The development of the assignment of various UCCs to Africa reflects the reactive character of U.S. foreign policy towards the continent since the end of World War II, as well as the low priority it has historically been given.<sup>8</sup> In 1946, the Outline Command Plan created seven UCCs—none of which were assigned an AOR in Africa. Throughout the Cold War, zero-sum calculations aimed at the Soviet Union determined U.S.-Africa policy. In 1960, the "threat of a communist takeover" in the Congo led American policymakers to assign Sub-Saharan Africa to a UCC. After a few modifications, "dismantling" the UCC responsible for Sub-Saharan Africa in 1971 ushered in an 11-year period during which the area remained unassigned. Finally, renewed concerns over Soviet and Cuban activities in Africa led the military to divide the continent between EUCOM and CENTCOM. This essentially mirrored the UCC structure before AFRICOM was officially established in 2008.<sup>9</sup>

In this way, AFRICOM represents a long-overdue internal

1 Advised by Clement Adibe, Department of Sociology. brianshevenaugh@gmail.com.

2 "U.S. Africa Command Stands Up." U.S. AFRICOM Home. 9 Oct. 2008. U.S. Africa Command. <<http://www.africom.mil/getArticle.asp?art=2177>>.

3 "Combatant Command." DOD Dictionary of Military Terms. U.S. Department of Defense. 24 Feb. 2008 <<http://www.dtic.mil/doctrine/jel/doddict/data/c/01040.html>>.

"DoD Almanac." Defense Almanac. U.S. Department of Defense. 24 Feb. 2008 <<http://www.defenselink.mil/pubs/almanac/>>.

4 "Unified Command Plan." DefenseLINK. U.S. Department of Defense. <<http://www.defenselink.mil/specials/unifiedcommand/>>.

5 Whelan, Theresa. "Africa; Testimony of Theresa Whelan - U.S. House Africom Hearing." AfricaFocus Bulletin 3 Aug. 2007. LexisNexis Academic. DePaul University, Chicago. 24 Feb. 2008.

6 Whelan. 4.

7 Cole, Ronald H., Walter S. Poole, and James F. Schnabel. The History of the Unified Command Plan 1946-1993. Boston: DIANE Company, 1996. 11.

8 Lawson, Letitia. "U.S. Africa Policy Since the Cold War." Strategic Insights VI. Jan. 2007. Naval Postgraduate School Center for Contemporary Conflict. <<http://www.ccc.nps.navy.mil/si/2007/Jan/lawsonJan07.asp>>.

9 Catoire, Richard G. "A CINC For Sub-Saharan Africa? Rethinking the Unified Command Plan." Parameters: US Army War College 30. Academic Search Premier. Winter 2000/2001. 2-4.

reorganization in the Department of Defense (DOD). The previous UCP framework was something of a relic from an era during which Africa was merely seen as a “chessboard for superpower maneuvers.”<sup>10</sup> As a result, it created geographical “seams between the [UCCs]”<sup>11</sup> that did not reflect contemporary African political “realities.”<sup>12</sup> For example, despite sharing a common border, the central African countries of Chad and Sudan were previously assigned to different UCCs.<sup>13</sup> The governments of both countries have a history of supporting rebel groups on their opponents’ territory that are hostile to the host government.<sup>14</sup> The previous UCP arrangement was problematic because taking military action against either side would require the resources of two UCCs. Such complications are not just hypothetical. The U.S. military had to bridge UCCs to make “extensive use” of basing facilities in Kenya (which fell under CENTCOM) when it intervened in Rwanda (which fell under EUCOM) in 1994.<sup>15</sup> Placing all African countries under AFRICOM significantly reduces these complications.

The previous UCP configuration also posed bureaucratic and operational challenges for the U.S. Because none of the three UCCs among which Africa was divided were primarily concerned with Africa itself, the competing demands placed on each UCC made it difficult to “prioritize...and pursue” their respective security interests in Africa. Moreover, this arrangement made it possible for unforeseen crises in Europe or the Middle East to distract the UCCs from their African responsibilities.<sup>16</sup> One could argue that the United Nations’ problematic humanitarian intervention in Somalia in 1993, from which the U.S. withdrew its troops shortly after footage of a “slain U.S. soldier [being] dragged through the streets of [the Somali capital]” was broadcast worldwide,<sup>17</sup> would not have ended so calamitously if the attention of the U.S. military commanders responsible for Somalia had not been divided between East Africa and the Middle East.

Moreover, the creation of AFRICOM is a pragmatic reprioritization of African affairs that is in line with shifting geopolitical circumstances. Africa’s natural resources are increasing in strategic importance to the U.S..<sup>18</sup> In 2006, the combined total of America’s oil imports from Angola, Algeria, and Nigeria was 19%, compared to just 14% coming

from Saudi Arabia.<sup>19</sup> African oil production is forecasted to double within the next decade, which would put it on a par with the Middle East in the U.S. oil import market.<sup>20</sup> Meanwhile, the U.S. is facing stiff competition from China for natural resources in Africa. China’s spectacular economic growth over the past few decades has transformed it from a net exporter of oil in 1993 to the world’s “second-largest energy consumer”. Accordingly, it now receives 30% of its oil from the African continent.<sup>21</sup> If the United States wants to reduce its dependence on Middle Eastern oil by expanding into Africa, increased Chinese penetration into the African market poses significant barriers to this goal.

In general, Chinese economic activity in Africa has flourished in recent years. Although the U.S.’ \$71 billion of bilateral trade with African countries in 2006 eclipsed China’s \$50 billion, China’s figure represents a four-fold increase on the trade it did with African countries in 2000.<sup>22</sup> Increased Chinese influence in Africa has important implications for its clout in multilateral organizations, such as the United Nations and the World Trade Organization. African countries “tend towards block voting” in these organizations, where they are usually the largest regional grouping of countries.<sup>23</sup> By devoting an entire UCC to the African continent, the U.S. is demonstrating the seriousness with which it regards its African ties. The aforementioned trends suggest that this could not come at a more opportune moment.

#### *...But Whose Scope Is Ill-Conceived*

An examination of the relevant statutes reveals that AFRICOM’s integrated command structure creates legal ambiguities relating to the lines of authority that separate the DOD and the State Department. Title 22 of the U.S. Code outlines the ambassador’s authority, and Title 10 delimits that of the UCC commander.<sup>24</sup> Title 22 gives the ambassador full authority over all executive branch employees working in that country—except for those that are under the UCC commander’s control.<sup>25</sup> By contrast, Title 10 states that the UCC commander will direct all “subordinate commands and forces necessary to carry out” the command’s missions.<sup>26</sup> Therefore, under normal conditions the ambassador’s authority ends where that of the UCC commander begins.

However, sources within the State Department maintain that the lines of authority become blurred once

10 Kraxberger, Brennan M. “The United States and Africa: Shifting Geopolitics in an ‘Age of Terror.’” *Africa Today* 52 (2005): 48.

11 McFate, Sean. “U.S. Africa Command: A New Strategic Paradigm?” *Military Review* (January-February 2008): 11.

12 Catoire, 9.

13 McFate, 11.

14 Flint, Julie. “Darfur’s Armed Movements.” *War in Darfur and the Search for Peace*. Ed. Alex De Walle. Cambridge: Global Equity Initiative, Harvard University, 2007. 162-163.

“Q&A: Chad rebellion.” 4 Feb. 2008. BBC News. <<http://news.bbc.co.uk/2/hi/africa/7225023.stm>>.

15 Catoire, 9.

16 *Ibid.*, 3, 10.

17 Hook, Steven W., and John Spanier. *American Foreign Policy Since World War II*. New York: CQ P College, 2006. 262.

18 Lyman, Princeton N., and Patricia Dorff, eds. *Beyond Humanitarianism: What You Need to Know About Africa and Why It Matters*. New York: Council on Foreign Relations, 2007. 199.

19 Authers, John. “The Short View: African Oil.” *Financial Times* 24 Apr. 2007. LexisNexis Academic.

20 Lyman, 204.

21 McFate, 13.

22 Alden, Chris. *China in Africa*. New York: Zed Books, Limited, 2007. 104.

23 Alden, 22.

24 “Interview with State Department official.” Personal interview. July 2008.

25 “U.S. CODE: Title 22,3927. Chief of mission.” Legal Information Institute at Cornell Law School. <[http://www4.law.cornell.edu/uscode/html/uscode22/usc\\_sec\\_22\\_00003927----000-.html](http://www4.law.cornell.edu/uscode/html/uscode22/usc_sec_22_00003927----000-.html)>.

26 “U.S. CODE: Title 10,164. Commanders of combatant commands: assignment; powers and duties.” Legal Information Institute at Cornell Law School. <[http://www.law.cornell.edu/uscode/uscode10/usc\\_sec\\_10\\_0000164----000-.html](http://www.law.cornell.edu/uscode/uscode10/usc_sec_10_0000164----000-.html)>.

representatives of civilian agencies are subordinated to a military official (as they are in AFRICOM). With this command structure, it is not clear how far into the State Department the UCC commander's authority extends—let alone whether it supersedes that of the ambassador. This arrangement would leave it unclear who “the real authority is” when conflict erupts in the country and U.S. troops become involved. One senior State Department official claimed that the tension in Iraq observed between ambassador Ryan Crocker and CENTCOM Commander Gen. David Petraeus is illustrative of these complications.<sup>27</sup>

Furthermore, some analysts warn that, despite numerous public statements emphasizing the humanitarian character of AFRICOM's expanded mandate, its *primary* focus will be military in nature. Several commentators point out that after 9/11, despite the incorporation of humanitarian measures, the DOD's “most significant endeavors in Africa” have been chiefly aimed at preventing Islamic militants from taking advantage of weak states to create an African Afghanistan.<sup>28</sup> Analyst Robert Berschinski expresses concern that this is true of U.S. military programs that are frequently cited as models “on which AFRICOM should build.”<sup>29</sup> He warns that combining military and humanitarian measures could cause African states to be “wary of U.S. intentions,” thereby closing off both sides to the benefits that could be derived from mutual engagement.<sup>30</sup> Indeed, headlines in the African press relating to AFRICOM, such as “New U.S. Command Will Militarise Ties with Africa” and “World's Biggest Military Comes to Town,” lend credence to his argument.<sup>31</sup>

### Recommendations

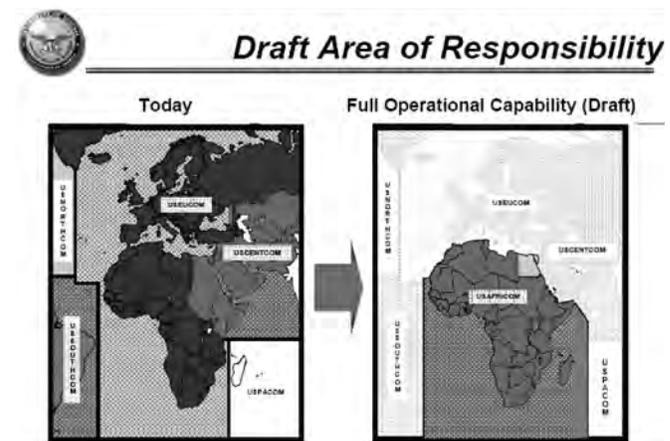
If the Obama administration intends to maintain AFRICOM's expanded mission, it will need to resolve the legal ambiguities created by the new UCC's integrated command structure. One Senior State Department official said that this could best be accomplished through an “Executive Secretary Memorandum” between the executive secretariats of the Departments of Defense and State, which would elucidate and formalize the powers of the ambassador and the UCC commander.<sup>32</sup>

Perhaps more fundamentally, the U.S. could avert the pitfalls outlined above that stem from AFRICOM's augmented responsibilities by focusing instead on increasing the level of cooperation between the government and U.S. multinational corporations (MNCs). One of the keys to China's rapid penetration of African economies has been the intimate relationship between its private and public sectors: Chinese MNCs are able to summon governmental

aid and diplomatic attention to supplement their business proposals. This policy allows Chinese MNCs to offer incentives to African governments that transcend those included in standard business transactions.<sup>33</sup> By contrast, the U.S. government has a more distant relationship with its large corporations: the government's Overseas Private Investment Corporation provides only loans and insurance to U.S. companies in an effort to facilitate commercial ventures abroad.<sup>34</sup> Increasing governmental assistance to those MNCs seeking to do business in Africa would enable the U.S. to expand its influence in the region without calling into question the ambassador's authority. What's more, it would allow the U.S. to pursue its strategic goals in Africa without projecting the image of militarizing its foreign policy.

**Figure 1:**

The image under the heading “Today” depicts the three UCCs that managed operations in Africa before the creation of AFRICOM. The image under the heading “Full Operational Capability” shows AFRICOM's AOR, which is highlighted in dark gray.<sup>35</sup>



27 “Interview with State Department official.” Personal interview. July 2008.

28 Berschinski, Robert G. AFRICOM's Dilemma: The “Global War on Terrorism” “Capacity Building,” Humanitarianism, and the Future of U.S. Security Policy in Africa. Rep. Strategic Studies Institute, 2007. 5.

Kraxberger, 55.

29 Berschinski, 11.

30 Berschinski, 3.

31 Berschinski, 7.

32 “Interview with State Department official.” Personal interview. July 2008.

33 Alden, 42.

34 Doing Business with Us. Overseas Private Investment Corporation. <<http://www.opic.gov/doingbusiness/index.asp>>.

35 United States. Department of Defense. USAFRICOM Public Brief. 7 Feb. 2007. <[http://www.defenselink.mil/home/pdf/AFRICOM\\_PublicBrief02022007.pdf](http://www.defenselink.mil/home/pdf/AFRICOM_PublicBrief02022007.pdf)>. 5.

## Layers of Loyalty: Tribalism, Ethnicity and State Building in Afghanistan

### Abstract

*The objective of my research is to bring to light the role that tribalism and ethnic identity play in state building in Afghanistan. My goal is to show that tribalism and ethnic identities pervade all layers of life in Afghanistan and that if the country is to form a stable government, all tribes and ethnicities must be successfully incorporated into it. Focusing on the historical relationship of tribe and state in Afghanistan, I performed my research by analyzing two Afghan Constitutions, reports published by international organizations, and scholarly articles and books concerning tribalism and ethnic identities. My findings suggest that it is possible to incorporate tribes and ethnicities into the formation of a new government, but that eventually it will be necessary for these identities and tribal loyalties to coalesce to form an "Afghan" identity. Without such a formation, the fragmentation of society will continue in Afghanistan and it will be difficult to form a national consensus on the future direction of the country.*

### Introduction

The successful reconstruction of Afghanistan will be an arduous task. After 30 years of fighting, the country faces the ravages of war and state failure. Bridging the division among diverse ethnic, tribal, religious, and regional communities is the greatest challenge facing the citizens of Afghanistan and the international donors who have pledged to rebuild the crippled nation. Plagued by internal and external religious extremists, regional actors jockeying for power, and a drug-fueled economy that allows no plausible alternative, the future of Afghanistan is dim. Amidst all these problems is an underlying ethnic and cultural split that has created a dichotomy of Afghan citizens.<sup>2</sup> There is tension between Afghanistan's fragmented tribal communities and the centralizing tendencies of the state structure. The objective of my research is to bring to light the role that tribalism and ethnic identities play in the state building process in Afghanistan. This paper argues that for Afghanistan to become a viable state it must become united in government, encompassing all layers of society.

### Methodology

As part of an undergraduate research grant, my research posed three questions: How can Afghanistan recognize its tribal legacy with the move to integrate diverse communities

into a common government system? What role have the various tribes in Afghanistan played in Afghanistan's government in the past? And, what role will they play in Afghanistan's reconstruction? .

To answer these questions I used textual analysis and trend analysis as my primary research methodologies. Through textual analysis I was able to obtain salient information from sources such as the Constitutions of Afghanistan. These sources helped to create a parallel view of past and current tribal, social, and governmental situations in Afghanistan. I chose to analyze Afghan Constitutions rather than other government documents because a Constitution is the fundamental law of a state, and exemplifies how the state is organized and how it views its citizens. By comparing the current Afghan Constitution with a previous one, I was able to evaluate the evolution of their articles concerning language and citizenship to see if they have become more inclusive or exclusive. By using trend analysis I was able to answer my research questions with information rooted in the historical accuracy of recurring events, patterns of social norms, and government policies. I evaluated the sources I chose based upon their relevance and the legitimacy of the institutions and authors they came from.

### Findings

The Islamic Republic of Afghanistan is home to more than 31 million people<sup>3</sup> from some 55 ethnic groups, four of which account for the majority of citizens: the Pashtuns, Hazaras, Tajiks, and Uzbeks.<sup>4</sup> Each ethno-linguistic group has a unique identity and social structure. The ethnic and linguistic fissures that permeate Afghanistan's society have made it difficult to consolidate political power and build a tolerant community. Although ethnic and tribal loyalties are not fixed, they remain one of the chief tools used to define groups in Afghanistan.<sup>5</sup>

The main ethnic groups in the region can be found in more than one country. For example, there are about 60 Pashtun tribes comprised of approximately 400 sub-tribes. These 400 sub-tribes are spread across the border of southern Afghanistan and the northwest province of neighboring Pakistan.<sup>6</sup> These ethnic diasporas and their cross-border constituencies are often associated with their specific geographic areas and unique cultures.

To understand why tribalism and ethnic identities play such an important role in the reconstruction of Afghanistan

3 "C.I.A The World Factbook: Afghanistan." Central Intelligence Agency. Summer 2008 <<https://www.cia.gov/library/publications/the-world-factbook/index.html>>.

4 *Afghanistan: The Problem of Pashtun Alienation: Asia Report N. 62.* Rep. no. 62. 5 Aug. 2003. International Crisis Group. Summer 2008, pg. 1 <<http://www.crisisgroup.org/home/index.cfm?id=1641&l=1>>.

5 *Ibid.*, 3, Rubin, Barnett R. *The Fragmentation of Afghanistan: State Formation and Collapse in the International System.* 2nd ed. New York: Yale UP, 2002, pg. 25.

6 "In The Dark: Afghanistan's Tribal Complexity." *The Economist* 2 Feb. 2008: 1-2. LexisNexis. DePaul University, Chicago., Rubin, Barnett R., and Andrea Armstrong. "Regional Issues in the Reconstruction of Afghanistan." *World Policy Journal* XX (2003): 31-40. *World Policy Journal.* Spring 2003. <<http://www.worldpolicy.org/journal/articles/wpj03-1/rubin.html>>, pg. 53.

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2 United States of America. U.S. Army War College. Strategic Studies Institute. *Overcoming the Obstacles to Establishing a Democratic State in Afghanistan.* By Dennis O. Young. Columbia International Affairs Online. DePaul University, Chicago. 26 Mar. 2009 <<http://www.ciaonet.org.ezproxy2.lib.depaul.edu/wps/ssi10527/ssi10527.pdf>>, pg. 2.

it is useful to understand what comprises tribalism in Afghanistan and its traditional relationship with the state. Tribal identity merged with ethnicity “rests on unified genealogies consisting of descendants of a common male ancestor whose name often provides the name of the group”.<sup>7</sup> Within each tribe there are familial divisions that consist of descendents of the tribe’s founder.<sup>8</sup> In his book *The Fragmentation of Afghanistan: State Formation and Collapse in the International System*, Barnett Rubin aptly describes the dichotomy of tribe and state:

Tribe and state are best thought of as two opposed modes of thought or models of organization that form a single system. As a basis for identity, political allegiance, and behavior, tribe gives primacy to ties of kinship and patrilineal descent, whereas state insists on the loyalty of all persons to a central authority, whatever their relation to each other. Tribe stresses personal, moral, and ascriptive factors in status; state is impersonal and recognizes contract, transaction, and achievement. The tribal mode is socially homogeneous, egalitarian, and segmentary; the state is heterogeneous, stratified, and hierarchical. Tribe is within the individual; state is external.<sup>9</sup>

In Afghanistan the state model of organization has been consistently weak, with the tribal model taking precedence. In Afghanistan’s history the Pashtun tribe has captured key positions in the state’s apparatus and has established its primacy. Founded in 1747 by the Pashtun Ahmed Shah Durani, Afghanistan has a long lineage of Pashtun rulers, each asserting his power and using external resources to “reign over an ethnically heterogeneous society while manipulating that social segmentation to weaken society’s resistance”.<sup>10</sup> Rather than integrating and penetrating the tribes in the countryside, the rulers in the capital of Kabul have historically pursued a strategy of co-opting traditional local institutions and acting as intermediaries between foreign powers and the main ethnic groups.<sup>11</sup> Each group has been linked to the government through ties with individuals in the government, leaving a disparity of communication and governance between the tribes, villages, cities, and the central government.<sup>12</sup>

This state structure was formed and proliferated under the tutelage of Britain and Russia. In the 19th Century, protecting its empire in India, the British made three attempts to conquer Afghanistan to prevent the expansion of the

Russian empire.<sup>13</sup> Afghanistan became a “rentier state”<sup>14</sup>, receiving aid from both Russia and Britain in what would be called the “Great Game.”<sup>15</sup> Chiefs and their tribes were manipulated and played against each other by the Afghan rulers to serve their own interest and consolidate power.<sup>16</sup> This manipulation enabled the Pashtuns to solidify their dominance; subsequently, their traditions and culture have been considered synonymous with the Afghan identity.<sup>17</sup>

Ironically, the traditions and institutions of the Pashtun *jirga* (tribal council) have played a significant role in consolidating and incorporating all of Afghanistan’s divisions into a new system of government. A *jirga* is a council formed of all adult males in a tribal organization that is ruled by consensus. This form of governance has been used in Afghanistan on a national level since the 1920s.<sup>18</sup> Although the Loya Jirga was used nationally, it was never in an official capacity. The Loya Jirga (Great Council) was officially reasserted as the main institution of decision-making for the reconstruction and transition of Afghanistan’s government by the Bonn Agreement. Held in 2001 to forge an agreement between groups on the formation of a transitional government for Afghanistan, the Bonn meeting (agreement)<sup>19</sup> established that, “The Emergency Loya Jirga will elect a head of the State for the Transitional Administration and will approve proposals for the structure and key personnel of the Transitional Administration”.<sup>20</sup> The agreement of all the groups on using the Loya Jirga as the main decision-making body suggested that a consensus could be made between the different groups. At the presidential Loya Jirga held in 2004, Hamid Karzai, a Pashtun, was elected president. Although voter turnout was low, this elections was significant: “The Loya Jirga had achieved its wider aim. It had mobilized the entire country in a national purpose. Afghans from every ethnic

13 Rashid, Ahmed. *Taliban : Militant Islam, Oil and Fundamentalism in Central Asia*. New York: Yale UP, 2001, pg. 11.

14 “The theory of the rentier state is a complex of associated ideas concerning the patterns of development and the nature of states in economies dominated by external rent, particularly oil rent. The theory in the broadest sense defines rentier states as those countries that receive on a regular basis substantial amounts of external economic rent.” Yates, Douglas A. “The Theory of the Rentier State.” *The Rentier State in Africa: Oil Rent Dependency and Neo-colonialism in the Republic of Gabon*. Trenton, N.J.: Africa Research & Publications, 1996. 11-40. 26 Mar. 2009 <<http://students.washington.edu/hattar/yates.pdf>>, pg. 11.

15 Ibid., 11.

16 Rubin 47.

17 Afghanistan: The Problem of Pashtun Alienation pg. 1

18 Rubin, 42.

19 Rubin, Barnett R., Abby Stoddard, Humayun Hamidzada, and Adib Farhadi. *Building a New Afghanistan: The Value of Success, the Cost of Failure*. Publication. New York: Center on International Cooperation, 2004. Columbia International Affairs Online. DePaul University, Chicago. 26 Mar. 2009 <<http://www.ciaonet.org.ezproxy2.lib.depaul.edu/wps/cic9979/cic9979.pdf>>, pg. 2.

20 Johnson, Thomas H. *Strategic Insight: The Loya Jirga, Ethnic Rivalries and Future Afghan Stability*. 6 Aug. 2002. Center for Contemporary Conflict: National Security Affairs Department. <[www.ccc.nps.navy.mil/si/aug02/southAsia.pdf](http://www.ccc.nps.navy.mil/si/aug02/southAsia.pdf)>. pg. 1, “The Interim Authority, Art. IV.” Proc. of Agreement on Provisional Arrangements in Afghanistan pending the Re-Establishment of Permanent Government Institutions (Bonn Agreement), Bonn. Nov. 2001. United States Institute of Peace. <<http://www.usip.org/library/pa/afghanistan>>.

7 Baxter, Craig. *Afghanistan : A Country Study/ Federal Research Division, Library of Congress*. Ed. Peter R. Blood. Grand Rapids: Claitor’s Division, Incorporated, 1997. Library of Congress/ Federal Research Division/ Country Studies/ Area Handbook Series/ Afghanistan. 1997. <<http://www.country-data.com/frd/cs/afghanistan/afghanistan.html>>.

8 Ibid.

9 Rubin, 11.

10 Ibid., 19.

11 Ibid., 20.

12 Rubin, Barnett R., and Helena Malikiyar. *The Politics of Center-Periphery Relations in Afghanistan*. Columbia International Affairs Online. Mar. 2003. Center on International Cooperation, New York University. 26 Mar. 2009 <<http://www.ciaonet.org.ezproxy2.lib.depaul.edu/wps/cic9983/cic9983.pdf>>, pg. 2.

group, tribe, and community had gathered under one roof in an atmosphere of discussion rather than conflict".<sup>21</sup>

### **Afghan Constitutions**

A comparison of the current and 1990 Afghan Constitutions illuminates the pervasive role of tribalism and ethnicity in the Afghan state. I reviewed the evolution of their specific articles concerning official languages and citizenship. In the 1990 Constitution of Afghanistan, Article Eight deemed Pashto and Dari the official languages; no other languages were mentioned. Article Thirty Three extended citizenship was extended to all citizens and said that every citizen shall be called an Afghan.<sup>22</sup> In the Constitution of the Islamic Republic of Afghanistan 2004, Article Sixteen named Pashto and Dari the official languages of the state, but also listed six other languages and stated that it would recognize the use of a language other than Pashto and Dari as a third national language wherever it was predominately spoken.<sup>23</sup> Citizenship was covered in Article Four, which stated that "The nation of Afghanistan is composed of all individuals who possess the citizenship of Afghanistan. The nation of Afghanistan shall be comprised of Pashtun, Tajik, Hazara, Uzbek, Turkman, Baluch, Pachaie, Nuristani, Aymaq, Arab, Qirghiz, Qizilbash, Gujur, Brahwui and other tribes. The word Afghan shall apply to every citizen of Afghanistan."<sup>24</sup> The differences between the constitutions show that the Afghan government is broadening its acknowledgment and inclusion of ethnic and tribal identities. By listing the different languages and ethnicities considered "Afghan" they are promoting inclusion and tolerance.

Although they are an integral part of the social and political structures of Afghanistan, some have argued against incorporating tribal and ethnic institutions and traditions. Imran Gul, program director of the Sustainable Participation Development Program, an NGO that works in Pakistan and Afghanistan, believes that "the tribal system is in crisis and that it can no longer provide 'peace, income, a sense of purpose, a social network' to the local youth, who then turn to radical movements as the only outlet where they can express their frustration and earn the prestige once offered by the tribal system".<sup>25</sup> A salient example of this would be the Taliban, a Pakistan-based Pashtun movement that attempted to take control of Afghanistan in 2001 and is

currently experiencing a resurgence.<sup>26</sup> Also pressing is the formation of a national identity.

In Afghanistan ethnic allegiance has taken precedence over national identity. This creates a two-fold problem. Not only does it denigrate any possible ruler's legitimacy, who will be accused of acting in his ethnic and tribal interests rather than those of his country, but it also leads to increased fragmentation. In his book *Taliban: Militant Islam, Oil and Fundamentalism in Central Asia*, Ahmed Rashid writes that, "Afghans no longer call themselves just Afghans or even Pashtuns and Tajiks, but Kandaharies, Panjshiris, Heratis, Kabulis or Jowzjanis. Fragmentation is both vertical and horizontal and cuts across ethnicity to encompass a single valley or town".<sup>27</sup> Increased fragmentation leads to a cacophony of voices that makes it increasingly difficult for a national consensus to be formed.

### **Strengths and Weaknesses**

The strength of my approach was focusing on the historical relationship of tribes and ethnic identities with the Afghan state and also the analysis of the two constitutions. This allowed me to see how, over time, the relationship between the variables changed and evolved. To more accurately examine the relationship between tribalism, ethnicity, and state building in Afghanistan, I would have to survey members of tribes, various ethnic groups, and figures in the Afghan government. The ability to read historical documents in Dari, Persian, Urdu, and Pashto would have also been helpful as it is often difficult to find pertinent documents translated from their original language into English.

### **Conclusion**

Balancing the interests of both tribe and government in Afghanistan will be difficult. Tribalism and ethnic identities pervade many different sectors of Afghan life. In my opinion, there need not be a bifurcation of power between tribe and government, but rather an integration of the two with institutions such as the Loya Jirga. Instead of eradicating tribal and ethnic affiliations altogether, they should be coalesced into an "Afghan" identity that retains the distinct cultural identities of each group. In his paper *Afghanistan: Reconstituting a Collapsed State*, Raymond A. Millen aptly concludes: "Ultimately, resuscitation of Afghanistan lies with the Afghan people, and government policies must be geared toward garnering their loyalty and trust".<sup>28</sup>

21 Rashid, Ahmed. *Descent into Chaos: The United States and the Failure of Nation Building in Pakistan, Afghanistan, and Central Asia*. New York: Viking Adult, 2008, pg. 141.

22 *Constitution of Republic of Afghanistan 1990*. 2007. Digitized Afghanistan Materials in English from the Arthur Paul Afghanistan Collection: University of Nebraska, Lincoln. <<http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1014&context=afghanenglish>>.

23 Afghanistan. Office of the President. *The Constitution of the Islamic Republic of Afghanistan, 2004*. 24 Jan. 2004. The Islamic Republic of Afghanistan: Office of the President. <<http://www.president.gov.af/english/constitution.msp>>.

24 Ibid.

25 Giustozzi, Antonio. *Koran, Kalashnikov, and Laptop: The Neo-Taliban Insurgency in Afghanistan*. New York: Columbia UP, 2007, pg. 39.

26 Rubin, Barnett R. "Saving Afghanistan." *Foreign Affairs* (2007). Columbia International Affairs Online. DePaul University, Chicago.

27 Rashid, Taliban 2008.

28 Millen, Raymond A. *Afghanistan: Reconstituting a Collapsed State*. Minneapolis: Strategic Studies Institute, U.S. Army War College Commandant (AWCC-DSI/Publications), 2005.

## The Effect of Sentence Context on Bilingual Language Processing in the Cerebral Hemispheres

### Abstract

*Recent research has found differences in the level of hemispheric activation during reading between monolinguals and bilinguals. In monolinguals, the number of possible word meanings and sentence context affect hemispheric activation. Using the divided visual field paradigm, we investigated how the left and right hemispheres of the brain process words in bilinguals compared to monolinguals. Our findings indicate that bilinguals recognized words in a sentence differently than monolinguals depending on the number of possible word meanings as well as the context of the sentence. Our findings suggest monolinguals and bilinguals differently process language in the right and left hemispheres.*

### Introduction

Despite the established dominance of the left hemisphere in language tasks, current research shows that the right hemisphere also receives activation during reading. For example, sentences that lead readers to strongly predict an upcoming word (i.e., strongly constrained) show a left hemisphere processing advantage, whereas sentences that do not lead readers to predict a specific upcoming word (i.e., weakly constrained) show a right hemisphere processing advantage (Virtue, van den Broek, & Linderholm, 2006). In addition, only the most frequent word meanings of ambiguous words appear to be activated in the left hemisphere, whereas both more and less frequent word meanings are activated in the right hemisphere (Beeman et al., 1994; Burgess & Simpson, 1988). Thus, when sentence context and the number of potential word meanings are taken into account, the right hemisphere is activated during reading.

Yet it is unclear if similar patterns of activation are evident in individuals who speak more than one language. Interestingly, early bilinguals (who learn both languages before the age of 5) show more right hemisphere activation during reading than monolinguals (Hull & Vaid, 2006). However, little is known about how textual factors influence hemispheric processing in early bilinguals. The aim of this research study is to examine how sentence context and the number of potential word meanings influence activation in the hemispheres of early bilinguals during reading.

Some studies have examined how factors such as sentence constraint and the number of word meanings affect word recognition during reading in bilinguals. Specifically, words that share the same spelling and meaning in both English and Spanish, known as cognates (e.g., banana), are recognized faster than words that have no shared spelling or meaning (Duyck et al., 2007). This finding is called a

cognate facilitation effect, suggesting that cognates receive additional activation because both the first and second language representation of the word is receiving activation (Schwartz & Kroll, 2006; Duyck et al., 2007). In addition, words that have the same spelling but different meaning, or interlingual homographs (e.g., pan means bread in Spanish), are recognized faster than words that have no similarities in spelling or meaning between languages (Duyck et al., 2007). However, word recognition time differences are not evident when cognates and interlingual homographs are presented in strongly constrained sentences (Schwartz & Kroll, 2006). While word recognition in bilinguals is influenced by sentence context and the number of word meanings, it is less clear how these processes influence activation in the hemispheres.

In the current study, we examine contextual constraint and word type (e.g., cognate, interlingual homograph, or control word) in the cerebral hemispheres to determine if bilinguals process language similarly to monolinguals. Specifically, if bilinguals process sentence context similarly to monolinguals (e.g., Virtue et al., 2006), then weakly constrained targets will be processed faster in the right hemisphere, and strongly constrained targets will be processed faster in the left hemisphere. If the number of word meanings differently affects word recognition in the hemispheres (Beeman et al., 1994), then words that have one meaning in both English and Spanish will be recognized faster than words that have different meanings in English and Spanish when presented to the left hemisphere. In contrast, words that have one meaning in both languages will not be recognized faster than words that have different meanings in each language when presented to the right hemisphere.

### Method

#### Participants

Fifty-four English-speaking college students and fifty Spanish-English bilingual speakers were recruited through an undergraduate research subject pool. Because early bilinguals were recruited for this study, bilingual participants completed a Language History Questionnaire (Schwartz & Kroll, 2006) to assess when each language was learned. All participants were right-handed as assessed through the Edinburgh Handedness Inventory (Oldfield, 1971) and had no history of brain damage.

#### Materials

Sixty-six real-word targets were used, consisting of 22 cognates, 22 interlingual homographs, and 22 control words. Sixty-six nonword targets were also used. The target words were embedded in sentences (see Table 1). The sentences used in this experiment were taken from materials used in a previous study examining the effect of sentence context and word type on reading in bilinguals (Schwartz & Kroll, 2006).

#### Procedure

Participants were seated 50cm from a computer screen, and a chin rest was used to maintain this distance throughout the experiment. Each sentence was presented in

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English, one word at a time in the center of the screen. At some point during the sentence, a small fixation “+” sign appeared in the center of the screen for 750ms. After the “+” disappeared, a target letter string was presented to either the right or left side of the fixation “+” for 176ms. This amount of time was used so participants could not move their eyes to the target (Bourne, 2006). When presenting a target in the left visual field, it is initially processed in the right hemisphere. Conversely, when a target is presented in the right visual field, it is initially processed in the left hemisphere. The target word was a cognate, an interlingual homograph, or a control word. The nonword targets consisted of a letter string that spelled a pronounceable nonword (e.g., “*farb*”). Participants were instructed to decide if the target was a real English word or a nonword (e.g., make a lexical decision) as quickly but as accurately as possible. Decisions were made by pressing one of two buttons using a Serial Response button box with either their left or right hand. Response times were recorded. Immediately after the response, the rest of the sentence appeared one word at a time until the end of the sentence was reached. Participants pressed a button to move on to another trial. A practice trial occurred before the actual experiment began to allow participants to adapt to the task. The response times were compared for bilingual and monolingual participants across all conditions.

## Results

Lexical decision response times to the target words were recorded from a group of 54 English-speaking participants and a group of 50 Spanish- and English-speaking participants. To minimize outliers, the longest and shortest 1% of response times within each condition were removed (Ratcliff, 1993). An alpha level of .05 was used to determine significance.

We conducted separate 2 (visual field) by 3 (word type) by 2 (level of constraint) analysis of variance (ANOVA) for monolingual and bilingual participants. In monolinguals, a main effect of visual field was found,  $F(1,53) = 5.3, p < .05$ , as well as a main effect of constraint,  $F(1,53) = 33.4, p < .05$ . More importantly, we replicated previous findings (Virtue, van den Broek, & Linderholm, 2006) by obtaining a visual field by constraint interaction,  $F(1,53) = 4.1, p < .05$ . Follow-up comparisons revealed that strongly constrained target words presented to the left hemisphere were recognized faster than weakly constrained target words for cognates  $t(53) = -4.1, p < .05$ , interlingual homographs,  $t(53) = 4.8, p < .05$ , and control word targets,  $t(53) = 2.0, p = .05$ . Target word recognition times did not differ based on level of sentence constraint when the target word was presented to the right hemisphere in any of the conditions. There was no main effect of target word type.

In bilinguals, we did not obtain a main effect of visual field, thus we did not find the same general left hemisphere advantage during reading as we did in monolinguals. There was a main effect of constraint,  $F(1, 49) = 18.5, p < .05$ , and a main effect of condition,  $F(1,49) = 9.9, p < .05$ . Finally, we also found a three-way interaction between visual field, condition, and constraint,  $F(2,98) = 3.3, p < .05$ . Follow-up  $t$  tests revealed differences in recognition times for cognates,

interlingual homographs, and control words presented to the right hemisphere when the sentence was weakly constrained. Specifically, weakly constrained cognates were recognized faster than weakly constrained interlingual homographs,  $t(49) = -6.1, p < .05$ , and weakly constrained control words,  $t(49) = -4.0, p < .05$ . In addition, weakly constrained homographs were recognized slower than control words when presented to the right hemisphere,  $t(49) = 2.3, p < .05$ . However, these differences in word type were not found when targets were presented to the left hemisphere. Additionally, follow-up  $t$  tests showed that target words embedded in strongly constrained sentences were recognized faster than weakly constrained sentences when presented to the right hemisphere for interlingual homographs,  $t(49) = -4.3, p < .05$ , and control words,  $t(49) = -3.0, p < .05$ . For targets presented to the left hemisphere, strongly constrained targets were recognized faster than weakly constrained targets for cognates,  $t(49) = -2.6, p < .05$ , and control words,  $t(49) = -2.6, p < .05$ .

## Discussion

The current findings show differences in hemispheric activation in monolinguals and bilinguals during reading. Specifically, results for monolinguals replicated previous findings by showing an overall speed-related advantage in the left hemisphere, as well as an interaction between constraint and hemisphere (Virtue et al., 2006). Monolinguals processed strongly constrained target words faster when they were presented to the left hemisphere, but did not show this difference for targets presented to the right hemisphere. Bilinguals also showed differences between strongly and weakly constrained sentences, but this difference was found in both the right and left hemisphere. This finding supports previous research claiming that early bilinguals process language similarly in the right and left hemispheres.

In addition, strong textual constraint reduced cognate facilitation in both hemispheres. This context effect is consistent with previous research examining the effect of sentence context in general (Schwartz & Kroll, 2006). However, weak textual constraint differently influenced word recognition in the hemispheres. In the right hemisphere, weakly constrained cognates were recognized faster than weakly constrained interlingual homographs and weakly constrained control words, which supports previous findings that cognates receive additional activation due to the cognate facilitation effect (Duyck, et al., 2007). In the left hemisphere, however, no differences were found based on the number of shared word meanings across languages. Thus, our findings revealed both similarities and differences between monolinguals and bilinguals.

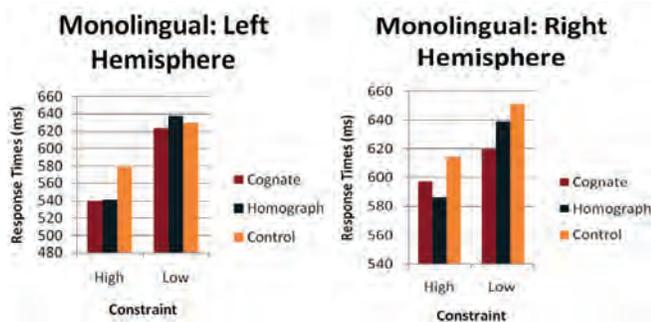
The current study adds to the existing literature by showing how bilinguals process language in the hemispheres in comparison to monolinguals. In addition, these findings help us understand the cognitive processes that occur when readers successfully comprehend a text, and perhaps more importantly, when comprehension fails. Perhaps these findings could assist in developing teaching strategies to help bilingual individuals who struggle with English as a second

language in schools or in the workplace. For example, instructors could present students with specific sentence contexts or use cognates and interlingual homographs. Finally, these findings may contribute to developing accurate models of second-language comprehension.

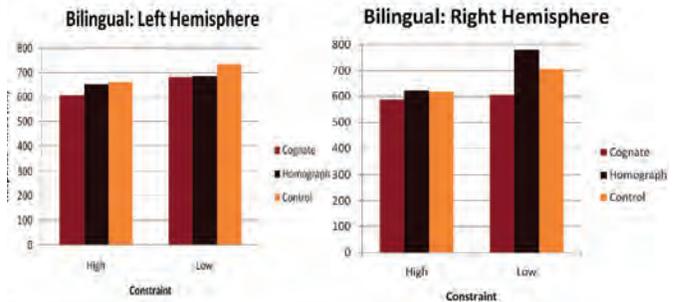
**Table 1:**  
Example Text

Target	Strong Constraint	Weak Constraint
<b>Cognate</b>	He did not get the Oscar because he was not a very good actor and there were better-deserving candidates.	She assured me that he was a wonderful actor and that the movie was great.
<b>Homograph</b>	He swallowed a small chicken bone and began to choke during last night's dinner.	I knew she would choke if she did not stop laughing so hard.
<b>Control</b>	The detective became impatient as he looked for a clue at the crime scene.	I hoped that the clue would help me solve the mystery.

**Figure 1:**  
Graph of response times for monolingual participants across conditions (cognate, homograph, and control target words) in high and low sentence constraints in the left and right hemispheres. Monolinguals displayed the fastest response times in the left hemisphere in highly constrained sentences.



**Figure 2:**  
Graph of response times for bilingual participants across conditions (cognate, homograph, and control target words) in high and low sentence constraints in the left and right hemispheres. Bilinguals displayed the fastest response times in highly constrained sentences.



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## The Influence of Need for Cognition on the Asymmetric Dominance Effect

### Abstract

*An experiment was conducted on 61 participants in the Chicagoland area to investigate how need for cognition (NC) impacts susceptibility to the asymmetric dominance effect (ADE). It was predicted that those high in NC would be more susceptible to the ADE. Results indicated that individuals were influenced by the ADE, regardless of level of NC. Unlike individuals high in NC, individuals low in NC did not recall the dominating option as better than the decoy. These findings contribute to the research on how different personality traits are related to consumer behavior.*

### Introduction

There is a great deal of interest in how consumers make decisions and what factors can influence their decisions. This study examines the asymmetric dominance effect (ADE), a phenomenon in which preference increases for one of the options in a choice set of two, pre-existing, equal consumer products when a decoy is added to the set. Equal options indicate that both options' attribute values are equally attractive for purchase. A decoy is another product option added to the choice set whose attribute values are less attractive for purchase. The purpose of a decoy is to influence the buying behavior of consumers to purchase one of the *original* items. The decoy is dominated by one of the options in the set, which means that it is less attractive for purchase than the dominating option. Therefore, when the decoy is present, the dominating option becomes the option most likely to be purchased<sup>2</sup> (Huber, Payne, & Puto, 1982; Wedell & Pettibone, 1996). The current research regarding the ADE has not investigated how different consumers are influenced. Therefore, the purpose of this research study is to investigate how the personality trait, need for cognition, is influenced by the ADE.

The ADE has been explained by several theories, such as the Justification of Choice model (Simonson, 1989), the Weight-Change theory (Ariely & Wallsten, 1995), and the Comparison-Induced Distortion theory (CID; Choplin & Hummel, 2002; 2005). The Justification of Choice model explains decoy effects by asserting that consumers want to justify their choices and by choosing the option that is most similar to the decoy, they feel their decision is justified (Simonson, 1989). The Weight-Change theory suggests that the attribute of the product on which the decoy is best will become the dimension on which consumers place most importance because the presence of the decoy places more emphasis or weight on that particular attribute. Therefore, it is on this dimension that consumers base their choice (Ariely & Wallsten, 1995). CID theory states that the

decoy alters the attractiveness of the options based on their attribute values. Specifically, given the close proximity of the decoy and the target, these options are verbally compared. This verbal comparison distorts consumers' mental representations of the options, such that the two options are biased apart. As a result, the target is perceived as better than it actually is and is preferred over the competitor (Choplin & Hummel, 2002). CID theory may hold true more for individuals high in NC than individuals low in NC. Each theory involves a cognitive aspect that requires reasoning and thought. Individual differences in the way people reason or process arguments may help explain the theoretical explanations for the decoy effects.

The need for cognition is a personality trait that distinguishes people based on how much they enjoy and engage in effortful thinking activities (Cacioppo, Kao, & Petty, 1984), and it may increase the chances that people will engage in cognitive thought as described by the theoretical explanations for the ADE. Individuals high in NC tend to enjoy and pursue thinking about complex ideas, problems, and solutions. Conversely, those low in NC tend to dislike and avoid activities that would require engaging in effortful thinking. Considering the cognitive aspects involved in the Justification of Choice, the Weight-Change, and CID theories, it is likely that NC will influence how consumers are affected by the ADE. Specifically, it is predicted that the need for cognition will influence one's susceptibility to the ADE, so that individuals with a high NC will be more likely than those low in NC to be susceptible to the influence of ADE (H1). Also, based on the CID theory (Choplin & Hummel, 2002), it is predicted that individuals with a high NC will be more likely than those low in NC to recall the target option (the option that dominates the decoy) as better than originally presented (H2).

This research will help to better understand consumer behavior and how product placement influences individuals' perception of product attributes. Research has indicated that the ADE is a robust effect (e.g., Doyle et al., 1999; Pratkanis & Farquhar, 1992). However, there is a paucity of research exploration on individual differences that may contribute to these effects. This study makes an important contribution to current research on the ADE because it helps explain *who* is and is not influenced by the effect.

### Method

#### Participants

Participants were selected at random from the general public in the Chicagoland area. A total of 61 participants completed the experiment. Demographics were not collected.

#### Materials and Procedure

A two-part survey was the primary material given to participants. The first survey packet included information to replicate the ADE. Three options of cars were presented that varied according to two attributes (miles/gallon and horsepower). The attribute values for the target option and the competitor were pre-determined through a pilot study

1 Faculty sponsor: Dr. Jessica Choplin, Department of Psychology, Graduate research assistant: Kristy Vance, Project completed Winter Quarter, 2008-2009. mollykmac@gmail.com.

2 See Figure 1 for a graphic depiction of the ADE.

that determined the equality in the value of the target and competitor options. The attribute values of the decoy were specifically picked to dominate one of the options. The middle option on the survey was always the decoy. To avoid order effects, the surveys were counterbalanced. That is, in half of the surveys the decoy was dominated by option 1, and in the other half the decoy was dominated by option 3. The survey instructed participants to review the three options and to assume that all other features of the options were equal. Participants were then asked to compare both the target option (the dominating option) and the other option to the decoy. For example, participants were asked, "Overall, do you think...option 1 is worse than option 2, option 1 is approximately the same as option 2, or option 1 is better than option 2?" Finally, participants chose which option they would like to purchase. For the second portion of the survey, participants completed a recall task in which they were instructed to write down the miles/gallon and horsepower for the three car options presented to them in the previous task. The recall task is a test of the CID theory. After the recall task, participants completed the 18-question Need for Cognition Scale (Cacioppo, Kao, & Petty, 1984), which asked them to indicate how much each statement was characteristic of them. The response set ranged from 1 (extremely uncharacteristic) to 5 (extremely characteristic). An example read, "I would prefer complex to simple problems".

## Results

The results are presented in Table 1. As part of the analysis, the Need for Cognition Scale was coded, and the median was calculated. A median split was conducted, such that participants who scored above the median were considered high in NC, while participants who scored below the median were considered low in NC. Two participants who scored exactly at the median were excluded from the analyses.

The first analysis verified whether or not the ADE had been replicated. The ADE is replicated when participants choose to purchase the target option. The chi-square results revealed that the percentage of people who purchased the target option (72%) was statistically greater than chance (50%). It was hypothesized that NC would influence the ADE, such that individuals with a high NC would be more likely than those low in NC to purchase the target option. A chi-square analysis was used to evaluate this relationship. Results showed that the percentage of people high in NC who purchased the target option (70%) was statistically greater than chance (50%). Additionally, the percentage of people low in NC who purchased the target option (72%) was statistically greater than chance (50%). These results fail to support H1 since both individuals high and low in NC were susceptible to the ADE.

Chi-square was also used to determine whether or not participants recalled the target option as better than presented. According to CID theory, participants who chose the target option should recall it as better than presented, as this explains why they would choose that option. Chi-square results revealed that the percentage of all individuals who

recalled the target option as better than presented (85%) was statistically greater than chance (50%). Individuals high in NC who recalled the target as better (90%) was statistically greater than chance (50%), and individuals low in NC who recalled target as better (79%) was statistically greater than chance (50%). The difference between these two results is not statistically significant. These findings fail to support H2 since both individuals high and low in NC recalled the target option as better than presented.

## Discussion

The purpose of this study was to investigate how the personality trait, NC, is influenced by the ADE. This study hypothesized that after replicating the ADE, individuals high in NC would be more likely to purchase the target option and more susceptible to the ADE than individuals who were low in NC. It was also predicted that individuals high in NC would be more likely than those low in NC to recall the target option as better than presented. However, contrary to what was predicted, no differences were found between individuals high in NC and low in NC in whether or not they purchased the target option (affected by the ADE). In other words, both individuals high in NC and low in NC were influenced by the presence of the decoy and were susceptible to the ADE. This finding is significant because it demonstrates how influential the ADE is on people, regardless of NC.

A statistically significant percentage of all individuals recalled the target option as better than originally presented. Individuals high in NC recalled the target option as better than presented at a rate of 90%, and 79% of individuals low in NC recalled the target as better. Although more individuals in NC recalled the target as better, both groups recalled at statistically significant levels. The difference between these results was also not significant, indicating that there are no differences in how individuals high and low in NC are affected by the ADE. According to CID theory, an individual who chooses to purchase the target option should remember that option as better than originally presented (Choplin & Hummel, 2002). Both individuals high and low in NC were not only susceptible to the ADE but also recalled the target as better than presented. This finding is important because it provides more support for CID theory as an explanation for the phenomenon of the ADE.

One limitation of this study is that the distracter task may not have been long enough to distract participants from the attribute values presented to them. A longer time period may allow for more differences in recall by the two groups. Future research may want to include more than two attributes to make the task more difficult and demonstrate greater differences between the two groups. A questionnaire at the end of the survey asking participants how they made their decisions would be helpful in future research. A self-report survey also could contribute to our understanding of CID theory and decision-making processes. For example, one question might ask, "Did you make verbal comparisons about which option was best?"

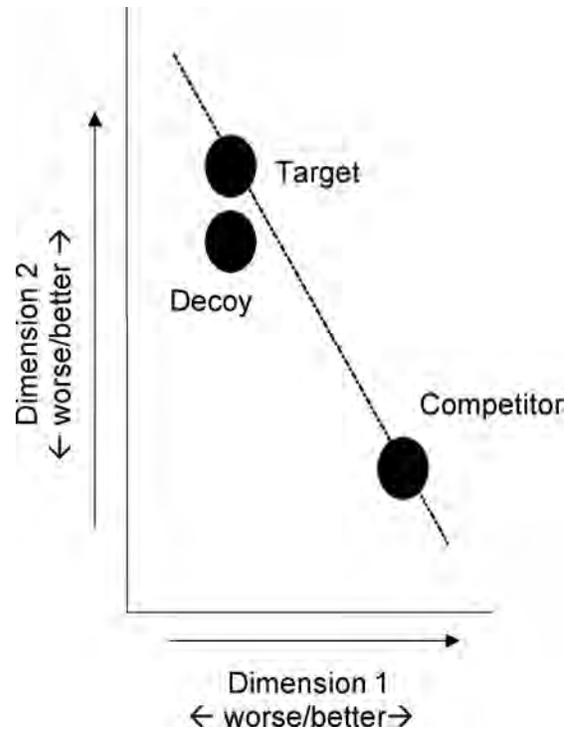
This study indicates that there is no overall difference

between individuals high and low in NC regarding whether or not they purchased the target option or recalled the target option as better than presented. Both results provide support for the strong influence of the ADE and the validity of the CID theory. This study adds to the previous literature regarding decoy effects by examining a personality trait (NC) in relation to the ADE. Finally, the results contribute to our knowledge about NC and consumer behavior by exploring the relationship between NC and the ADE. NC can be examined further in its relationship to other consumer behavior phenomena. Additionally, the influence of the ADE should be examined in relation to other personality traits.

**Table 1:**  
**Results of the experiment using susceptibility to the ADE and recall of the target option as dependent measures**

Susceptibility to the ADE:	
Susceptibility	Significance
Overall: 72% susceptible	$\chi^2(1, N = 61) = 11.95, p < .001$
High in NC: 70% susceptible	$\chi^2(1, N = 30) = 4.8, p < .028$
Low in NC: 72% susceptible	$\chi^2(1, N = 29) = 5.83, p < .016$
Recall of the target option as better than originally presented:	
Recall better than presented	Significance
Overall: 85% recall better than original	$\chi^2(1, N = 59) = 28.49, p < .000$
High in NC: 90% recall better than original	$\chi^2(1, N = 30) = 19.2, p < .000$
Low in NC: 79% recall better than original	$\chi^2(1, N = 29) = 9.97, p < .002$
Difference between high and low in NC	$\chi^2(1, N = 59) = 1.34, p > .05$

**Figure 1:**  
**The Asymmetric Dominance Effect**



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## Self Perceptions of Sexual Orientation Identity Among Gay/Bisexual Male Adolescents

### Abstract

*The purpose of this project was to explore multiple systemic factors that impact gay/bisexual (GB) male adolescents' sexual orientation identity. Data were collected from in-depth qualitative interviews of 63 GB adolescents from Chicago (N=42) and Miami (N=21) aged 14-22. Thematic analyses revealed five major factors related to sexual orientation identity development: a) external messages regarding being GB, b) sources of messages, c) positive conceptualizations of being GB, d) negative societal/cultural forces and e) positive perceived roles/responsibilities. These findings provide valuable information regarding factors that impact sexual orientation identity comfort and acceptance of GB male adolescents, and have implications for interventions.*

### Introduction

Research on the needs of gay, lesbian, bisexual, and transgender (LGBT) adolescents has primarily focused on topics of low self-esteem, increased mental health concerns/suicide, and other deficit-focused needs (Lemoire & Chen, 2005; Talburt, 2004). Some have emphasized the role of "cultural and institutional structures" in the development of sexual orientation identity and the effects of peers and heterosexual environments (Goldfreid & Bell, 2003; Risser & Murphy, 2001). While these studies provide insight into varying aspects of adolescents' sexual orientation identity, they are limited in several ways since they have: 1) focused on literature reviews and theoretical models without data, 2) relied primarily on quantitative research methods, 3) directed attention on deficits and negative health outcomes, 4) included small sample sizes, and 5) did not include ethnically diverse samples. The purpose of the current study was to address some of these limitations and provide insights into how gay/bisexual (GB) male adolescents perceive their sexual orientation identity.

### Methods

Data for the current project were taken from in-depth qualitative interviews conducted as part of a research study funded by the National Institute on Child Health and Human Development (awarded to faculty sponsor Gary W. Harper). Participants included 63 males (Chicago N=42; Miami N=21) between the ages of 14-22 who identified as gay or bisexual, and were African American, Latino, or White. All were recruited from community agencies and social venues. The interviews assessed the relationship between risk behaviors and sexual orientation, and ethnic and masculine gender identity development. An interview guide was created based on phenomenological and constructivist frameworks to learn about participants' life experiences and their behaviors, language, roles, and

interactions. The guide examined five topics: 1) masculine identity; 2) ethnic/racial identity; 3) sexual identity; 4) the integration of identities; and 5) high-risk behavior. Data for this study primarily came from the section of the interview focused on sexual identity. The constructivist approach was critical when defining and describing participants' sexual orientation using their own terms and conceptualizations.

Interview transcripts were uploaded into NVivo 8.0 software to assist in coding qualitative data. The software grouped data based on created codes and further organized the text by theme. Data matrices were also created as visual representations of the findings, and to assist with the identification of critical factors and emerging themes.

### Results

Five factors emerged as influences of sexual orientation identity development: a) external messages regarding being GB, b) sources of messages, c) positive conceptualizations of being GB, d) negative societal forces and e) positive perceived roles/responsibilities. Each of the following sections is characterized by themes that emerged from the interviews. Quotes from participants are offered to illustrate the primary themes which emerged across all of the interviews, and to permit a better understanding of the lived experiences of GB adolescents. The names of participants are concealed to protect their identity and replaced with a pseudonym.

#### *External Messages Regarding Being GB*

Themes that emerged regarding external messages focused on a) personal characteristics and b) behavior. Participants discussed personal characteristics as stereotypes associated with being GB, including presentation, individual-level attributes, and psychological functioning.

Some of the youth interviewed discussed presentation as an important characteristic. Participants described the message about dressing in drag, or in clothing of the opposite sex, or the expectation of presenting oneself as feminine, weak, and flamboyant.

Yeah, I just think that they [people in society] expect a gay person to be really flamboyant and not have any masculinity and I don't know, that's, they'd expect just the opposite of masculinity. They'd just expect a really emasculated man. ... I'm not gonna prove that to be wrong. Because I mean, there's nothing wrong with that end of the spectrum. But I mean, it's just as well that people realize there's a lot more in the spectrum. (James, 19, African American gay male)

Other young men discussed individual-level attributes as perceived characteristics of being GB. Participants gave examples of existing external messages of GB persons as greedy, selfish, or strictly concerned with cleanliness regarding health and disease. Some focused on negative societal messages regarding psychological functioning. Their responses were structured around the concept of instability or immorality due to sexual orientation identity.

...Being gay. Um, just that you're not really welcome,

<sup>1</sup> Gary W. Harper, Ph.D., M.P.H., Faculty Sponsor, Psychology Department, Winter 2009. abrodsk2@students.depaul.edu.

it's kind of like, um, gay men are just, even though our society is where it is right now with gay people and being open accepting, it's still like gay men are just kind of like, like de facto like kind of like something went wrong. Like something, something is wrong with you, even though people are like more polite about the open accepting, like yeah, I do accept you, but you're gonna go to hell because God, whatever, and if not, then they're just thinking something's wrong with you... (Thomas, 21, Mexican gay male)

Other participants discussed external messages they have received regarding behavioral traits. The youth who emphasized that they have heard such messages focused either on self-destructive behavior or sexual practices. Several participants acknowledged messages of GB men as primarily concerned with sex, as promiscuous persons or as carriers of disease.

AIDS. That's the first one that popped in my head.... Like they just think you're gay, you have AIDS. Have some kind of herpes or have STDs (Carlos, 19, Latino gay male)

#### **Sources of Messages**

For the majority of the youth, sources of external messages came from a) family, b) television, c) religion, or d) the general population. Stereotypes of a gay identity were noted by participants within their own nuclear family or among their relatives. Other participants discussed hearing messages on TV, whether from specific shows or celebrities. The general population served as another source for some of the GB adolescents. Participants noted homophobic comments made by both gay and straight individuals. Finally, a few men cited religion as a source, describing reading passages from the Bible or attending churches.

...Yes, I have been in the church, I had walked out of several churches because last year, during my phase of me seeking the Lord and trying to change things about myself, I started visiting different churches and when I hear a pastor talking about it's so wrong to be a homosexual and just preach so much against that sin, and say how much that sin's not welcome, it makes me mad and I just get up and leave. (Sean, 22, African American gay male)

#### **Positive Conceptualizations of Being GB**

Aside from general messages the youth received about being gay, participants reported positive conceptualizations regarding being GB. Themes that emerged focused on a) flexibility and b) social closeness. Many of the youth discussed how being GB made them more adaptable, specifically in terms of sexual flexibility, environmental flexibility, and gender flexibility. Bisexual men described the ability to have sexual relations with males and females. Participants who described the concept of environmental flexibility commented that being GB allowed them to explore more places, specifically ones that are gay-friendly. Others who discussed gender flexibility reported the ability to experiment with gender roles.

I think you're free from some of the things that we talked about, some of the ideas of what it means to be a man. You don't really have to, it's not something you really have to think about when you're gay. You can kind of be who you are and not have to worry about, um, being masculine or being, ah, a stereotypical man. (Michael, 22, White gay male)

Some participants discussed conceptualizations regarding social closeness focusing either on female closeness or closeness to the gay community. The men who described female closeness emphasized that females find gay men trusting and valuable in providing emotional support. Other participants commented on their sense of closeness to the gay community and feeling connected to others who had gone through similar experiences.

...Positive things about being gay. Um, it's, it's very easy to, to, when you do find somebody that is, that is very similar to yourself, it's very easy to find a connection with them because they've endured a lot of the same hardships that you have and, and you, and it's easy to talk, I feel like it's very easy to talk to somebody else who is gay, because they've experienced a lot of the same things that I have in coming and developing their identity. (John, 20, White gay male)

#### **Negative Societal/Cultural Forces**

Many of the young men interviewed reported societal and cultural factors that contributed to negative aspects associated with their identity, focusing chiefly on heterosexism. Such messages were grouped into one of the following sub-themes: a) cultural heterosexism, b) psychological heterosexism, and c) homophobia. Participants who cited cultural heterosexism, focused their comments on customs and institutions that discriminated against GB individuals. Their responses centered on the influences of general heterosexism, religion, marriage and employment discrimination, and hetero-normativity.

I think that you're prone to violence ...there's not equality for you from the government. You're given second-class status. So all these things that are not fair. (Hector, 17, Mexican American gay male)

Participants who discussed psychological heterosexism described internalized messages about stereotypes, as well as experiences of harassment (i.e., name-calling and threats) or physical violence. They described other people's negative homophobic thoughts or actions toward GB individuals, as well as their own internalized homophobia.

...Because sometimes I feel confused and like it's, and it's, not a great thing to feel confused... there was one time that I was actually thinking, why am I with a guy? Why should, why can't, I just be with a girl? And with a girl only? That's how it could also mess you up and then if you really start thinking about it and, like say you're really in love with this person, they're in love with you, you break it off with them just because you got confused and you didn't know what you want

and you didn't want to hurt them, you end up hurting yourself more. That can lead to a big depression and stuff like that. (Justin, 17, Latino bisexual male)

### **Positive Perceived Roles/Responsibilities**

The majority of participants acknowledged the need to fulfill certain positive roles and responsibilities as GB men, including a) self-care, b) fighting stereotyping, and c) activism. Those that stressed the importance of self-care discussed the need to take care of oneself on both an emotional and physical level. Others focused on the need to break stereotypes that exist about GB persons. Participants who believed in activism noted the importance of being knowledgeable and educating youth about issues that have affected the LGBT community:

To me, and this is something that I argue with a lot of gay people, it's kind of like the same as being Latino which is like right now you're history and all, like right now where you came from because being gay is more than just being attracted to somebody of the same sex. There's a history behind it. People made sacrifices. People died for this. And just knowing where you've been, or where your people have been, so you know where you're going. I think it's the responsibility of every gay person to know where they want to go. I know a lot of the young people that I work with are like, yeah, they don't really care about gay marriages. But they're like, well, in ten or fifteen years, you may care about it. And this is something that affects your brothers and sisters, and just seeing people like that in that view of knowing where you're coming from and fighting for stuff that your community needs. And not being like, oh, that's not my issue, because I don't want to get married. (Peter, 23, Puerto Rican gay male)

### **Discussion**

The findings from this study contribute important information regarding the multiple systemic factors that impact sexual orientation identity among GB male youth. Despite receiving negative messages regarding their sexual orientation and enduring harassment and violence, these youth were able to embrace positive aspects of being GB and express a desire to combat damaging forces. Data from this study can be used to shed light on broader issues of social/cultural components of GB male adolescents' sense of self and self acceptance, which may influence future healthy development. The study's findings offer a clearer understanding of how societal messages play a role in GB male adolescents' self perceptions and offer insight into ways to improve the healthy functioning of GB youth by challenging negative societal messages.

These findings may also offer information for the development of mental and physical health promotion programs that emphasize the positive aspects of GB sexual orientation identity, and for the role of self acceptance in promoting healthy thoughts and behaviors. Interventions for GB youth that go beyond basic education and address these systemic factors may have more sustainable effects since they can support the formation of a well-developed positive identity

(Harper, 2007). By focusing on positive conceptualizations of being GB, interventions may help improve GB youths' self esteem and decrease the likelihood that they will participate in health-risk behaviors. Programs may use a range of delivery modalities (e.g., interactive activities, group discussions, etc.) and focus on sustainable structural-level change that involve both LGBT people and straight allies.

By understanding the varied messages GB male adolescents receive about their sexual orientation and how they integrate this information into their self perception, individuals working with GB male youth will be better prepared to help them develop a healthy sense of self. In addition, if care providers are aware of community connections that support healthy identity development, they can help adolescents make critical social support connections.

The information presented in this study advances our understanding of factors that influence the self perceptions of sexual orientation identity among GB youth. However, some limitations exist. The participants in this study were gay and bisexual youth recruited from two large urban areas with active LGBT communities, thus limiting the ability to generalize findings to youth living in other geographic regions. In addition, the sample was restricted to male youth; the life experiences of lesbian and bisexual young women were not captured. Future qualitative and quantitative research focusing on various aspects of self perception among LGB youth is needed. Such information will assist in the creation of successful interventions that support the healthy growth and development of LGB adolescents.

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## Researching the Historical Geography of White Supremacy in Chicago's Suburbs: A Case Study of Glen Ellyn and Wheaton

### Abstract

*James Loewen describes the history of institutional racism in the United States, stating that, "Across America, most suburbs...excluded African Americans".<sup>2</sup> My project explored the extent of this claim in Chicago's western suburbs of Glen Ellyn and Wheaton between 1890 and 1930. Drawing on U.S. census data and contemporary newspaper archives, I show the systematic exclusion of African Americans from property ownership in DuPage County, a practice that reflected national trends in suburban housing policy.*

### Introduction

A century ago, a train struck and killed a man near Roselle in DuPage County, less than five miles from where my childhood house would be built later. Identifying a mutilated body's race in 1907 was simple: "He was a colored man about 35 years of age, ... a chicken was found in his overcoat pocket, being proof positive that the man was a negro".<sup>3</sup> Spatially, my childhood and his death occurred quite close to one another, but the DuPage County of 1907 seems remote. Yet, the 2000 U.S. census reveals that whereas Chicago's African American population is 35.6%, DuPage County's is only 3.05%. That led me to ask how racism pervaded the past and produced the social landscapes of DuPage County. To begin, I analyzed the villages of Glen Ellyn and Wheaton.

The events I investigate in this paper reflect U.S. suburban housing policies that excluded African Americans between 1890 and 1930, a period characterized by worsening race relations and described by James Loewen as the "nadir of race relations in the United States".<sup>4</sup> According to Loewen, for numerous political and economic reasons, in the twilight of the Reconstruction era, the United States broke its commitments to equality and spurned the rights of African Americans—a stark reversal of the previous national ideology. This regression was not confined to the South, as one might suspect. The revocation of African Americans' newly conferred rights occurred in northern areas as well, indicating that these processes of discrimination were national. White Americans formed a new ideology that allowed for the systematic exclusion of African Americans, which Loewen described: "Marginal people make for a marginal neighborhood, and no people have been more margin-

alized than African-Americans."<sup>5</sup> This marginalization was so pervasive throughout the nation that "sundown suburbs" arose—places that forbade black persons from remaining within their borders after dark and, therefore, in any permanent capacity. To white adherents of this ideology, exclusion "not only makes aesthetic sense and provides a more pleasant lifestyle, it makes for a better investment as well".<sup>6</sup>

As Amanda Seligman explains, white residents feared "blight," a common term for the decay of a neighborhood's material integrity. This term "became suffused with racist assumptions about the effects of African-Americans on their surroundings".<sup>7</sup> White residents intent on keeping African-Americans from these neighborhoods, however, made a point to "not speak in racial terms"<sup>8</sup> and employed the "murky language of property values,"<sup>9</sup> justifying their actions as necessary for maintaining their "investments". David Freund identifies an economic rationalization for racist housing policies, asserting that, with the rise of the real estate trade as a profession in the early 20th Century, industry organizations such as the National Association of Real Estate Brokers "assumed the relevance of race to protecting private property",<sup>10</sup> and presented racial segregation "not as a choice reflecting property owners' class or racial preferences, but rather as a nonideological...tool for protecting the robust free market for property".<sup>11</sup>

Though the connection between black residents and property values became real, this supposed economic phenomenon originated in white preference. James and Nancy Duncan examine such racial preferences in the New York suburb of Mount Kisco in the 1990s, where white residents described Latinos "hanging out" in public spaces as an "eyesore" or "unsightly".<sup>12</sup> Evidently, the presence of a nonwhite element is incompatible with residents' preferences; as Seligman and Freund describe, this preference is commonly articulated as mere "concern over property values."<sup>13</sup> The economic-racial model of "blight", alongside the real effects of racial preferences and policies, betrays a more fundamental racist ideology in American life. In this paper, I demonstrate something more engrained in American thought than contingent housing policies, namely, the pervasiveness of racism. I hope to reveal this as something materially productive, extending to the places in which we live to an extent that no aspect of American life escapes its influence.

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5 Ibid., 121.

6 Ibid.

7 Seligman, Amanda. *Block by Block: Neighborhoods and Public Policy on Chicago's West Side*. (Chicago: University of Chicago Press, 2005), 4.

8 Ibid., 128.

9 Ibid., 165.

10 Freund, David M.P. *Colored Property: State Policy and White Racial Issues in Suburban America*. (Chicago: University of Chicago Press, 2007), 57.

11 Ibid., 77.

12 Duncan, James and Nancy Duncan. "Aesthetics, Abjection, and White Privilege in Suburban New York," in *Landscape and Race in the United States*, pp. 157-176, ed. Richard Schein. (New York: Routledge, 2006), 168. Emphasis in original.

13 Ibid., 166.

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2 Loewen, James W. *Sundown Towns: A Hidden Dimension of American Racism*. (New York: Simon & Schuster, 2005), 119.

3 *Wheaton Illinoian*, Dec. 13 1907, (n.p.).

4 Loewen, 25.

## Research Methods

James Loewen approached me to research the sundown status of towns in DuPage County, and I began with his recommended procedure. First, I chose four townships in the county, each comprised of two and four villages, and gathered pertinent census figures on African American populations. I searched for any sharp population deviations in relation to the white population by accessing the manuscript census pages in the *Heritagequest* and *Ancestry.com* databases, and verifying population data through town histories such as *DuPage Discovery, 1776-1976: A Bicentennial View*.<sup>14</sup> In keeping with the “nadir of race relations,” my research focused on the census years 1880 to 1930. Next I searched newspaper archives in the Proquest Historical Newspapers computerized database. Loewen recommended using common search terms such as “black,” “negro,” and “race riot” to better identify articles on Sundown events. Eventually, my research centered on Milton Township and the villages of Glen Ellyn and Wheaton, due to the amount of information about them. After finding a newspaper article describing a relevant event, I would cross-reference it with the microfilm archives of local DuPage County newspapers at the Wheaton Public Library, seeking multiple accounts of each event. Finally, to research information regarding home ownership among African Americans, I examined the DuPage County Grantor/Grantee indexes.

### Glen Ellyn

On Friday, November 29, 1907, the *Wheaton Illinoian* published a small paragraph on its Glen Ellyn news page regarding a meeting that had taken place the night before. Apparently, “[d]iscrimination against liquor dealers” had led many residents of the small village to question the presence of African Americans and, according to the report, this sentiment had “fallen flat”.<sup>15</sup> No subsequent mention of these proceedings appeared in any Glen Ellyn reporting. But this is not the story other newspapers presented. The next day, November 30, 1907, the *Chicago Tribune* published a story entitled “Color Worries Glen Ellyn”. This report described the meeting of racially motivated persons in real estate who were responding to the sale of property to a black man, George Dunham, who had purchased a “choice lot” through the estate agent A.G. Hulbert. In his “defense” of Dunham’s character (or his sale), Hulbert suggested that a suitable “nigger district” in Glen Ellyn would be ideally inhabited by “a Frenchy mongrel, who, though noisy and profane, is regarded by the whites as otherwise harmless”.<sup>16</sup> Opposition to the sale was led by William Grimshaw and E.W. Zander, who aimed for the outright exclusion of African American property owners and called on residents to consider Naperville, which had effectively employed race-restrictive legislation. Grimshaw’s and Zander’s logic exhibited a familiar myth connecting race to property values. Responding to the protests of Fannie Weir (Dunham’s aunt), Zander stated,

14 Maas, David E. and Charles W. Weber. *DuPage Discovery, 1776-1976: Bicentennial View*. (No City Given: Columbian Lithography Co. 1976).

15 *Wheaton Illinoian*, Nov. 29, 1907. (n.p.).

16 *Chicago Daily Tribune*, Nov. 30, 1907, p. 1.

“[I]t is not on account of race or color that we do this. It is merely because colored people depreciate the value of property”.<sup>17</sup> The following step is illuminating: when Weir asked why and on what basis anyone could justify this restriction, keeping in mind that the issue was supposedly not about “race,” Zander conceded, “I guess it is the color”.<sup>18</sup> Glen Ellyn, then, took up a policy that was conscious of its racial intent. Even after the rhetoric had been dismantled, its leaders remained resolute. Far from “falling flat” as the *Illinoian* suggested, the *Tribune* reported that “Glen Ellyn residents adopted resolutions opposing presence of negroes in suburb”.<sup>19</sup> Likewise, a Wheaton reporter for the *Illinoian* described the action as “draw[ing] a dead line around the ‘black belt,’”<sup>20</sup> and soon after, Hulbert included “prohibitions against liquor dealers and negroes” when advertising his available property.<sup>21</sup> These racial restrictions seem to have lifted around 1919 when the *Chicago Defender* congratulated Benjamin Bertha, an African American, on moving to Glen Ellyn<sup>22</sup>; however, the village’s black population had already decreased greatly. By 1912, both Fannie Weir and the Dunham family had sold their property and left Glen Ellyn.<sup>23</sup> By 1930, the village had only six black families, three of whom owned their property.

### Wheaton

The percentage of African Americans in Wheaton increased from 0.4% in 1880 to 1.3% in 1900, and almost 1.7% in 1910.<sup>24</sup> In 1907 the *Wheaton Illinoian* published a telling statement in its personals section: “From the way colored people are becoming residents of Wheaton, they must think this is the state of Mississippi”.<sup>25</sup> This remark, in the *Illinoian*’s trademark middle-class, tongue-in-cheek manner, reveals the Wheaton majority’s attitude towards its non-white residents: a minimal “tolerance” concealing open racism behind patronizing rhetoric. These deeper sentiments, and their material consequences, were revealed in a moment of crisis.

On October 13, 1911, the *Illinoian* reported a violent assault on Mable Tremke. “Girl Is Attacked By Colored Youths” described the events of the previous night: “She was walking down Franklin Street when suddenly two colored boys, Lloyd Hunt and Odie Medley, ran up and seized her”.<sup>26</sup> Hunt and Medley were soon arrested. Again, the local newspaper was not the most revealing. Two days later, the *Chicago Tribune* described a more complex series of events. With the more revealing title, “Wheaton Blacks Fear Lynchers,” the subtext continues, “Citizens, Aroused Over Attack on Girl, Threaten to Break Into Jail”; “Clash with

17 Ibid.

18 Ibid.

19 *Chicago Daily Tribune*, Nov. 30, 1907, p.1.

20 *Wheaton Illinoian*, Dec. 6, 1907, (n.p.).

21 *Chicago Daily Tribune*, Dec. 17, 1907, p.18.

22 *The Chicago Defender* (Big Weekend Edition), May 10, 1919, p.16.

23 Obtained from the Grantor/Grantee Indexes available at the DuPage County Recorder’s Office.

24 United States Census, 1880, 1900 and 1910.

25 *Wheaton Illinoian*, Dec. 6, 1907, (n.p.).

26 *Wheaton Illinoian*, Oct. 13, 1911, (n.p.).

Whites Expected, as Colored Men Are Said to Be Armed”.<sup>27</sup> Apparently, “[t]alk of lynching [the] two negroes,”<sup>28</sup> was conspicuous enough to receive coverage in Chicago, especially after Medley escaped. By October 15, 1911, the suburb had what some would have called the makings of a “race riot,”<sup>29</sup> but the only evidence given of this in the Wheaton paper is a veiled threat in a piece entitled “Our Race Problem”:

Our Colored Neighbors have enjoyed a full measure of brotherly treatment and if they desire to remain here as citizens it behooves the better class to see that their more reckless and younger brothers conduct themselves in a law abiding manner.<sup>30</sup>

Adopting an attitude similar to their Glen Ellyn neighbors, for Wheatonites the presence of non-whites soon became undesirable. Following this isolated crime committed by two African Americans, white Wheatonites began to consider “driving every one [of the black residents] out of town”;<sup>31</sup> unlike Glen Ellyn, however, there is no evidence to suggest that Wheaton formally adopted a policy of exclusion. In fact, it would seem that legislators and police had a firm hold in the face of such crises, and that their respective agendas never involved a radical racial policy. In a similar event from 1915, Mrs. F.E. Schwartz of Wheaton was attacked and robbed by Jesse Williams (a black man) and, after his capture and confession, the *Illinoian* again reveals the prevailing attitude in Wheaton towards non-white residents: “Happily, no demonstration or act of violence against him was attempted although...if he had proved to be a murderer it is possible that some trouble might have occurred.”<sup>32</sup> Again, the village betrays its conditional acceptance of African Americans, as the *Illinoian* laments, “If there was such a way to investigate the record of every negro before he was allowed to become a resident here... it might help to eliminate outbreaks of such a nature.”<sup>33</sup> In much the same way as Glen Ellyn, Wheaton employed a “rhetorical” racism that, though denying any form of determinism initially, eventually revealed, through the concepts of “value,” “safety,” and others, that it really is just the color of one’s skin that makes these residents so unappealing to the majority. This, however, never materialized into a formal “prohibition”.

### Conclusion

Glen Ellyn and Wheaton betray a racial basis behind some of their historic housing policies that admit to the influence of racism in their history. Glen Ellyn exercised a more explicit and active exclusionary policy with substantial documentation in the newspaper archives of the *Wheaton Illinoian* and *The Chicago Daily Tribune*. In this sense, Glen Ellyn is demonstrably constituted out of its former racial restrictions on property ownership. Wheaton, though less

forthright about its use of a racial criterion, still provides clear evidence of a racial ideology through its slanted reporting and eagerness to quell the potential uprisings of a perceived “race problem”, threatening force if black residents did not comply with the expectations of whites. Thus, the racial policies become emphatically real; they denote something more than just some well-constructed lie about “blight” or “property values”. They provide an ideological base for a white majority, hiding behind the rationale of a free market for housing.

This study represents an isolated moment of this national phenomenon. The story in Wheaton and Glen Ellyn continues. In the 2000 census, each had a disproportionately small African American population: Glen Ellyn’s was 2.13% and Wheaton’s was 2.82%. Further research assessing the 1950s and 1960s would enable us to determine the pervasiveness of these policies in the Civil Rights era, and the suburbs’ response. Many other villages in DuPage are unexamined; their racially restrictive housing policies would be fertile ground for future research.

27 *Chicago Daily Tribune*, Oct. 15, 1911, p. 3.

28 *Wheaton Illinoian*, Oct. 20, 1911, (n.p.).

29 *Ibid.*

30 *Ibid.*

31 *Chicago Daily Tribune*, Oct. 15, 1911, p. 3.

32 *Wheaton Illinoian*, March 5, 1915, (n.p.).

33 *Ibid.*

Laura Levy<sup>1</sup>

## Mapping Gentrification in Pilsen: Community Empowerment through GIS Technology

### Abstract

*Chicago's Pilsen neighborhood has experienced dramatic changes in recent years as a result of gentrification. This paper presents the results of research conducted in conjunction with the Pilsen Alliance, a grassroots community organization, during the summer of 2008. The results are a series of maps depicting various factors involved in neighborhood change in Pilsen and are intended to present evidence of gentrification. The research was supported by an undergraduate research grant from DePaul University.*

### Introduction

Historically, Pilsen is a working class neighborhood, settled in the late 1800's to house industrial workers. It was an important entrepot for newly arrived immigrants from Czechoslovakia, Poland, Lithuania, and Italy. In the 1950's the neighborhood's Latino population rose—mainly immigrants from Mexico. The influx of Latino residents continued, and in 1970 Pilsen became the first majority Latino community in Chicago. Today the neighborhood is an important cultural center for the city's Latino immigrants (Betancur, 2005).

Pilsen has many characteristics conducive to gentrification. Foremost is its proximity to downtown; Pilsen is only a few miles southwest of the Loop. Figure 1 shows the neighborhood and its environs. The community is well-served by public transportation and is close to several major highways. It is also close to major amenities and employers. The Chicago campus of the University of Illinois and the new housing development, University Village, are located directly to the north of Pilsen, and to the northwest is a major medical center, home to the largest medical school in Illinois (Curran et al, 2007).

Pilsen's advantageous location vis-à-vis transportation, employment, and the amenities of the central business district (CBD), in addition to its desirable architectural and aesthetic qualities, make it an attractive place to live and a compelling target for gentrifying urban developers. This research will use GIS mapping to analyze the spatial patterns of building age, and changes in property tax change and market values to determine where gentrification is occurring in Pilsen. The goal is to utilize thematic mapping to elucidate spatial patterns and document the process of gentrification block by block.

### Literature Review

Gentrification can be understood in the most general sense as a process whereby an influx of affluent residents

transforms formerly working class urban neighborhoods into higher income ones. These changes typically result in the displacement of lower-income residents and often affect immigrant communities and racial minorities. Neil Smith's influential rent gap theory is one way of understanding gentrification (1996). Starting in the 1970s deindustrialization caused some inner-city neighborhoods to be devalued as a result of population loss and neglect. This process of "hollowing out" the inner city results in a rent gap, with real estate values that are much less than they could be considering the area's proximity to the CBD. Over time these areas become attractive again because of their convenient location and relatively low cost. At that stage gentrification may occur.

Atkinson (2000) recognized that displacement resulting from gentrification is notoriously difficult to measure and trace, to the degree that gentrification literature has moved away from even attempting to document it (Slater, 2006). While tracing displacement is beyond the scope of this research, anecdotal evidence from community leaders and meetings with residents suggest that the problem is widespread. Although displacement is difficult to document, demographic changes and population shifts can be useful in researching gentrification. However, it is important to note that gentrification is only one of a myriad of possible causes of demographic change. Betancur (2005) has presented a compelling case that a population shift is occurring in Pilsen, especially in the northeast section near University Village, where he observed increases in owner-occupied housing, new construction, and property values, and a decreasing proportion of foreign-born and Latino populations.

Local community organizers face several obstacles in their attempts to prevent the displacement of vulnerable populations. Residents often have little to no control over the local-level mechanisms that promote gentrification such as zoning changes or the decisions of developers. Furthermore, the specific effects of these mechanisms are often hard to quantify. Comprehensive data on the progress of gentrification is essential for effective community organization, as it can be used to promote local awareness and participation in the political process. For example, in 2006 data collected by DePaul University students as part of the Pilsen Building Inventory Project was used by the Pilsen Alliance to gather community support for a referendum intended to slow gentrification by changing zoning laws (Curran and Hague, 2006). Sawicki and Craig have documented additional problems facing community organizations, including difficulty managing large amounts of data, their reliance on outside partners for data analysis, and difficulty sustaining projects once these partnerships end (1996).

Geographic information systems (GIS) is a widely-used information technology that allows the processing of massive geographically referenced data sets. It has emerged as a mainline spatial analysis tool and can be an important empowerment tool for community groups with a wide range of objectives. A community can inventory the neighborhood's assets and needs, and then model the

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neighborhood's spatial-functional relationships to other geographic scales of organization. However, several limitations of GIS can prevent community groups from realizing its full potential. This makes for an unequal relationship between the community organization and other more powerful actors, such as property developers or local governments, who can afford GIS capability. Thus, GIS technology can be seen as both empowering and disempowering for community groups (Elwood, 2002).

## Methods

ArcMap 9.3 GIS software was used to map three main aspects of gentrification in Pilsen: the age of residential building stock, market value change, and property tax increases. While most of the data collected covered the entire community area, the results presented here will focus specifically on the northeastern portion of the neighborhood. The population shifts documented by Betancur (2005) suggest that the northeastern corner of Pilsen is where gentrification is most likely to be occurring. This area also contains the majority of the new housing construction and is home to a major art district that has encouraged redevelopment. For mapping, data were collected for each individual land parcel by individually searching the publicly available databases of the Cook County Treasurer and the Cook County Tax assessor by the property identification number (PIN). Due to time constraints, only the data for building age and market value are comprehensive. Data on property taxes were collected only for a smaller section in east Pilsen, within the focus area.

Mapping the age of residential properties highlights the locational pattern of newly constructed buildings and indicates possible "hotspots" of gentrification within the larger area. The data on building age is from the Cook County Tax Assessor's website and was collected only for residential buildings. These data are somewhat limited, however, because they do not account for possible rehabilitation of older properties for condo conversion or other improvements.

Maps showing the change in the estimated market value of individual residential properties from 2005 to 2006 were also created. This data was also collected from the Cook County Tax Assessor's website. The period from 2005 to 2006 was selected because these were the two most recent years for which comprehensive data were available. It should be noted that this period was prior to the recent bursting of the real-estate bubble and subsequent economic crisis, and that estimated market values may have decreased since then.<sup>2</sup> Increasing property values also suggest displacement, as lower-income potential buyers are often "priced out" of the neighborhood.

Finally, increases in property taxes for residential properties were mapped. All of the data used were obtained from public records available at the Cook County Treasurer's

<sup>2</sup> Although there is some debate among economists over exactly when the housing bubble burst, it is generally accepted that home prices nationally began to decline in 2006. However, home prices in the Chicago metropolitan area did not begin to decline until early 2007 (National Association of Realtors, 2008).

website. Property taxes are of interest because increasing taxes can strain lower-income homeowners, potentially forcing them to relocate to another neighborhood or risk foreclosure. Landlords also face pressure to raise rents, making renters especially vulnerable. This is especially relevant in Pilsen, where the percentage of renters is considerably higher than the rest of the city (74% in Pilsen as compared to 56% in the city as a whole) (chicagoareahousing.org, 2009).

## Results

Figure 2 shows the age of residential properties. The GIS shows that properties under 50 years old tend to be clustered together on the same block. Only about 2.5% of the properties were constructed within the past ten years, as opposed an estimated 4.6% for the city of Chicago (Betancur, 2005). The vast majority of residential buildings (87%) in Pilsen are more than 100 years old. The GIS shows that properties under 50 years old tend to be clustered together on the same block. There is a cluster of new construction in the area east of the Dan Ryan Expressway which includes some larger parcels. There is also a small cluster near 17th Street and Carpenter.

Figure 3 shows the percent change in estimated market value from 2005 to 2006. Less than 1% of the properties observed decreased in value, and only 1.3% saw increases in the 0-25% range. Many dramatic increases were observed, with 14% of the properties increasing in value by more than 100%. Most property value increases were in the 25-75% range (71%) and there is little evidence of clustering of high increases in value. The average increase in Chicago for this period was only 14% (U.S. Census Bureau, 2009)

Figure 4 shows the percent change in property taxes from 2005 to 2006. The number of properties where taxes decreased was larger than expected: 18% of properties surveyed showed a decrease in the total property taxes paid. Extreme increases (150% or more) occurred in a large number of properties on 18th Place, including several properties in a row between Sangamon and Morgan Streets. There was also a concentration of extreme increases in the area south of 19th Place between Peoria and Halsted. The average change in property taxes for the properties surveyed was an increase of 88%, which is considerably higher than the city as a whole, which reported an average increase in property taxes of 41% in the same period (City of Chicago, 2008).

## Discussion

The results indicate that gentrification is occurring in Pilsen. Market value increased dramatically for almost every property, with a significant portion of homes increasing by more than 100% from the year before. Property taxes have also increased for many properties. These increases are not consistent with the average rates of increase for the rest of the city. A possible explanation for the unusually high number of decreases in property taxes paid is that more homeowners are claiming tax exemptions for owner-occupiers and seniors. Hague and Curran (2006) observed that many homeowners in Pilsen were not taking advantages of tax exceptions; informing homeowners about these exemptions

has been an important focus of the Pilsen Alliance.

The cluster of new construction east of the expressway is of particular interest because many of these sites were larger in area, indicating that the new construction was likely to be condominiums or other multi-family development instead of single-family homes. The results of this research, however, are less useful for determining the spatial patterns of gentrification than hoped. Examining gentrification on such a small scale may require more comprehensive data and a longer timeframe for analysis.

**Conclusion**

The analysis presented above indicates the need for further action by the Pilsen Alliance and others to address displacement. Much work remains to be done to fully understand the mechanisms by which gentrification is occurring in Pilsen. The data collected and the maps created by this project are not without value, however. The evidence that gentrification is occurring is an important part of increasing local participation in the Pilsen Alliance. Moving forward, the process of data analysis must include some element of community participation. Most local residents are intimately familiar with the changes occurring in their own neighborhood, and are far better interpreters of maps and other forms of information than any outside researcher. It is recommended that future research be conducted keeping the goal of public participation in mind.

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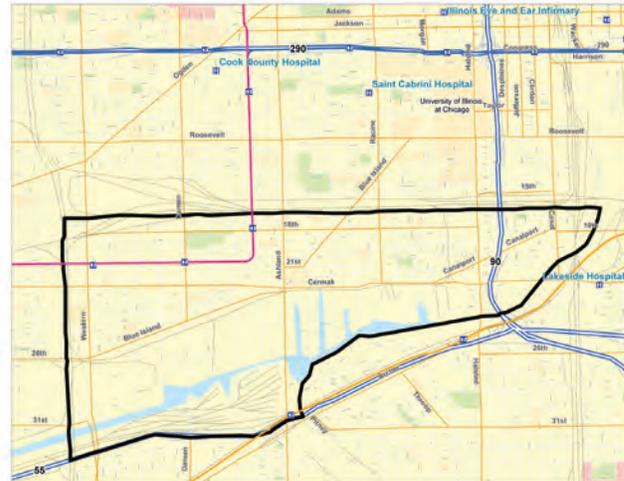
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**Figure 1:**  
**Location of Pilsen**



**Figure 2:**  
**Residential Property Age**

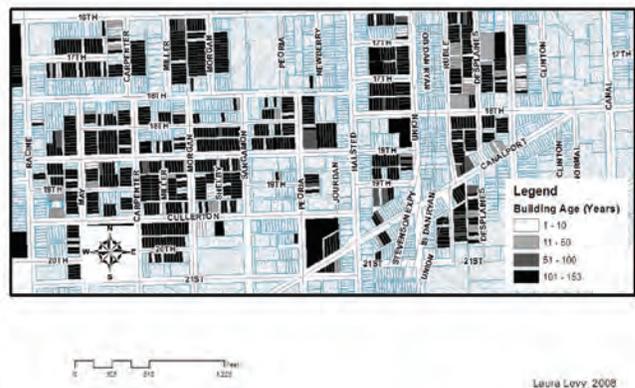


Figure 3:

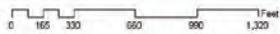
### Change in Estimated Market Value of Residential Properties 2005-2006



Laura Levy, 2008

Figure 4:

### Percent Change in Property Tax 2005-2006



Laura Levy, 2008



**Life Is a Journey**  
**Emily Pease**  
**Print, 2008**

Jennifer A. Lawlor<sup>1</sup>

## The Effects of Climate Change on Grasshoppers in Colorado

### Abstract

Climate change has shown itself to be a problem worldwide, affecting all types of plant and animal species. Using data collected through the University of Colorado-Boulder's Alexander project, the lengths of grasshopper seasons were analyzed at three elevations in Colorado for three species of grasshoppers to determine if there was a correlation between the climate change noted at the sites and the length of the grasshopper season each year. The results showed no statistically significant evidence for a change in season length.

### Introduction

Scientists worldwide have been examining the effects of climate change on the global environment for years. The Alexander project has been examining one such example of the effects of global warming by collecting data about grasshoppers in several locations in Colorado during the last few years and comparing it to data collected 40 years ago. The data show how many grasshoppers of a species are located in an area at one time. Researchers counted grasshoppers at various elevations each day during the research periods in addition to collecting climate change data at the sites (Grasshoppers and Climate Change [updated 2008]). The data are important because the effects of climate change on a smaller species could be a preview of its effects on larger species in the future.

The purpose of the analysis was to examine the data to determine if they showed that the grasshoppers' seasons have shifted to start earlier and end later because of the warmer climate. Weather data collected in the areas where the grasshopper data were taken have shown an increase in temperature during the period in which the study took place (C. Nufio, Personal Communication).<sup>2</sup> As a result, climates favorable to grasshoppers occur for more days than they did in the past, so the grasshoppers' seasons could last longer. Another purpose was to determine if season lengths have had a greater change at higher elevations.

The scientific value of this research is to help determine the effects that climate change could have on larger species and on the global environment. Further, this research highlights the changes over a defined period of time and could contribute data concerning the future effects of climate change.

### Methods

The data for this experiment were collected by researchers working for the Gordon Alexander Project at 14 sites around the University of Colorado-Boulder, but the analysis includes data from only three of these sites (Grasshoppers

and Climate Change [updated 2008]). Each site represents a different altitude. The first will be referred to as A-1 (elevation 7,200 feet). The second will be referred to as B-1 (elevation 8,500 feet). The third site will be referred to as C-1 (elevation 10,000 feet).

Researchers collected grasshoppers at each of these sites and determined the species and stage of life of each grasshopper they found. Weather stations at each site kept track of climate change during the time the data were being collected. Data were collected in 1958, 1959, 1960, 2006, 2007, and 2008 (except for certain elevations during 2006 and 1960). All of the available data for each of these years were examined.

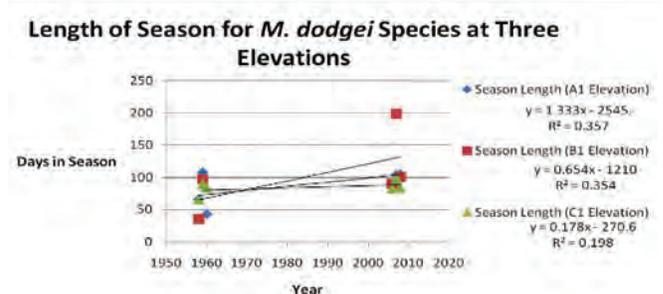
Altogether, researchers found 13 species of common grasshoppers, but this study focused on the three species of grasshoppers found at the three elevations where temperature changes were tracked. The three species considered in this experiment were *Camnula pellucida*, *Melanoplus dodgei*, and *Chloaltis abdominalis*. They were found at multiple elevations and could be useful in analyzing whether a change in season length was related to climate change, elevation, or species type. The other species for which data were collected did not have these characteristics. For analysis, the first and last dates that the grasshoppers were seen each year were noted and converted to ordinal dates. Once the ordinal dates were determined, the earlier date was subtracted from the latter to determine the number of days in the season for that year.

Next, scatter plots (see Figures 1.0, 1.1, and 1.2) were created with the year as the x-axis and the season length as the y-axis. These scatter plots were fitted with trend lines and the  $r^2$  value was determined for each trend line. Next, a significance test was performed on each  $r$  value to determine its statistical significance.

### Results

The results show that there is no statistically significant change in season length. The points were all far enough from the trend line that the trend lines do not provide the information required to determine if there is a change in season length. This happened for each of the species at each elevation.

Figure 1.0:



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<sup>2</sup> Data Contributed by Cesar R. Nufio

Figure 1.1:

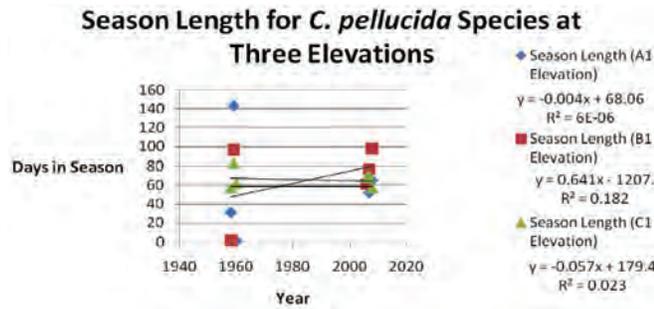
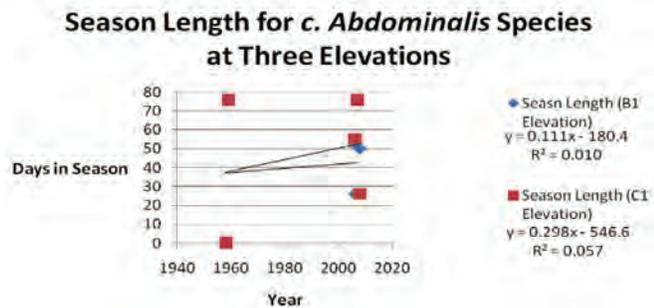


Figure 1.2:



### Discussion

The results of this experiment show no statistically significant relationship between climate change and season length for *M. dodgei*, *C. abdominalis*, or *C. pellucida* grasshoppers.

These results could mean that different changes are occurring. For example, the grasshopper seasons could have the same length, but could be shifting the start and end dates. When the grasshopper data were examined, one species from each of the following groups—Gomphocerinae, Melanoplinae and Oedipodinae—was chosen. Each of these groups has a different set of physical characteristics that could be affected differently by climate change or other environmental factors.

An example of the different factors that could affect a grasshopper species is shown by the feeding habits of the *C. pellucida* species. *C. pellucida* is known for eating small grains (Grasshoppers: Their Biology, Identification and Management [updated 1994]). If temperature has an effect on the growing seasons for small grains, that same effect might also occur in the *C. pellucida* species' season length. Additionally, if the grain shifts, but stays the same length, the *C. pellucida* season could do the same, but other grasshoppers that do not eat small grains would not undergo the same change in season length.

The *C. pellucida* species is also found in meadows, so if other grasshoppers are more likely to be found in different types of terrain that are affected differently by climate change, the grasshoppers will exhibit different responses based on the changes (Capinera, Scott, Walker 2004, 81).

Another factor contributing to grasshopper season change could be whether a grasshopper is polylectic (a generalist) or monolectic (a specialist). A polylectic grasshopper would seem to be more adaptable because it eats

a wider variety of food and can exist in a greater range of environments, making it seem less likely to be affected by climate change, whereas, a monolectic grasshopper would seem more likely to be affected due to the restrictions it puts on its environment. To ultimately determine if any of these factors has an effect on the species, more studies would need to be undertaken.

In addition, because the study only uses six years of data, the relationship between the points would have to be very strong to find a statistically significant result. If the study continued over a greater number of years, a statistically significant result might offer more definitive evidence on the relationship between climate change and grasshopper season lengths; again, further study would be needed.

### Acknowledgements

I would like to extend my gratitude to Cesar R. Nufio, Professional Research Associate at the University of Colorado's Museum of Natural History, who contributed the research necessary to complete the study as well as the information and support necessary to write this paper.

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## The Effects of Restoration Management on Hyperdiverse Arthropod Assemblages: Results of a Manipulative Field Experiment

### Abstract:

*The invasive shrub, Rhamnus cathartica (European Buckthorn), poses a threat to Midwestern biodiversity conservation. After successful invasion, it modifies soil properties making subsequent restoration difficult. We examined the effects of soil remediation methods on soil-arthropods (free-living mites and collembola), a diverse but understudied biota, which contributes to decomposition and nutrient cycling. Here, we observed species abundance and species diversity within a controlled field experiment to assess the effects of restoration strategies. We found a significant difference in species abundance among the treatments, with buckthorn-invaded treatments having the highest mean value. There was no detectable difference in species diversity (Shannon Diversity Index or Berger-Parker Dominance Index).*

### Introduction

Biodiversity has been defined as the total number of ecosystems, genera, species, and complex interactions which contribute to the maintenance of diversity at all ecological scales (Chicago Wilderness Recovery Plan 1999). Preserving or restoring biodiversity has become a regional priority for nature conservation. Traditionally, conservation has focused on preserving natural areas but few remnant ecosystems remain in the Chicago region. Thus, restoration seeks to restore ecosystem function to severely degraded areas via active land management (Heneghan et al., 2008). A primary factor contributing to the degradation of natural areas is invasion by exotic species, the second leading threat to biodiversity. Invaders impact an ecosystem by modifying processes (resource partitioning, nutrient cycling, decomposition, etc.) in a way that reduces the competitiveness of native biota (Heneghan et al., 2002; 2008; Sax and Brown, 2000). Restoration management is of growing interest, as it may be the most effective way of returning a degraded ecosystem to a sustainable state.

Restoring natural variability to a degraded site requires an understanding of numerous, complex interactions occurring in heterogeneous landscapes (Allen et al., 2002). Current restoration practices focus on the above-ground components of these systems (i.e., removing invasive and re-planting native) while neglecting below-ground (i.e., nutrient cycling, microarthropod, fungal composition, etc.) (Heneghan, personal communication). Restoring a degraded site to a resilient, sustainable and healthy state requires simultaneous management of various attributes of the system, both above- and below-ground.

Soil processes, important for integrated restoration

management, typically involve the participation of a diverse community of organisms. Decomposition and nutrient cycling, for instance, are performed by microbes and soil fauna. In the temperate climatic zone both groups are hyperdiverse on small spatial scales. A key functional group, collectively referred to as microarthropods, are so diverse they have been described as a “poor man’s tropical rainforest” (Giller, 1995). Although there is high biodiversity in soil arthropod communities, their role in restoration has been underappreciated. Since, these organisms have been shown to have an integral function in ecosystems, knowing how management practices affect them is an important first step in integrative strategies, combining above- and below- ground perspectives (Beare et al., 1992; Belnap and Phillips, 2001; Heneghan et al., 1999; 2002; Wardle, 2002).

In this study, a component of a long-term project, we examine the implications of a variety of restoration techniques, designed to remediate the effects of *Rhamnus cathartica* (European Buckthorn) on microarthropods (free-living mites and collembola). Heneghan et al. (2008) observed that buckthorn disrupts soil properties which facilitates the success of future generations, consequently creating a monoculture. Current methods for eradication of buckthorn involve physical removal, the use of herbicide, and planting native seeds. This changes the above-ground nature for a short period but fails to remediate damage to the soil. We hypothesized that restoration techniques targeted at remediating the soil will have a better chance of restoring a native community and, therefore, ecosystem function. However, strategies that manipulate the soil can change microarthropod communities that have adapted to the invaded site. Thus, long-term management will benefit from understanding these impacts as well as ascertaining the recovery of this community.

### Methods

Arthropod samples were collected on October 18, 2008 from research sites owned by the Village of Mettawa, Illinois, approximately 50km from DePaul University. The site was abandoned in 1990 and became dominated by buckthorn in subsequent years. About 2500m<sup>2</sup> is managed by the Heneghan lab to experimentally assess restoration techniques designed to remediate the soil. The site was divided into 45 hexagonal plots (52m<sup>2</sup>), consisting of nine different treatments (five replicates each), randomized within a five-block design, established along a hydrological gradient.

Samples were taken from four treatments: 1) no buckthorn removal (control), 2) buckthorn removal followed by mulch (BM), 3) buckthorn removal and buckthorn mulch (followed by native seed) (BMNS) and 4) buckthorn removal with mulch absent (followed by cover crop) (BCC). Soil cores (5cm d x 5cm h) were collected at random from three of the five replicated plots. Two samples were taken within each plot, homogenized in a plastic bag and stored on ice for transportation to DePaul University.

To extract microarthropods from the soil, a modified Tullgren apparatus was assembled in the laboratory. This apparatus extracts organisms via downward migration, to

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avoid desiccation when exposed to heat at the soil surface. Ten (114mm) holes were cut into plywood (122 x 61cm) and ten metal funnels (150mm diameter) with Pyrex funnels (145mm diameter) covered with aluminum mesh placed inside. This set-up enabled the extraction of ten independent samples at one time. As a heat source, ten 120V halogen lights, with dimmers to control light intensity, were secured to an additional piece of plywood and positioned above each funnel. A collection vial partially filled with 70% ethanol was placed under each funnel. As the intensity of the light was increased, the soil heated, causing the microarthropods to move downward and fall into the collection vials.

Each sample was placed randomly in the apparatus for approximately 72h and gradually heated. To avoid overheating the lights were turned off 2100–0900h and a temperature of 45°C was not exceeded.

The contents of each collection vial, were transferred to a Petri dish and microarthropods (collembola and free-living mites) were separated from soil particles that fell into the collection vial using a dissection microscope (Nikon SMZ 1500). The microarthropods were mounted on slides using mounting media (CMC-10, Masters Company, Inc.) and identified to morphospecies (species based on morphological differences).

Species abundance and two indices of species diversity were calculated for each treatment (Shannon Diversity Index and Berger-Parker Dominance Index). Shannon Diversity is influenced by species richness and rarity. On the other hand, the Berger-Parker Dominance Index is influenced by the distribution of the most dominant species. We used the inverse of this measure because a low Berger-Parker value indicates high diversity. We used Analysis of Variance (ANOVA) to detect statistical differences among the treatments in species abundance and the two diversity indices.

## Results

In all, 1,043 individual microarthropods from over 60 genera were identified in this study. The control treatment had the highest mite abundance, followed by BCC, BMNS, and BM (Figure 1). There were significant differences in mean mite abundance between treatments (ANOVA, df 3,  $F=4.06$ ,  $p=0.05$ ). Differences were found between the control and BM treatments (Tukey's HSD test) while the others did not differ significantly. No difference was found among the treatments in collembola abundance. The mean values followed a similar pattern to the mite abundance, except that there was higher collembola abundance in the BMNS than the BCC treatment.

The mite and collembola abundances were used to calculate Shannon Diversity and Berger-Parker Dominance indices for each treatment. An ANOVA of the two diversity indices detected no difference among the treatments (Figures 2 and 3), therefore indicating that species diversity did not differ among the different restoration techniques.

## Discussion

The higher abundance in the control plot, compared to

the others, reveals that individuals were adversely affected by certain restoration techniques, in particular the mulching of soil with buckthorn wood. We assume this is due to the physical disturbance of the experimental treatments. Similarly, Caruso et al. (2007) found that disturbances decrease the density of some oribatid mite species in a Mediterranean ecosystem. Other factors contributing to the decreased abundance of mites include the modification of fungal-bacterial ratios, in the soil, associated with tilling (Beare et al., 1992). Mites are typically fungivores and the manipulation of soil properties may have decreased the amount of fungi, thereby decreasing their food supply. Additionally, there is evidence for this site suggesting that fungal to bacteria ratios are affected by restoration (Umek, personal communication).

Across all treatments the Shannon Diversity Index and Berger-Parker Dominance Index did not differ, indicating that diversity was relatively unaffected by restoration. Thus, after the initial shock of the system, it may be suggested that species diversity may reestablish. Although aggregate measures of diversity reveal no significant treatment effects, specific microarthropod assemblages within the treatments can be affected. Newly established microarthropod species have been known to colonize sites in response to ecosystem changes from invasion, thus changing the composition of the assemblages (Belnap, 2005). We have evidence from the preliminary identifications of species that some are especially impacted by the treatments. Several species are common in the controls but eliminated in certain treatments.

The data presented show the importance of considering more than just the above-ground components of the ecosystem. Future studies will repeat this analysis asking if abundances recover some time after the establishment of these treatments.

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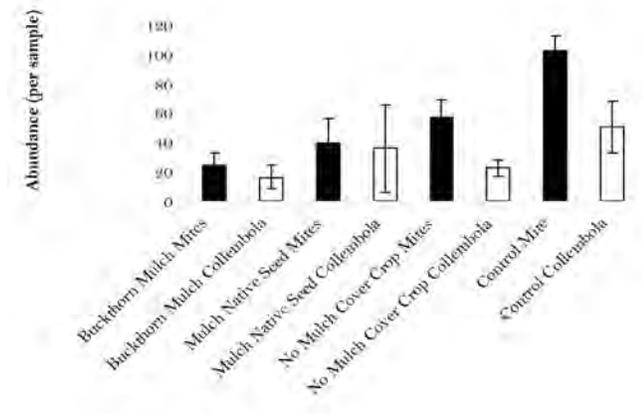
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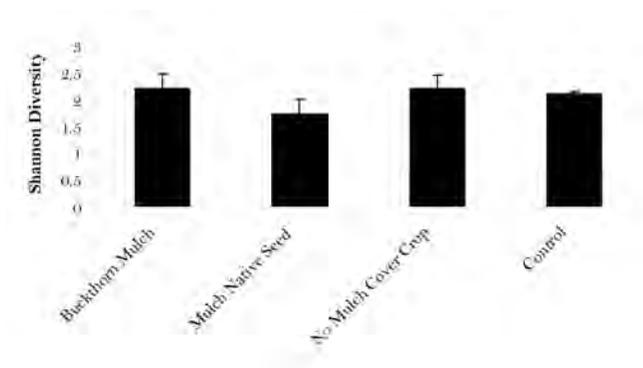
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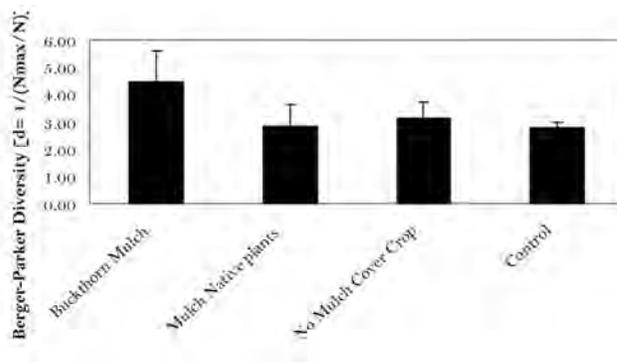
**Figure 1:** Mite (black bars) and collembola (white bars) abundances per sample. \*\*\* indicates a statistical difference between BM mite and control mite abundance. There was no difference detected in collembola abundances.



**Figure 2:** Shannon diversity index. There was no statistical difference among the treatments.



**Figure 3:** Berger-Parker dominance index. No statistical difference was detected among the groups.



## Direct and Indirect Effects of Allelopathic Compounds Produced by the Tree of Heaven (*Ailanthus altissima*)

### Abstract

The Tree of Heaven (*Ailanthus altissima*) is an invasive plant species which produces an allelopathic compound—a chemical that affects the growth and development of nearby plants. To determine whether or not the allelopathic chemical produced by the Tree of Heaven is a direct toxin, or if it works in conjunction with soil microorganisms, an experiment was set up with *A. altissima* in sterile and non-sterile soil. Sterile and non-sterile soil without the plant were used for control. It was found that soil primed with *A. altissima* significantly reduced the growth of radish (*Raphanus sativus*) seeds compared to soil that lacked the plant. Inhibition of growth was greatest in sterile soil where the seedlings grew larger, suggesting that it may be due to larger root biomass. When variation due to *A. altissima* root biomass was removed, there was still inhibition of radish growth in sterile soil. This suggests that soil microorganisms break down the chemical, or that mycorrhizal fungi symbiotic root infections are initially a negative association for *A. altissima*, using energy that is otherwise allocated to production of the allelopathic chemical.

### Introduction

One of the most critical environmental issues today is the loss of biodiversity in natural ecosystems, and one of the most pressing factors influencing this loss is the invasion of non-native species (Dirzo and Raven, 2003). Non-native species are known to become extremely successful in new environments because so often their natural predators, competitors, and pathogens are absent. It is also thought, for invasive plants in particular, that their success is attributed to an evolutionary advantage; exotic plants have increased competitive ability because native plant populations have not yet had the chance to develop evolutionary “weapons” with which to fight the invaders (Callaway, 2004). For similar reasons, the urban invasive Tree of Heaven (*Ailanthus altissima*), native to China, has become a weedy problem in urban areas in the United States. The Tree of Heaven is a species known to have allelopathic properties; that is, the production of chemicals that inhibit the growth of neighboring plant competitors. Researchers have been developing the compound, which has been identified and named Ailanthone, as a natural herbicide (Heisey, 1996). The Tree of Heaven has been thriving in Chicago’s Lincoln Park urban forest and its continued growth has implications for the fate of biodiversity in the city. While it is known that the Tree of Heaven produces allelopathic chemicals, it is not known whether their impact is directly on other plants, or indirectly through an impact on soil chemistry and/or soil microorganisms. The purpose of this study was to find the

route through which Ailanthone is allelopathic. Through planting the Tree of Heaven in sterile and non-sterile soil, it may be observed whether or not soil microorganisms alter the effect of Ailanthone. In understanding this route, scientists may better understand urban ecosystem health through maintenance of biodiversity.

### Methods

Approximately 20kg of soil was collected from an urban lot in Chicago in June 2008. The soil was split in half. Half of the soil was sterilized in an autoclave to remove soil microorganisms, and the other half remained untreated (non-sterile). Fifteen pots were filled with 630g of non-sterile soil and 15 pots were filled with 630g of sterile soil. *A. altissima* seeds from Chicago’s Lincoln Park neighborhood were collected in the Spring of 2008. Many seeds were allowed to germinate in June 2008. Of the seeds that germinated, 20 that showed the most vigorous growth were picked and randomly assigned to 20 of the 30 soil pots—10 sterile and 10 non-sterile. Ten pots (5 sterile, 5 non-sterile) were left with no *A. altissima* for control.

The seedlings were allowed to grow in the pots from June 2008 until January 2009. Of the 20 pots containing *A. altissima*, 10 were assigned a regular watering treatment (approximately 60mL of water every 3 to 4 days), designated as “W” for wet, and 10 were assigned a drier watering treatment (approximately 60mL of water every 7 days), designated as “D” for dry. The watering treatments were not followed into the autumn season, when many of the seedlings began to lose their leaves. In an attempt to break autumnal dormancy, extended daylight conditions were applied in November 2008.

In January 2008, the soil and seedlings were removed from each pot. The root mass of each *A. altissima* plant was recorded. The soil from each pot was divided into three smaller pots, for a total of 90 small pots with soil, 60 containing soil from under *A. altissima* and 30 containing soil in absence of the plant. Three radish (*Raphanus sativus*) seeds were planted in each of the 90 pots and were watered approximately every 2 days. At the end of the 8<sup>th</sup> day, the radish seedlings were clipped from the ground level up and were weighed. The total number of radish seeds that germinated was also recorded. Data from the three small pots were averaged for a single value for each *Ailanthus* treatment replicate, maintaining the appropriate number of independent replicates for the experiment. Data were analyzed by ANOVA and regression using SPSS version 15.5.

### Results

Upon analysis, it was observed that *A. altissima* grew significantly more root mass in sterile soil than in non-sterile soil ( $F_{1,16} = 11.585$ ;  $p=0.004$ ; Figure 1). There was no significant effect of the water treatment and no significant interaction between water treatment and soil sterility.

It was also observed that radish plants grown in soil primed by the Tree of Heaven were inhibited from growth compared to radish plants grown in soil without Tree of Heaven ( $F_{1,26}=4.96$ ,  $p=0.035$ ; Figure 2). Inhibition was greatest in sterile soil that previously contained the Tree of

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Heaven (Comparison of radish in sterile vs. non-sterile soil:  $t_{18} = 2.206$ ,  $p = 0.041$ ; Figure. 2).

Figure 1:

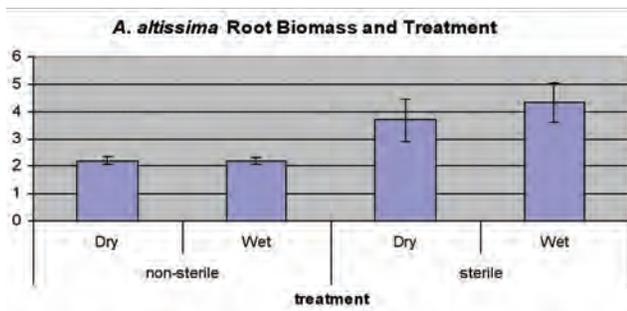
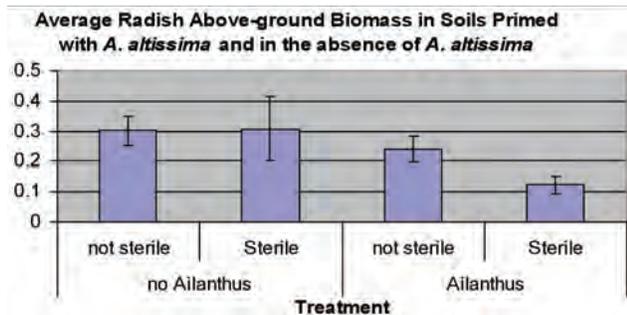
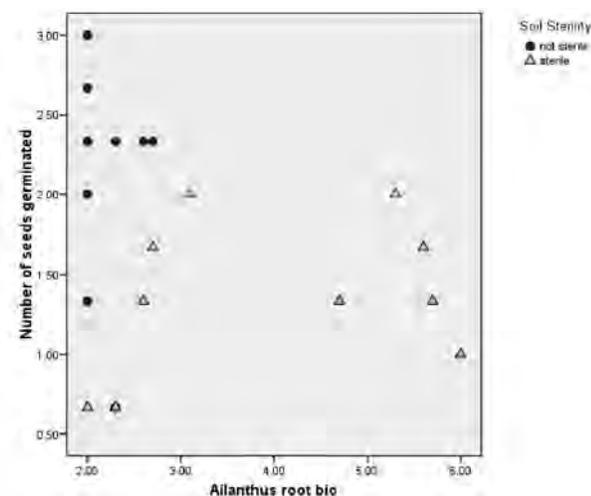


Figure 2:



To assess whether or not the effect of reduced radish growth in sterile soil was caused by the greater Ailanthus root biomass in sterile soil, radish germination and pot biomass grown in Ailanthus primed soil were analyzed again for a sterility effect using Ailanthus root biomass as a covariate. The sterility treatment remained significant after controlling for root biomass ( $F_{1,17} = 4.655$ ,  $p = 0.046$ ; Fig 3).

Figure 3:



**Discussion**

The analysis of the growth of the Tree of Heaven in sterile versus non-sterile soils, determined that there was significantly more root biomass of the tree in non-sterile soil. This may be due to increased nutrient availability for the plant in the absence of soil microorganisms. Assessment of radish

seeds grown in soil primed with the Tree of Heaven and in soils that lacked the plant revealed a significant difference between sterile and non-sterile treatments, with sterile soil that contained the tree having the highest inhibitory activity. These data suggest that the plants with larger root biomass, the sterile treatment, have more inhibitory activity and thus more production of Ailanthone. However, upon removal of the variation due to the Tree of Heaven root biomass, the sterile soil treatment still inhibited growth and germination of radish seeds. Thus, in this case, larger root biomass does not correlate to more inhibition of radish seed growth. This idea was supported by a preliminary study done in July 2008 that surveyed *A. altissima* seedlings in Lincoln Park. Seedlings of varying root mass were weighed and a bioassay was performed to determine if the root mass correlated to inhibition of the germination of radish seeds. There was no correlation.

In short, the Tree of Heaven in the absence of soil microorganisms significantly reduces the growth of radish seeds, and it is not a factor in how large its roots are. This finding suggests that the soil's microorganisms mediate the effect of the plant's allelopathic chemical. Additionally, the success of the Tree of Heaven must then depend upon the composition of microbes present in the soil. Mycorrhizal fungi might also play a role in this relationship; they are known to associate with the roots of many plants in a symbiotic relationship. However, our findings may suggest that upon infection of the Tree of Heaven, the mycorrhizal relationship is initially beneficial for the fungi and detrimental to the Tree of Heaven, possibly taking away energy that could be allocated towards producing Ailanthone. This is supported by the results showing that *A. altissima* in non-sterile soil has less root biomass and less inhibition of radish seed germination and growth. Thus, the Tree of Heaven may be a better or worse invader depending on what kind of fungi and microbes are present in the soil. Further research concerning mycorrhizal fungi infection of the roots of the Tree of Heaven is needed to confirm the conclusions of this study.

**Acknowledgements**

I'd like to thank my thesis advisor Dr. Judith Bramble for her guidance and support throughout my project. I'd also like to thank the DePaul College of Liberal Arts and Science Undergraduate Research Program and the Louis Stokes Alliance for Minority Participation (LSAMP) for granting me the funds necessary to carry out this research.

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## Atomic and Micro-structural Analysis of Zinc Oxide Materials

### Abstract

We studied the atomic and micro-structural properties of bulk- and nano-sized zinc oxide (ZnO) powders. Zinc oxide is an interesting material due to its reduced cost and increased abundance compared to currently commercial transparent conductors. ZnO powders with various impurity levels and different grain sizes were investigated. The purity level of the pellets was determined using x-ray fluorescence. The atomic structure and micro-structure of the samples was studied using x-ray diffraction and scanning electron microscopy. The impurities and grain size distribution had an effect on the electrical behavior of these zinc oxide materials.

### Introduction and Theory

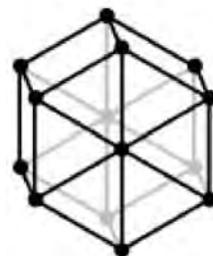
Transparent conducting oxides (TCOs) are semiconductors with high-optical transparency as well as high-electrical conductivity. TCO electrodes have many commercial applications in liquid crystal displays, flat-panel displays, plasma displays, touch panels, organic LED, solar cells, antireflection coatings, and smart windows. Currently the most commercially used TCO is indium-tin oxide, which is expensive and is in increased demand but limited supply.<sup>2</sup> Our study of zinc oxide (ZnO) was motivated by its abundance, non-toxicity and lower cost compared to current TCO materials. Furthermore, ZnO can potentially exist both as an n-type and p-type semiconductor, which is desirable for industrial applications.

The electrical conductivity in semiconductors is due to charge carriers. These carriers exist either in the form of free electrons (negative charges) or electron holes (positive charges), which are essentially the absence of electrons. Intrinsic semiconductors are pure materials which tend to have an equal number of free electrons and holes. Zinc oxide usually has more free electrons and is therefore called an n-type semiconductor. While it is currently unclear why ZnO is intrinsically n-type, it is most likely related to inherent defects (such as missing oxygen atoms) in its atomic structure.<sup>3</sup> ZnO is most commonly found with a hexagonal structure, as shown in Figure 1.

The most commonly used semiconductors, called extrinsic semiconductors, use a process called doping to increase their carrier concentration, resulting in improved electrical behavior. Doping involves the introduction of controlled impurities into the semiconductor which either increases the carrier concentration of free electrons, making

the semiconductor n-type, or increases the concentration of electron holes, making it p-type. By determining the impurities in our samples and measuring the conductivity of these same materials, we can then correlate the effect of the impurities on the electrical behavior of ZnO. This correlation will then allow us to predict what doping would be most beneficial when future work focuses on zinc oxide as an extrinsic semiconductor.

**Figure 1:**  
Hexagonal symmetry commonly found in zinc oxide structure



Our team characterized the atomic structure and micro-structure of ZnO while another team<sup>4</sup> simultaneously worked on characterizing the electrical properties of ZnO. Some impurities within the crystal lattice seemed to produce an excess of carriers thereby making the material more conductive, while other impurities depleted the carriers resulting in a more insulator material.

### Procedure

We used x-ray diffraction, x-ray fluorescence, and scanning electron microscopy to study the purity levels of ZnO materials, to determine the atomic structure and presence of phases in the powders, and to observe the shape, size, and distribution of individual grains in the samples. Five different batches of ZnO powders were purchased. We labeled the bulk-powder batches according to their purity, expressed as a percentage, as B1 (Puratronic, Alfa 99.9995%), B2 (Acros, 99.999%), and B3 (Alfa, 99.99%). The nano-powder batches were N1 (American Elements, 99.5%) and N2 (Nanotek, 99%). These labels allowed us to refer to each sample by a short name that conveyed both their size (either nano or larger bulk samples) and relative purity.

The x-ray diffraction (XRD) experiments allowed us to determine the atomic structure of our samples. In this technique x-rays of a specific wavelength are bounced off a sample at different angles. These x-rays experience either constructive or destructive interference depending on an equation called Bragg's Law,

$$2d \sin(\theta) = n\lambda \quad (1)$$

where  $d$  is the distance between lattice planes,  $\theta$  is the scattering angle that results in constructive interference,  $n$  is an integer, and  $\lambda$  is the wavelength of the x-ray. By looking at

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<sup>2</sup> Transparent Conducting Oxides, DS Ginley and C Bright, MRS Bulletin. 25, 22 (2000).

<sup>3</sup> Dopability, intrinsic conductivity, and nonstoichiometry of transparent conducting oxides, S Lany and A Zunger, Phys. Rev. Lett. 98, 045501 (2007)

<sup>4</sup> Leonel Hernandez and Alexander Slawik, "Improving the Electrical Properties of Zinc Oxide," Department of Physics, DePaul University.

what values of  $\theta$  give the most intense constructive interference we can determine the values of  $d$ , allowing us to directly map the atomic arrangement in the sample to help us identify what crystallographic phases are present.

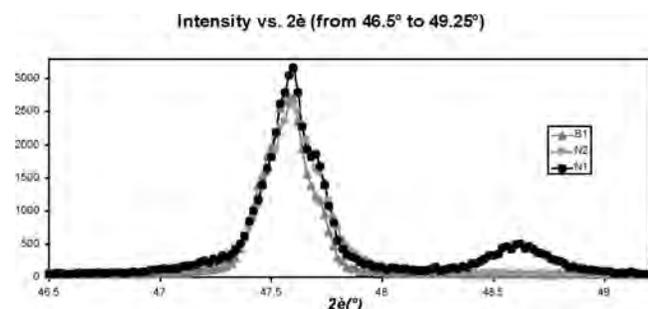
X-ray fluorescence (XRF) uses the fact that the electrons of an atom can only be found at specific energies which correspond to different orbits around the nucleus. Fluorescence occurs when an x-ray of the proper energy excites an electron to a higher energy orbit. Another electron from a larger orbit then replaces the initially displaced electron and energy is released in the form of radiation. This fluorescence energy has a wavelength that directly corresponds to the energy difference in the transition between orbits. This wavelength is given by

$$\lambda = hc/E \quad (2)$$

where  $\lambda$  is the wavelength emitted,  $h$  is Planck's constant,  $c$  is the speed of light, and  $E$  is the energy lost due to orbit change.<sup>5</sup> The fact that electrons can only be found at specific energies, depending on their orbit and on the atom, means that each element produces a unique fluorescence spectrum which corresponds to the element's allowed energies. By measuring the relative intensities of the different peak wavelengths being emitted an XRF detector is able to determine not only what elements are present in the sample but the relative concentration of each element. This is very useful in measuring impurities of a sample and can be used in conjunction with x-ray diffraction studies.

Scanning electron microscopes are similar to the more commonly used optical microscopes. Optical microscopes use lenses to magnify objects, but since the source is visible light, only objects larger than one micron (one micron is  $1 \times 10^{-6}$  m) can be seen. Electron microscopes use electron beams (which have much smaller wavelengths) as sources allowing the study of nanometer-sized objects (one nanometer is  $1 \times 10^{-9}$  m).

**Figure 2:**  
Section of the x-ray diffraction spectra for B1, N1, and N2 samples



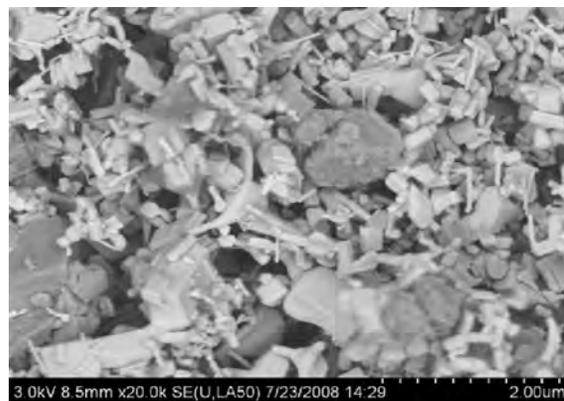
The XRD and XRF experiments were conducted at the JB Cohen X-ray Diffraction Facility at Northwestern University. A Scintag XDS 2000 diffractometer equipped with a copper  $K_{\alpha}$  x-ray source and a solid-state detector was used for

XRD studies. ZnO powder was packed on the window of a glass sample holder, and XRD data were collected in the  $2\theta$  range of  $20^{\circ}$  to  $140^{\circ}$ . For fluorescence measurements, ZnO pellets of one-inch in diameter were pressed and placed in a sample holder using mylar foil. A Bruker-AXS Inc., S40 Pioneer instrument with a rhodium x-ray source measured the fluorescence spectra of the samples. The scanning electron microscopy (SEM) measurements were performed at the Electron Probe Instrumentation Center at Northwestern University. The ZnO powders were sprinkled on conductive carbon tape and placed inside a Hitachi S-4800-II electron microscope.

## Results

The data from x-ray fluorescence experiments are shown in Table 1. Some of the batches were not as pure as the manufacturers claimed. Batch N1 was advertised as being 99.5% ZnO but consisted of only 75% ZnO (the remaining 25% was a carbonate phase). The purity of the other batches agreed better but was still less pure than the manufacturers' specifications.

**Figure 3:**  
SEM micrograph of the N1 bi-phasic powder batch



The diffraction results showed that the atoms in the powders were arranged in crystals of hexagonal symmetry, which is the most common form of ZnO. The XRD spectra from the B1, B2, B3, and N2 batches contained only the wurtzite crystallographic phase. However, the XRD spectrum of the N1 batch showed extra peaks indicating the presence of a secondary phase. The XRD analysis for N1 shows that only 75% of the sample consisted of ZnO while the remaining 25% was a carbonate phase. Figure 2 shows a section of the XRD spectra for B1, N1, and N2 samples. The strong peak corresponds to the wurtzite phase, and the peak around  $48.6^{\circ}$  is due to the carbonate phase. The shape of the diffraction peaks correlated well with the grain size of the materials (discussed below). Nanometer-sized grains exhibited broad diffraction peaks, while micron-sized grains had sharper peaks. This effect can also be seen in Figure 2, where the N1 and N2 peaks are broader than the peak of B1.

SEM micrographs showed that the shape of the B1, B2, and B3 grains was uniform. The grain sizes for these bulk samples were on the order of micrometers, and the particle

5 PA Tipler and RA Llewellyn, Modern Physics, WH Freeman and Company, fourth edition (2002).

distribution was fairly homogenous. The N1 and N2 powder batches had a heterogeneous distribution of grain sizes: some grains were one micrometer as opposed to 30 nanometers, as we originally anticipated from the manufacturers' specifications. Both N1 and N2 batches also exhibited non-uniformity in the grain shapes. Some grains were long and thin (a possible reason the manufactures mistook their actual size) while some grains were wide and thick. Figure 3 is a micrograph taken of the N1 sample using a 20,000 magnification, showing the non-uniform size distribution and shape of the individual grains. The SEM micrographs of the N1 batch also suggested the presence of two phases, in agreement with the XRF and XRD results.

### Discussion

X-ray diffraction, x-ray fluorescence and scanning electron microscopy were used to study the atomic- and micro-structural properties of ZnO powders. From XRD results, we found that the samples crystallized in the wurtzite phase. The XRF results indicate that the B1, B2, and N2 batches were highly pure. The SEM micrographs of the B1, B2, and B3 bulk-samples showed a homogeneous distribution of micron-sized grains with uniform shape. The N1 and N2 batches had less uniform grain shapes and wider particle-size distributions. Our XRF and XRD results show that the N1 batch was only 75% pure even when the manufacturer specified 99.5% purity. The impurities and the size homogeneity in the samples directly affected the electrical behavior of ZnO. Our colleagues measured the electrical properties of these same batches and found that the conductivity results changed dramatically from one batch to another. The least pure batches—B3 and N1—were highly resistive. B2 (and B1) pellets resulted in more consistent electrical results among different samples from the same batch, probably due to the homogenous size distribution. Our results are a starting point in understanding the effect of impurities and grain size in the electrical behavior of ZnO materials. Future experiments can build on our results.

**Table 1:**  
**X-ray fluorescence data**

X-ray Florescence Spectroscopy (Sample)						
%Comp	B1	B2	B3	N1	N2	Blank (Mylar 6µm)
ZnO	99.86%	99.86%	99.48%	75.84%	99.87%	1.23%
Fe <sub>2</sub> O <sub>3</sub>	0.07%	0.08%	0.06%	0.06%	0.06%	5.76%
CaO	0.07%	0.06%	0.27%	23.66%	0.07%	64.47%
SiO <sub>2</sub>	0.00%	0.00%	0.18%	0.18%	0.00%	11.71%
TiO <sub>2</sub>	0.00%	0.00%	0.00%	0.21%	0.00%	0.00%
SrO	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
PbO	0.00%	0.00%	0.00%	0.04%	0.00%	0.00%
Al <sub>2</sub> O <sub>3</sub>	0.00%	0.00%	0.00%	0.00%	0.00%	14.21%
CuO	0.00%	0.00%	0.00%	0.00%	0.00%	2.30%
Ag	0.00%	0.00%	0.00%	0.00%	0.00%	0.32%

## Improving the Electrical Properties of Zinc Oxide

### Abstract

*Zinc oxide (ZnO) is a potential substitute for commercial transparent conductors. A good transparent conducting oxide is characterized by high-electrical conductivity and optical transparency in the visual range. Since ZnO in its pure form is an insulator our aim was to increase its electrical properties to make it more commercially useful. Various ZnO pellets were prepared and reduced in forming gas to improve their electrical properties. The thermopower and electrical conductivity were measured before and after reduction. For the high purity samples, the conductivity increased up to 1400% while the electron concentration showed smaller changes.*

### Introduction and Theory

Transparent conductors have vital applications to industry, but the mechanism resulting in their desirable properties is currently not completely understood. Due to their transparency and electrical properties these materials are used commercially in a variety of applications such as liquid-crystal displays and solar cells. The modeling of the electrical properties of these materials centers on determining the theory behind the mobility and carrier concentration of charge carriers. The flow of charge occurs through the movement of small charged particles. An n-type semiconductor has electrons as charge carriers, while a p-type semiconductor has electron holes as positive charge carriers. A hole is created by the removal of an electron [1]. In certain materials, some electrons are loosely held to the nuclei and are able to flow from atom to atom. The magnitude and speed of the charge carried is dependent upon the number of free electrons (carrier concentration) and their mobility. Materials with a relatively high carrier concentration, such as metals, or with a high mobility, such as some semiconductors, conduct well.

The transparent conductors that are commercially used are indium- or tin-based oxides. Zinc oxide (ZnO) is a potential substitute due to its lower cost. ZnO is typically found as an n-type semiconductor. The mechanism responsible for its n-type behavior is not currently understood. Our aim was to study the effect of impurities and different heating treatments on the electrical properties of ZnO samples. The reduction of ZnO samples in forming gas at high temperatures would ideally increase the electron population and the mobility of these carriers by creating defects or imperfections in the atomic structure. For example, a defect consisting of a missing oxygen atom in ZnO can result in two additional free electrons. Thus, just a few percent of these oxygen vacancy defects can substantially increase the electron population. A four-point probe can be used to measure electrical conductivity. The four-point probe is placed on top of

the material to measure the difference in electric potential between two probes, while providing a current through the sample. By applying different currents and measuring the corresponding voltage drops, it is possible to determine the electrical resistance of a sample using Ohm's Law

$$R = \frac{V}{I} \quad (1)$$

where R is the resistance in ohms, V is the voltage in volts, and I is the current in amperes. Using this resistance, the conductivity of the sample can be calculated using equation (2):

$$\sigma = \frac{1}{\rho} = \frac{l}{RA} \quad (2)$$

The conductivity,  $\sigma$ , is equal to the inverse of the resistivity,  $\rho$ . The dimensions of the sample, l (length) and A (base area), have to be taken into account [2,3]. The material's conductivity is directly proportional to both carrier mobility and carrier concentration (number of carriers) [1].

The thermopower of a material, however, depends only on the number of carriers. The thermopower is measured by inducing a thermal gradient in the sample, which causes an electrical voltage drop in the material. The sign of this voltage change depends on the charge of the predominant carriers: a negative voltage drop corresponds to electron carriers while a positive voltage drop corresponds to hole carriers [4]. Since the magnitude of the thermopower depends on the number of carriers in the material, any change in conductivity can be compared with a change in thermopower to separate the individual contributions of mobility and carrier concentration. For example, if a sample shows an increased conductivity but has no appreciable change in thermopower, it can be concluded that the number of carriers remained the same but they became more mobile.

### Procedure

Five different batches of ZnO powders were purchased from different manufacturers. These samples had different purity levels and different grain sizes. The batches with largest grain size, or bulk-powder batches, were labeled, according to their purity, as B1 (Puratronic Alfa, 99.9995%), B2 (Acros, 99.999%), and B3 (Alfa, 99.99%). The nano-powder batches, composed of ZnO powder with smaller grain size, were N1 (American Elements, 99.5%) and N2 (Nanotek, 99%). The percentages in parentheses correspond to the purity specifications from the manufacturers. The grain sizes for the bulk powders were on the order of micrometers, while the nano-powders ranged from one micrometer to ten nano-meters. Different grain size and purity levels were chosen to study their effect on the electrical behavior of the samples. The impurities, phase composition, and shape and size distribution of these samples were determined by T. McManus and J. Hennen [5]. Since zinc oxide was in powder form, pellets were pressed to test their electrical properties. For reproducibility purposes, eight samples from each batch were prepared under identical conditions. The procedure described below was followed for all five ZnO powder batches.

Powder from the same batch was homogenized with

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acetone. Approximately 0.16 grams of powder was placed inside a pellet die of 6 mm in diameter. A force of 900 lbs. was applied to the die using a hydraulic press. ZnO loose powder was placed inside a high-temperature alumina crucible to provide a protective layer or “sacrificial bed”. The eight pellets from the same batch were buried inside this sacrificial bed to prevent any crucible contamination and to minimize evaporation. A tight-fitting lid covered the crucible. The crucible was heated for 48 hours at 1100°C inside a Lindberg box furnace.

### Testing of Samples

The electrical conductivity was measured for each pellet using a C4S four-point probe head (Cascade Microtech) connected to a programmable current source and a multimeter (both obtained from Keithley Instruments, Inc.). Automated measurements were made using a computer running LabView. The applied current ranged from -60 mA to 60 mA. The data obtained allowed the calculation of the resistance in the sample using equation (1). The conductivity was obtained from equation (2) using the measured dimensions of each sample.

The thermopower instrument consisted of two gold foils spot-welded to S-type (platinum rhodium) thermocouples. The thermocouples were attached to the previously mentioned multi-channel multimeter, which was then connected to a computer running LabView. The pellet was placed between the two gold foils. A soldering iron heated the top foil, and the voltage drop due to the thermal gradient in the sample was recorded every 7 seconds. Using the data, the thermopower was calculated for each sample.

Some ZnO samples were subjected to a reducing environment to increase their electrical properties. The pellet was placed inside a combustion boat prepared with sacrificial powder (as described previously). The boat was positioned in the center of a Thermo-Fisher tube furnace. The tube was sealed with tight-fittings and connected to a forming gas tank (4% hydrogen, 96% nitrogen mixture). The sample was heated for ten hours at a temperature of 500°C inside the forming gas atmosphere. The pellet was then taken out, and the conductivity and thermopower properties were measured again. The post-reduction and pre-reduction results were compared.

In order to catalog the results, the pellets from each batch were labeled 1 through 8. For example, the first pellet of the bulk powder B1 (with highest purity according to the manufacturer’s specifications) was labeled as B1-1. The electrical conductivity and thermopower of all the B1, B2, and N2 samples were tested. The available instruments could not measure the conductivity of B3 and N1 due to the highly resistive nature of those samples. Samples 4, 5, 7, and 8 from batch N2, samples 1 and 2 from batch B1, and samples 1 and 2 from batch B2 were reduced in sets of two pellets of the same composition per treatment.

### Results

As mentioned before, the electrical conductivity of the B3 and N1 samples was so small that the instrument could not obtain any results. Interestingly, these batches

had a substantial amount of impurities [5], which probably decreased their electron concentration. Table 1 shows a summary of the electrical conductivity results for the measured samples. The conductivity of the B2 samples was the highest and more consistent before any reduction treatment. However, the reducing atmosphere only increased the conductivity by 10% to 15% in the two B2 samples that were measured. The reduction treatment of N2 samples had a more dramatic increase in the conductivity compared to the B2 samples. Two B1 samples were reduced, and they showed a dramatic increase in the conductivity, on the order of 1400%. The B1, B2, and N2 batches had high purity levels, but their grain size and shape distributions were different [5].

Table 2 shows the values for the thermopower ( $Q$ ) of the tested samples. The sign of the thermopower measurements indicates that all the samples were n-type. A smaller magnitude of the thermopower corresponds to a higher electron concentration. The reduction treatment increased dramatically the conductivity of B1 samples but did not produce any significant change in the electron concentration. The B2 samples had a slightly smaller electron concentration compared to the B1 samples. Within experimental error ( $\pm 5\%$ ), the reduction treatment did not increase the electron concentration of the B1 samples either. The N2 samples showed the most significant increase in electron population after reduction.

### Discussion and Conclusions

Before the reduction process, the B1 pellets were the most resistive. Interestingly, the two B1 pellets that were reduced showed great increases in conductivity, up to 1400%. The B1 pellets had a smaller  $Q$  magnitude, which indicates that they contained bigger electron populations compared to B2 and N2 samples. The conductivity of the N2 samples was not as consistent before reduction, probably due to the heterogeneous size distribution in the samples as measured by J. Hennen and T. McManus [5]. For both the B1 and B2 batches, the combined electrical results indicate that the electron population remains the same but the carriers become more mobile due to the forming gas reduction. The N2 samples showed the most significant increase in electron population after reduction.

From the data collected it is apparent that forming gas reduction increases the conductivity of ZnO samples. The overall effect is highly correlated with the starting powder batches which had different impurity levels and size distributions [5]. In general, batches with more homogenous microstructure result in more consistent electrical properties. Higher purity samples are also more conductive. For the reduced samples the lowest increase in conductivity was about 10% and the largest reproducible increase was on the order of 1400%. The largest increase is dramatic and more reductions on similar samples should be performed in the future to reproduce these results. The inability of the available equipment to measure the conductivity of the B3 and N1 samples indicates that they are highly insulating (less than 0.0001 S/cm), which is probably due to the significant amount of impurities present [5]. Most of the samples that were reduced had a decrease in thermopower.

This means that the number of electrons increased. The largest decrease in Q was about 40%. Two samples had a slight increase in thermopower, probably due to the experimental error associated with the technique.

In the future, more tests need to be done on the same batches to confirm these results and correlations. Isolating a single powder type ought to assist in this process by decreasing the number of variables in consideration. In addition, different heating and reduction procedures should be tested to find the optimal preparation conditions. The results obtained so far may not solve the problem of how to use zinc oxide for commercial applications, but they provide a good starting point for understanding and improving its electrical behavior in the future.

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 Thomas McManus and Jared Hennen, Department of Physics, Atomic and Micro-structural Analysis of Zinc Oxide Materials, *Creating Knowledge: The LA&S Student Research Journal*, Vol. 2, (2009).

**Table 2:**  
**Thermopower results of ZnO samples**

Sample <sup>†</sup>	Q (μV/K)	Q (μV/K) (Reduced)	Increase in Q (%)
B1-1	-602.1	-592.1	-1.66
B1-2	-522.2	-512.2	-1.91
B1-3	-588.8	*	*
B1-4	-602.2	*	*
B1-5	-661.6	*	*
B1-6	-671.7	*	*
B1-7	-453.9	*	*
B1-8	-606.2	*	*
B2-1	-684.5	-729.4	6.56
B2-2	-777.1	-813.6	4.70
B2-3	-692.7	*	*
B2-4	-779.7	*	*
B2-5	-835.5	*	*
B2-6	-801.1	*	*
B2-7	-790.6	*	*
B2-8	-757.9	*	*
N2-1	-715.7	*	*
N2-4	-784.4	-616.3	-21.4
N2-5	-916.3	-656.8	-28.3
N2-6	-837.7	*	*
N2-7	-875.1	-518.2	-40.8
N2-8	-839.4	-665.4	-20.7
N2-9	-940.4	*	*
N2-11	-832.6	*	*

†B1 and B2 samples had micro-sized grains. N2 samples had nanometer-sized grains.  
 \* indicates that the sample was not reduced

**Table 1:**  
**Conductivity results of ZnO samples**

Sample <sup>†</sup>	Conductivity (S/cm) Side one	Conductivity (S/cm) Side two	Conductivity (S/cm) Side one (Reduced)	Conductivity (S/cm) Side Two (Reduced)	Increase in Conductivity (%) Side One	Increase in Conductivity (%) Side Two
B1-1	0.1942	0.2100	3.0049	3.1979	1447.32	1422.81
B1-2	0.1647	0.1170	2.5203	2.6953	1430.24	2203.68
B1-3	0.0032	0.0032	*	*	*	*
B1-4	0.0059	0.0034	*	*	*	*
B1-5	0.0021	0.0031	*	*	*	*
B1-6	0.0023	0.0043	*	*	*	*
B1-7	0.0020	0.0015	*	*	*	*
B1-8	0.0011	0.0018	*	*	*	*
B2-1	0.6882	0.7457	0.7858	0.8037	14.18	7.78
B2-2	0.6514	0.6844	0.7543	0.7633	15.80	11.53
B2-3	0.8418	0.7389	*	*	*	*
B2-4	0.6642	0.6947	*	*	*	*
B2-5	0.7113	0.7255	*	*	*	*
B2-6	0.7778	0.6362	*	*	*	*
B2-7	0.2318	0.1640	*	*	*	*
B2-8	0.8311	0.8670	*	*	*	*
N2-1	1.3114	1.5904	*	*	*	*
N2-4	0.3540	0.2738	0.6679	0.5650	88.67	106.36
N2-5	0.4902	0.4112	0.5698	0.6144	16.24	49.42
N2-6	0.0671	0.5412	*	*	*	*
N2-7	0.4239	0.2796	0.6104	0.5236	44.00	87.27
N2-8	0.5468	0.4250	0.6262	0.8707	14.52	104.87
N2-9	0.0479	0.4899	*	*	*	*
N2-11	0.6593	0.6012	*	*	*	*

†B1 and B2 samples had micro-sized grains. N2 samples had nanometer-sized grains.  
 \* indicates that the sample was not reduced.

## Finding Fractals in Galaxy Distribution Using Wavelet Transform

### Abstract

*While galactic matter distribution shows homogeneity at large scales, at small scales it likely degrades as the distribution becomes more intricate. Using the Sloan Digital Sky Survey and wavelet and fractal analysis, we studied the fractal nature of 600,000 galaxies. We find galaxies to have fractal distribution through all data observed. A separation in the fractal occurs at 800 Megaparsecs, when dark energy is suggested to be the dominant factor in cosmic expansion.*

### Introduction

#### **Lambda-CDM Model**

General relativity gives insight into how the universe evolves. That is, given a set of initial conditions, the size, shape and matter density of the universe can be predicted. One of the important initial conditions is the universe having no preferred direction. We call this property homogeneity. This property is observed at large scales. A completely homogenous universe should have a random matter distribution, with any equal-volume cut out of space having the same amount of matter. On smaller scales the distribution of galaxies is not perfectly homogenous because they cluster. Various models describe these dynamics. The model that best describes our universe is called the Lambda-Cold Dark Matter ( $\Lambda$ -CDM) model. It contains the set of parameters that, when used with general relativity, best describes the evolution of our universe. We seek to find out at what scale the homogeneity of the universe breaks down because this scale gives clues as to when clustering due to gravity becomes less important than the expansion of the universe.

#### **Sloan Digital Sky Survey**

The Sloan Digital Sky Survey (SDSS) is the most ambitious survey of astronomical objects ever attempted. Its database is free and accessible to anyone. The survey attempts to map in detail one quarter of the northern sky, determining the position, spectra, etc., of more than 100 million objects including stars, galaxies, quasars, and other objects. SDSS uses a 2.5-meter optical telescope with 120 megapixel resolution<sup>1</sup>. The data obtained by this survey are being used to address some of the most fundamental questions about the universe.

Because this survey covers so much of the sky, it is an ideal probe for investigating the breakdown of homogeneity. We make extensive use of the almost 700,000 galaxies which SDSS has mapped and classified to reasonable precision. The data are manipulated through reformatting and filtering into a form suitable for our methods of analysis.

### **Wavelet and Fractal Analysis**

The concept of homogeneity in our context refers to how smooth the data are. Viewed from afar, all galaxies appear to be a smooth, evenly distributed blob. Closer examination, however, reveals a structure in this distribution. A simple analogy would be the difference between looking at a mosaic from far away and close up. When viewed from afar one can only see the smooth picture depicted, but closer up the individual pieces (structures) that make up the mosaic are plainly visible.

The distribution of galaxies is said to be homogeneous if each scale shows a similar smoothness. Using fractal analysis, we can observe the breakdown of homogeneity in galactic distribution. We do this by modeling the data as self-similar mathematical constructs known as fractals. The fractal dimension, the measurement of the space taken up in a fractal, tells us whether there is a breakdown of the homogeneity. The distribution of galaxies is homogeneous if each scale viewed has an integer value of the fractal dimension. We aim to find the scale where the fractal dimension changes from integer to non-integer values.

Calculating the fractal dimension is difficult. To make it easier, we use a technique called wavelet analysis, which allows us to break down the data into different scale components that can be studied in relation to one another. We use a discrete wavelet transformation developed in 1988 by Ingrid Daubechies<sup>2</sup>.

The wavelet transform captures local variation of a signal at different scales. When the variation is plotted against the scale, we obtain a quantity called the power spectrum for the distribution of galaxies. The power spectrum shows how much local variations differ from the mean number of galaxies (in a given area) for different scales.

The slope of a power spectrum is a quantity known as the Hurst exponent. This number tells us the breakdown of homogeneity in galaxy distribution because it is directly related to the fractal dimension. If the distribution is homogenous, the variations of the power spectrum lead to an integer value for the slope; deviations from integer values indicate fractals.

### **Procedure**

#### **Data Collection and Formatting**

We obtained data releases one through six of the SDSS galactic spectra and filtered out all information except the celestial coordinates and redshift. Celestial coordinates are the position of any object in the sky. Redshift is a phenomenon that occurs when an object is moving away from an observer. From the perspective of this observer, the wave of light from the object is stretched, causing it to appear redder. The extraneous data was filtered by converting the raw data in FITS format to text using the NASA HEASARC's **fv** program and the standard Unix **AWK** for processing. We kept only data which had at least 95% confidence in the redshift value and sorted it according to redshift value. All manipulation and analysis of our data was done through Fortran.

<sup>1</sup> Completed under the guidance of Dr. Jesus Pando of the DePaul Physics Department, Summer of 2008. jj110888@gmail.com and costuu@gmail.com.

**Distance**

Galactic redshift occurs through the expansion of the universe. There is a relationship between the lengthening of light waves (redshift) and a measurement called the co-moving distance. Co-moving distance is a coordinate system that takes into account the expansion of space in between objects. The relationship between co-moving distance and redshift is found from general relativity to be

$$d_p = \frac{c}{H_0} \int_0^z \frac{da}{a^2 \sqrt{\Omega_m a^{-3} + \Omega_\Lambda + \Omega_\Lambda - 1 + \Omega_\Lambda a^{-2(1+w)}}}$$

where  $d_p$  is the co-moving distance,  $c$  is the speed of light,  $H_0$  is Hubble's Constant; a measurement of the rate of the expansion of the universe,  $z$  is the redshift obtained from SDSS,  $a$  is the scale factor; a measure of the size of the universe,  $\Omega_m$  is the matter density parameter; the proportion of matter to all that composes the universe,  $\Omega_\Lambda$  is the cosmological constant; the proportion of dark energy to all that composes the universe, and  $w$  is the quintessence parameter; a number describing the effect of dark energy in the expansion of the universe.<sup>3</sup> For each of these parameters, we used the currently accepted values of  $\Omega_m=0.266$ ,  $\Omega_\Lambda=0.76$ ,  $w=-1$  and  $H_0=4095.53 \sigma$ . The integration was done using the Cauter's Adaptive Romberg Extrapolator (CADRE)<sup>4</sup> technique applied to each galaxy's redshift. Since our data was previously sorted by redshift, it is now sorted by the value of co-moving distance. Data past 2,800 Mpc was removed since there are very few galaxies past this distance.

**Binning and Pixelization**

To study the homogeneity and the fractal dimension over time, we divide up our data based on radial distance away from us. This is done by binning the data, specifically in 100, 80, 50, 40 and 25 Mpc bins. Our data had galaxies with distances between 6 and 2,800 Mpc. Binning this data in 100 Mpc bins, the result is 28 separate data sets (bins) containing the two dimensional celestial coordinates of galaxies between 6 and 106 Mpc away, between 107 and 207 Mpc away and so forth. See Figure 2 for a visual example of this binning technique.

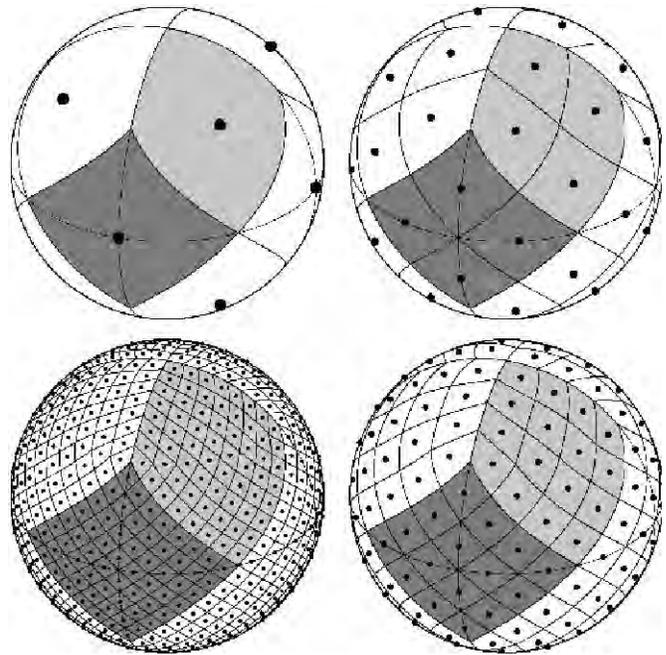
To analyze the data computationally, we must first discretize the celestial sphere. For our method we chose a pixelization scheme. Pixelization is a way of dividing up the sky based on angular coordinates as seen in Figure 1. We used a technique called SDSSPix, which ensures equal area pixels that are indexed according to their relative location on the sphere.

**Analysis**

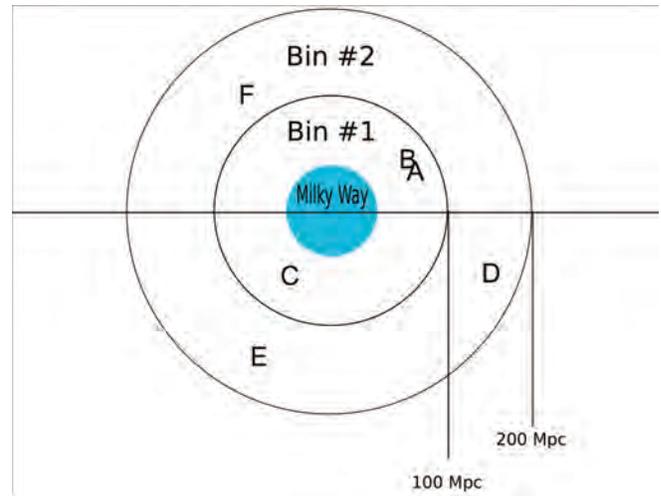
We performed a wavelet transformation of each bin using the algorithm described by Daubechies<sup>2</sup>. The wavelet transform works on data with lengths that are a power of two. Each iteration of the wavelet transform produces a smoothed approximation of the original data at half the original resolution and captures the local fluctuations at each scale. At each of these scales we can calculate the variation and so obtain the power spectra seen in Figure 3.

The slopes in Figure 3, the Hurst exponents, are used to calculate a measurement of the fractal dimension of the data in the bin we look at. These fractal dimensions, given by  $D = 3 - H$ , where  $H$  is the Hurst exponent, are plotted against the lowest co-moving distance of their bins. As Figure 4 shows, the fractal dimension increases as the space (and equivalently, time away) increases.

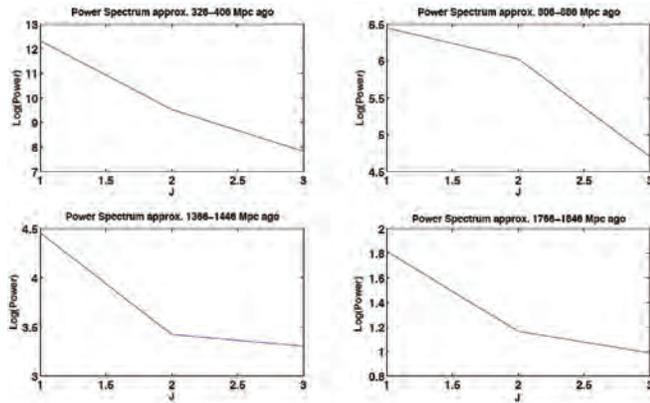
**Figure 1:** Pixelization using the Healpix algorithm<sup>5</sup>. This algorithm forms the basis of the SDSSpix algorithm used.



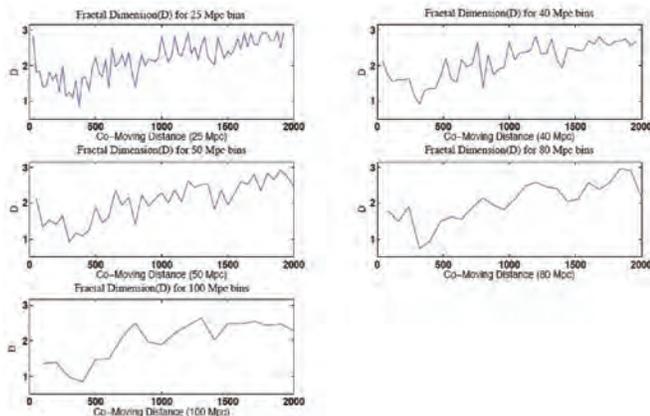
**Figure 2:** A demonstration of the simple binning technique using 100 Mpc bin sizes. Example galaxies A, B and C are in bin #1. Example galaxies D, E and F are in bin #2. None of these galaxies except A and B appear to be clustered, which is why we must use a pixelization scheme in addition to a binning scheme.



**Figure 3:**  
**Various power spectrum using 80 Mpc bins. J is the scale, while the power is determined from the wavelet analysis.**



**Figure 4:**  
**Graphs of the fractal dimension for each bin. Each graph corresponds to each bin size we used.**  
**Conclusion**



Our fractal analysis using the wavelet transform detected non-homogeneity in the galaxy distribution. This is seen in the non-integer fractal dimensions of Figure 4, which indicates the fractal nature of galactic distribution. Since our fractal dimensions increase as we go farther back in time, the complex structure of galaxy distribution is changing over time. Because of the relationship between distance and time in cosmology, our analysis shows that fractal behavior in the galaxy distribution has been occurring for approximately the last ten billion years. In order to have seen homogeneity, we likely would have needed finer resolution for the pixelization (see Section 2.3) so that the wavelet transformed described would be able to work on scales of that magnitude.

With the use of better scales to find homogeneity, our experience and results from using the wavelet transformation would be important for future work in determining if the universe has a preferred direction, a property called anisotropy. Anisotropy is shown in the wavelet transformation because the mathematics causes the variations along different directions to be in specific places in the result. Comparing this at each scale would allow us to determine if anisotropy is present in our universe.

The change in the fractal dimension that occurs between

800 and 1000 Mpc is interesting. Above 1000 Mpc, the fractal dimension is generally 2 whereas below 800 Mpc the fractal dimension is generally below 2. It's worth noting that this is the time where dark energy became dominant in cosmological evolution. Further work is needed to determine whether this is coincidental. We believe that the fractal spike observed in recent times is caused by the significant amount of time that galaxies have felt gravitational effects.

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## Light-Induced Repression of Direction Change in Moving Diatoms

### Abstract

The effects of high-intensity light irradiations ( $>105 \mu\text{mol}/\text{m}^2/\text{sec}$ ) on cell movement were studied for three diatom species: *Stauroneis phoenicenteron*, *Pinnularia viridis* and *Craticula cuspidata*. While irradiation at the leading end of moving cells caused rapid direction change, exposures at the leading or trailing ends of moving cells repress the effect of subsequent leading-end irradiations for up to 60 seconds. Leading-end irradiations in blue light caused repression in *P. viridis* and *C. cuspidata*, while green light repressed only *C. cuspidata*. Trailing-end irradiations in blue light caused rapidly diminishing repression in *P. viridis* and *C. cuspidata* cells; *S. phoenicenteron* showed maximal repression after a 20-second delay.

### Introduction

Diatoms, a group of unicellular golden algae, are an essential component of aquatic ecosystems believed to contribute 20-25% of the earth's primary oxygen production (Round, 1990). Aquatic ecosystems cover 70% of the earth's surface and diatoms have been found in all of them. Due to the abundance of diatoms and their role in the carbon cycle, their fossils and chlorophyll pigmentation have been used to study the effects of climate change, greenhouse warming and pollution (Falkowski, et al., 1998; Round, 1990). Diatoms also stabilize offshore sediments, where motility has been shown to indicate a healthy sedimentary environment (Weitzell & Cohn, 1996; Mann, 1999). They are a fundamental source of food affecting almost all trophic (feeding) levels in most aquatic environments.

This unicellular golden algae is one of very few organisms that build their cell walls with silica (glass). Oxygen is the most abundant element in the earth's crust, closely followed by silica (Round, 1990). Although most silica found in the earth's crust is unusable, diatoms can harness dissolved silica to use in forming their glass-like cell walls (Round 1990). Diatoms are found either free-floating in water (planktonic) or in the sediment (benthic). Some benthic diatoms have evolved a motility mechanism that uses the secretion of mucilage from their raphe to essentially glide over a substrate. While the actual biochemical mechanism of diatom motility is not fully understood, it is thought to involve actin cables that redistribute attachments to this mucilage secretion. It is hypothesized that biochemical signals initiate the attachment redistribution through the cell's photoreceptors (Poulsen, 1999). Since these cells acquire their energy photosynthetically, their ability to regulate cell movement can lead to maximizing light absorption for energy production, while minimizing damage to cells and their photoreceptors.

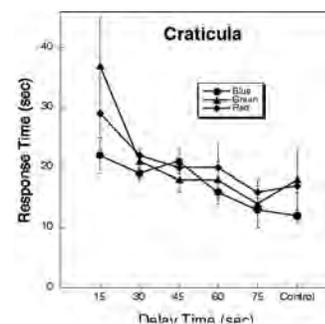
Our work has centered on understanding the regulation of diatom movement in response to high-intensity light stimulation. Previous experiments have shown that diatoms exhibit specific sensitivities to light of different intensity levels and wavelengths, and that specific sites of exposure can induce a direction change. Specifically, high intensity light exposed to the front ends of cells, or lower level irradiation at the back end of cells, can induce a rapid reversal of the cell's direction (Cohn, et al., 2002).

While high irradiation exposure to the trailing end of cells does not cause a reversal of direction, our work has investigated whether such exposure causes a temporary repression of subsequent direction changes. We tested this hypothesis by exposing cells to irradiations at each end (separated by increasing delays) and determining the effect of these irradiations on response time.

### Procedure

Cell cultures of *Stauroneis phoenicenteron*, *Pinnularia viridis*, and *Craticula cuspidata* were isolated from pond water in Boulder, Colorado. The cells were washed several times with distilled water and transferred to polystyrene Petri dishes with a defined Diatom Medium to grow cell cultures. The cells were incubated at 10-12°C for two weeks. For experiments, healthy cells were isolated from each culture and washed three times—twice with distilled water and once with fresh diatom medium. Washed cells were transferred onto a slide chamber, sealed with a cover slip and incubated in the dark for 10 minutes. Cells were observed at 40x magnification on a Zeiss Axioscope microscope with narrow band filters and an epi-illumination system attached to a programmable shutter to control exposure times. The shutter was set for 1000-2700 ms as needed to ensure that cells were exposed to equal irradiance at all three wavelengths used [blue (470 nm), green (550 nm), red (650 nm)].

Figure 1:  
***C. cuspidata* Response Time vs. Delay Time (Front-Front Double Irradiations)**

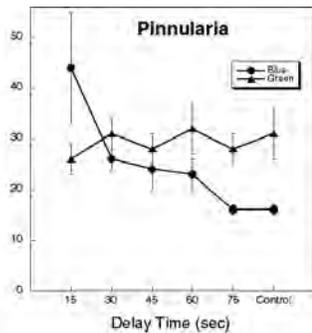


For the purpose of our experiments, the tip of the cell in the direction of cell movement was defined as the leading end (front end) and the tip located opposite the direction of cell movement was defined as the trailing end (back end). In front-front double exposures (irradiations), *C. cuspidata* and *P. viridis* were subjected to high irradiance exposure ( $>105 \mu\text{mol}/\text{m}^2/\text{s}$ ) at their leading end. The cells were allowed to change direction after the first exposure and then irradiated again at

<sup>1</sup> Advised by Stanley A. Cohn, Ph.D., Department of Biological Sciences; research completed Fall 2008. Alexander. charles.pike@gmail.com jsbarboro@comcast.net.

the new leading end with high irradiance. The delay for each trial begins from the time the cell was first irradiated and the second irradiation starts immediately after the set delay time. Delays were set from 15-75 seconds for blue and green irradiations of *C. cuspidata* and for irradiations of *P. viridis* in all three wavelengths. For rear-front double irradiations, the trailing-end was exposed to high irradiance followed by a delay, then a high irradiance exposure at the leading end. Delays were set at 5-60 seconds and the response times for a cell direction change were recorded for irradiations of the three species at blue, green, and red wavelengths.

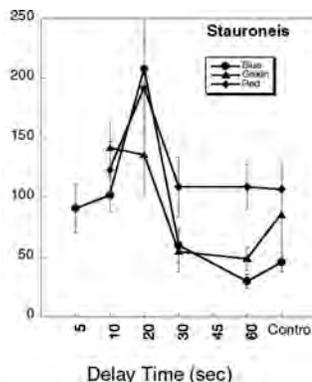
**Figure 2:**  
***P. viridis* Response vs. Time Delay Time (Front-Front Double Irradiations)**



**Results**

In front-front irradiations, the initial light exposure induced a significant repression in *C. cuspidata* and *P. viridis* for up to 60 seconds [Figures 1 and 2]. The average response time for a control (single leading-end) irradiation of *C. cuspidata* was 15 ± 1 seconds (blue), 18 ± 5 seconds (green), and 17 ± 1 seconds (red) [Figure 1]. In comparison, front-front irradiations showed the greatest repression at 15-second delays with increased response times of 37 ± 8 seconds (green), 29 ± 6 seconds (red), and 22 ± 3 seconds (blue) [Figure 1]. These correspond to average response time increases of 19 seconds (green), 12 seconds (red), and 7 seconds (blue) [Figure 1]. Increasing the delay time to 30-60 seconds shows that the effect of the initial irradiation in all three wavelengths dissipates over 60 seconds and shows insignificant repression after 60 seconds.

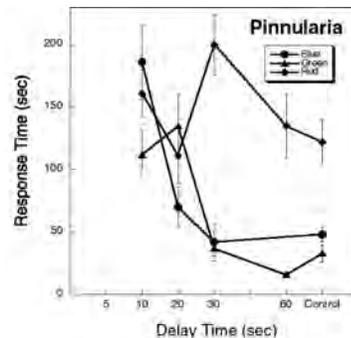
**Figure 3:**  
***S. phoenicenteron* Response Time vs. Delay Time (Rear-Front Double Irradiations)**



The average response time for control irradiations (single front-end) of *P. viridis* to change direction was 16 ± 1 seconds (blue) and 31 ± 5 seconds (green) [Figure 2]. Front-front irradiations showed the greatest repression at 15-second delays in blue with a response time of 44 ± 11 seconds, while green irradiations showed no significant repression with a response time of 26 ± 3 seconds [Figure 2]. Experiments in red light proved to be highly variable and yielded inconclusive results. The effect of front-end irradiations dissipated over 60 seconds with no significant response by 60-second delays.

Rear-front irradiations resulted in a significant repression of direction change response in *S. phoenicenteron*, *P. viridis* and *C. cuspidata*, for up to 30 seconds [Figures 3-5]. Single trailing-end control irradiations were generally insignificantly different from the response time for unirradiated cells. Rear-front double irradiations of *S. phoenicenteron* showed the greatest repression with blue light irradiation, where cell reversal response times increased to a maximum of 208 ± 49 seconds, compared to a single front-end control of 46 ± 8. Similar significance was shown for repression using red and green light, which showed two-fold and three-fold increases in response time for red and green, respectively, compared to single front-end controls [Figure 3]. This effect lasted up to 30 seconds for all three wavelengths.

**Figure 4:**  
***P. viridis* Response Time vs. Delay Time (Rear-Front Double Irradiations)**



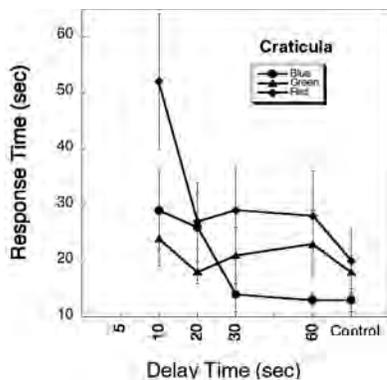
Rear-front double irradiations of *P. viridis* showed strong repression by green and blue light that rapidly decreased to control levels by 30 seconds [Figure 4]. In contrast, results with red light were considerably more variable and showed little repression compared to red control irradiations. The maximal repression in response time was 186 ± 30 seconds in blue and 135 ± 26 seconds in green [Figure 4]. When subjected to rear-front irradiations in blue and red, *C. cuspidata* showed significant repression of subsequent leading-end response irradiations. This effect lasted up to 30 seconds in red and 20 seconds in blue. Using a 10-second delay, blue and red irradiations led to cell reversals after 29 ± 7 seconds and 52 ± 12 seconds, respectively. When *C. cuspidata* was subjected to green light, no significant repression was found [Figure 5].

## Discussion

It was confirmed that single trailing-end irradiations in all three species showed little to no effect in stimulating direction changes. However, irradiations on the trailing end of *S. phoenicenteron* cells caused significant repression to subsequent leading-end irradiations, with maximal repression at 20 seconds after the trailing-end exposure. This repression dissipated over time; no repression of subsequent front-end irradiations was seen after 45-60 seconds. In *P. viridis*, blue trailing-end irradiations caused repressions of subsequent leading-end irradiations, but this effect was shorter lived (only 10-20 seconds), compared to 30 seconds in green was not observed with red light. In *C. cuspidata*, both red and blue showed significant repression, which lasted about 20-30 seconds. Species-specific differences for each species were shown at different light wavelengths in response to a direction change. The lack of apparent response by single rear-end irradiations is likely due to the fact that cells normally take much longer than 30 seconds to display any direction change.

Front-front irradiations have shown significant repression in diatom response (change in direction) to a second irradiation within 60 seconds of the first irradiation in *C. cuspidata* and *P. viridis*. *P. viridis* irradiations in red and *S. phoenicenteron* irradiations in green, red and blue irradiations have not been conducted, but will be soon.

**Figure 5:**  
***C. cuspidata* Response Time vs. Delay Time (Rear-Front Double Irradiations)**



The repression of subsequent direction changes biases cells to continue in their established direction longer in order to move out of high intensity light and allows cells to move into areas that will maximize their energy gathering, while avoiding damaging light levels, such as seen in UV-photodamage (Mewes & Richter, 2002). Light sensitivity specific to each species may also allow cells to migrate to slightly different areas in the algal community, reducing local competition for resources and increasing their chances for ecological success.

Further experiments will help identify the inverse relationship of diatoms to various intensities of light. Future directions of this research include front-front irradiations of *P. viridis* with green light and *S. phoenicenteron* in all colors in addition to rear-front irradiations of *S. phoenicenteron*

with green and red light. The continued investigation of diatom photosystems responses to high-intensity and low-intensity light may lead to the identification of specific light levels desired.

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## Steric Modifications to the $P_4(NR)_6$ Ligand and Preparation of Coordination Polymers

### Abstract

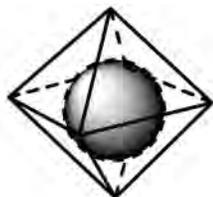
The focus of this project is the synthesis of the  $P_4(NR)_6$  ( $R = 1^\circ$  alkyl) family of ligands that can bridge metal ions to form coordination polymers and networks. The goal is to study the effect of  $R$  group size on the structure of coordination polymers formed between  $P_4(NR)_6$  and metal salts containing  $Cu(I)$  ions. By synthesizing ligands with larger side chains, such as ethyl and  $n$ -propyl groups, the solubility of the ligand is increased. This increased solubility slows precipitation of the polymers, and allows solution equilibrium chemistry to be studied.

### Introduction

Metal-organic frameworks (MOFs) are networks formed from coordinate covalent bonds between metal ions and organic, or hybrid inorganic, ligands. The synthesis of these frameworks, which self-assemble into regular crystalline structures, are generally both highly reproducible and favorable for larger reaction scales.<sup>2</sup> The structure of the product is a direct result of its molecular constituents; the shape of the ligand-metal complex dictates the physical properties of the resulting crystal. Because of this correlation, it is possible to tune the properties of the final product by modifying the structure of the ligand or metal before forming the complex. MOFs are unique in this respect and are important for the storage of volatile molecules, such as hydrogen gas, in which the pores found in the crystals are used to “house” gas molecules.<sup>3</sup>

### Figure 1:

An example of an MOF with hydrogen storage properties. The polyhedron represents the metal-ligand skeleton, which creates the internal spherical cavity. The shape and size of the cavity, and thus the properties of the material, can be adjusted by modifying the ligand and/or metal.

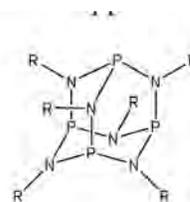


Nearly all MOF structures use oxygen or nitrogen as the electron donating atoms on the ligand.<sup>4</sup> Phosphorus

ligands, for which little MOF research has been conducted, are widely used to catalyze many commercially important reactions. An MOF based on phosphorus containing ligands could be an attractive system for use as a catalyst. An insoluble MOF that catalyzes a reaction on its surface is easily removed from the products. The tunability (the relative ease of modifying) of the ligand provides a way to easily modify the structure and reactivity of the MOF catalyst. Previous research<sup>5</sup> has demonstrated that the  $P_4(NCH_3)_6$  ligand self-assembles into a metal-organic framework when reacted with copper chloride.

### Figure 2:

The general structure of the  $P_4(NR)_6$  ligand family, where  $R =$  an organic alkyl group. This ligand is capable of bridging up to four metal ions and is a good candidate for linking MOF phosphorus bridges. When  $R = CH_3$ , the ligand reacts with  $CuCl$  to form an MOF.



The structure of the product and the rate of its precipitation are inversely related to the initial ligand-metal reactant ratio. Three types of structures: a molecular monomer, a linear “ladder” type monomer, and three-dimensional lattice structures have been formed, where each structure is produced by a specific ratio of reactants.

These observations suggest that multiple intermediate products may be present in solution. Because the  $P_4(NCH_3)_6/CuCl$  complexes are only sparingly soluble, the equilibrium between these intermediates cannot be studied by conventional methods. The purpose of this research is to synthesize analogs of  $P_4(NR)_6$  having  $R = C_2H_5$  and  $C_3H_7$  to determine if the ligands have similar reactivity with copper salts and whether or not the solubility of the complexes is increased.

This paper reports the first synthesis and crystal structure of the  $P_4(NC_2H_5)_6$  as a complex with  $CuI$ . Also reported is the first synthesis of the  $P_4(NC_3H_7)_6$  ligand. The successful synthesis of  $P_4(NC_2H_5)_6$  and its ability to coordinate with  $Cu^+$  demonstrates that the ligand, and thus the structure and properties of MOFs it forms, can be modified through synthetic chemistry.

### Methods<sup>6</sup>

All reactions were carried out under an inert atmosphere of  $N_2$  gas to prevent decomposition of the reactants and products. The  $P_4(NC_2H_5)_6$  and  $P_4(NC_3H_7)_6$  ligands were synthesized by the following procedure: The reaction vessel

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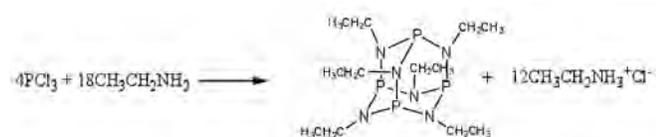
3 Ibid.

4 Nathaniel L. Rosi, Mohamed Eddaoudi, Jaheon Kim, Michael O'Keeffe and Omar M. Yaghi, *CrystEngComm*, 2002,

used was a three-neck round bottom flask to which an addition funnel, mechanical stirring mechanism, and condenser were connected. The ethylamine was added directly to the reaction vessel. The phosphorus trichloride was added drop-wise over two hours. The reaction was cooled using a dry ice/acetone bath to prevent the ethylamine from vaporizing. Once the reactants were added, the mixture was slowly warmed to 130°C for five hours; this process completes the cyclization of the product from its linear intermediate structures. The reaction mixture was then treated with hexanes and filtered to remove the ethylamine hydrochloride. The hexanes were then removed to isolate the product, which was analyzed using NMR spectroscopy. If needed, the product can be further purified under vacuum or by vacuum distillation.  $P_4(NC_3H_7)_6$  was synthesized and analyzed using the same procedure.

**Figure 3:**

The synthesis of  $P_4(NC_2H_5)_6$  was carried out at -78° C under  $N_2$ ; the ethylamine hydrochloride byproduct was removed by filtration.



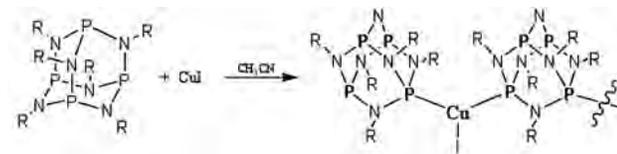
Pure  $P_4(NC_2H_5)_6$  was then reacted (separately) with CuI in various molar ratios in acetonitrile to determine the best conditions for isolating crystalline materials. The acetonitrile solvent was slowly evaporated to encourage crystal growth. Reaction ratios that produced a crystalline or near-crystalline solid were then studied further at a larger scale.

### Results

The 2:1 ratio reaction of  $P_4(NC_2H_5)_6$  to CuI produced a 1:1 product ratio over 48 hours that propagated as a linear chain. The first crystal structure of the polymer  $\{P_4[(NCH_2CH_3)_6](CuI)\}_n$  was determined using X-ray crystallography and powder diffraction techniques; the reaction was also reproducible at a larger scale with identical results. Copper complexes of both  $P_4(NC_2H_5)_6$  and  $P_4(NC_3H_7)_6$  show increased solubility compared to those of the  $P_4(NCH_3)_6$  ligand.

**Figure 4:**

Adding CuI to  $P_4(NC_2H_5)_6$  yielded a crystalline linear polymer linked by P-Cu-P bridges.



The  $P_4(NC_3H_7)_6$  ligand has been successfully synthesized and reproduced, but has proven more difficult to purify. Current work is focused on appropriate purification methods.

**Figure 5:**

The 1:1  $\{P_4[(NCH_2CH_3)_6](CuI)\}_n$  crystal structure; the hydrogen atoms and the nitrogen/carbon labels have been omitted for clarity. P' is the phosphorus atom of the next  $P_4(NC_2H_5)_6$  ligand. Note how the  $Cu^+$  acts as a bridge connecting the ligands.



### Discussion and Conclusions

We have now been able to synthesize two new ligand compounds having the general formula  $P_4(NR)_6$ . Our work here represents the first structural characterization of the  $P_4(NC_2H_5)_6$  ligand. The results of the reaction of  $P_4(NC_2H_5)_6$  with CuI are identical to those found when  $P_4(NCH_3)_6$  is reacted with CuI<sup>3</sup>; both reactions produced linear chain polymers connected by phosphorus-copper bonds. The of the  $\{P_4[(NCH_2CH_3)_6](CuI)\}_n$  polymer has demonstrated that the  $P_4(NR)_6$  ligand system can be modified easily through synthetic chemistry, and is still capable of forming extended structures in the solid state. Moreover, the solubility of the ligandmetal complex seems to increase when larger R groups are placed on the ligand. The successful synthesis of  $P_4(NC_3H_7)_6$  and preliminary results for the first synthesis of still larger R groups has also demonstrated that there is a wide range of possible variations that can be made to the  $P_4(NR)_6$ . Current work is focused on purification techniques and copper coordination studies with  $P_4(NC_3H_7)_6$ , the results of which will help determine the extent of metal reactivity in comparison to the previously synthesized  $P_4(NCH_3)_6$  and  $P_4(NC_2H_5)_6$  ligands. The natural extension of this work to  $R = C_4H_9$  and larger side chains is underway, and will help demonstrate the versatility of the  $P_4(NR)_6$  family of molecules as effective bridging ligands for building extended networks in the solid state with synthetically tuneable physical properties.

### Acknowledgments

The author would like to thank Dr. Roger Sommer, Dr. Bruce Noll, DePaul University Department of Chemistry, the Undergraduate Summer Research Program, and the Undergraduate Research Assistantship Program for continued support.



*Untitled*  
*Gerardo Victor*  
*Photo, 2008*

## Particle Concentration Dependence of Viscosity

### Abstract

Three models which attempt to predict the relationship between particle concentration and viscosity are examined for accuracy. Viscosity measurements of glycerin have been made at five rotation rates for two particle sizes in suspensions ranging from 0% to 60% particle concentration by volume. One model, developed by Einstein, fits the data well within the dilute limit. The other two models appear to be incomplete. The Mooney and Krieger-Dougherty models contain parameters which depend on particle shape and the jamming concentration. This study has found that these values also vary with respect to the radius of the particle and shear rate.

### Introduction

The behavior of complex fluids has been of great interest in recent years. A complex fluid is any fluid that is not pure, containing for example, some particulate or even another fluid. Suspensions of particles are a specific class of complex fluids that are prominent in both natural and man-made settings. A better understanding of complex fluids will allow glues, crude and refined oil, and other products to be better engineered. The erosion of riverbanks and hillsides, air contaminants, and watersheds can also be better managed through the development of complex fluid rheology, the study of the behavior of complex fluids.

The relationship between particle concentration and viscosity has never been fully understood. Sir Isaac Newton defined viscosity as the shear force required to maintain a linear velocity gradient. Shear force refers to the force or motion that is tangential, or parallel, to the motion of the fluid. Einstein was the first to propose a mathematical model describing the viscosity of dilute suspensions.[4] Mooney and Krieger-Dougherty later suggested alternative models for suspensions of higher concentration.[8, 5] A particular point of contention, even today, is the location of the jamming point and whether it is a function of particle size and rotation rate or a constant value. Jamming occurs when the particles that are suspended in the solution can no longer flow past each other. Consequently, the solution can no longer maintain a uniform velocity gradient, the definition of flow.

All the above models are only valid in the low shear regime. The limits of this project are well within the low shear regime, meaning only laminar, or uniform, flow is observed. Different shear regimes are approximated through the use of the Reynolds number which describes the balance of inertial forces to viscous forces within the solution. A Reynolds number of one thousand is considered high shear, whereas a number below one hundred is low shear. The Reynolds number during this project stayed below ten.

In order to thoroughly examine these models the viscosity

of suspensions ranging in particle

concentrations from 0% to 60% by volume for two particle sizes at five shear rates were measured. Previous experiments on suspensions have used particles that did not deviate in size and did not incorporate varying shear rates so experimentation in this area was greatly needed and included in this project. The increase of viscosity was thought to have a dependence on shear rate and particle radius not yet accounted for in the models. This dependence was confirmed through experimentation.

### Theory

The relative viscosity,  $\eta_r$ , of a suspension is given by the ratio

$$\eta_r = \frac{\eta}{\eta_0}$$

where  $\eta$  is the viscosity of the suspension at some concentration, and  $\eta_0$  is the viscosity of the pure solvent. The relative viscosity is used in all plots in this paper.

Einstein derived the following equation for the relative viscosity of a dilute suspension of hard spheres using Stokes' law for fluids [4, 6]:

$$\eta_r = \frac{1 + 0.5\phi}{(1 - \phi)^2}$$

Although Einstein predicted that this equation would only be useful in the dilute limit, the exact definition of "dilute" has not been precisely given.

The Mooney equation models the increase of relative viscosity as an exponential relationship[9, 8].

where  $S$  is a parameter that depends on particle shape, but not size. For hard spheres the value of 2.5 is used, as suggested by Einstein. Mooney suggested that  $k$  was approximately 1.25 for hard spheres suspensions.  $k$  is equal to

$$\eta_r = e^{\frac{S\phi}{1-k\phi}}$$

where  $\phi_m$  is the maximum allowable concentration, beyond which jamming occurs. The literature suggests that this value is approximately 64%[5, 7, 8].

Krieger and Dougherty suggested a power-law relationship for the relative viscosity of concentrated suspensions

$$\eta_r = \left(1 - \frac{\phi}{\phi_m}\right)^{-S\phi_m}$$

where  $S$  and  $\phi_m$  are defined above[5, 7]. The value that has been suggested for  $\phi_m$  is the same as above.

### Procedure

A *rheometer* was employed to measure the viscosity of each concentration using a concentric cylinder geometry. A rheometer is a machine that uses the torque on the rotating head to determine the shear resistance of a fluid. Free rotation of the head is ensured by a compressed air bearing. A custom geometry comprised of a 38mm diameter cylinder inside a 51mm diameter outer cylinder is used to house the glycerin solution. Temperature stability is achieved by submerging the outer cylinder in a water bath kept at 20:°C. The particles are silica glass spheres approximately 71 $\mu$  and

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46 $\mu$  in diameter. The ratio of major and minor axes of the spheres determined their roundness to be 1:138 and 1:001, respectively. The fluid employed was glycerin. This non-hazardous material is a favorite among the rheology community and has been used in experiments similar to this before.

The rheometer is programmed to start with an hour pre-shear during which time no data is taken and the geometry is rotating at 0:1000rad/s. During this hour any bubbles in the solution will be eradicated and the solution will reach thermal equilibrium. The rotating geometry ensures that the temperature distribution is uniform. Following the pre-shear, viscosity data is taken for two minutes at a rate of 5 points per second while the geometry continues to rotate at 0:1000rad/s. An interposing 1-minute pre-shear is initiated while the geometry accelerates to the next rotation rate. Data is taken at :1000rad/s, 0:5000rad/s, 1:0000rad/s, 2:0000rad/s, and 4:0000rad/s for both particle sizes and all concentrations. Multiple runs were taken to ensure the accuracy of the data.

### Results and Discussion

Figure 1 shows that the Einstein model given in equation 1 deviates considerably after about  $\phi \approx .27$ . This indicates the dilute limit resides between :25  $\leq \phi \leq$  :30. This fit corresponds to Einstein's prediction that his relationship would only work well in dilute solutions.

Both the Mooney and Krieger-Dougherty functions did not work well when constraining the parameters in equations 2 and 3 to their suggested values indicated above. Figure 3 shows the Krieger-Dougherty fit to the 46 $\mu$  and 71 $\mu$  data for the 0:1000rad/s rotation rate. The values of  $S$ ,  $k$  and  $\phi_m$  in equations 2 and 3 were determined using the least squares method. The best fits were obtained using  $S \approx 3:77$  for both sizes, and  $\phi_m \approx 58.3\%$  and  $\phi_m \approx 61.2\%$  for the 46 $\mu$  and 71 $\mu$  particles, respectively. The Mooney model achieved best results using  $S \approx 2:62$  and  $S \approx 2:83$ , respectively; and  $k \approx 1:39$  and  $k \approx 1:28$ , respectively. Figure 3 also illustrates that particle size dependence is not a significant factor until about  $\phi \approx 30$ . This also illustrates a change in the fluid's behavior as the dilute limit is passed.

Figure 2 shows that the high shear viscosity plummets at about 52.3%. This could indicate the actual jamming point. There are no graphical jamming points indicated for 0:1000rad/s, 0:5000rad/s, and 1:0000rad/s. The viscosity within these shear regimes continues to increase exponentially.

### Summary

It can be seen that the models suggested by Einstein, Mooney, and Krieger-Dougherty accurately reflect the concentration dependence on viscosity; however, the parameters  $S$ ,  $k$ , and  $\phi_m$  strongly depend on both particle size and shear rate. Further investigation is necessary to determine this precise relationship. Correcting these formulas or developing an entirely new model will be necessary in the future to fully explain the relationship between particle concentration, particle size, shear rate, and viscosity.

Figure 1:

The line can be seen deviating more and more from the data as concentration increases past 25%. The data are from the 7 $\mu$  beads sheared at 0.100 rad/s. This same deviation was found for the 46 $\mu$  beads.

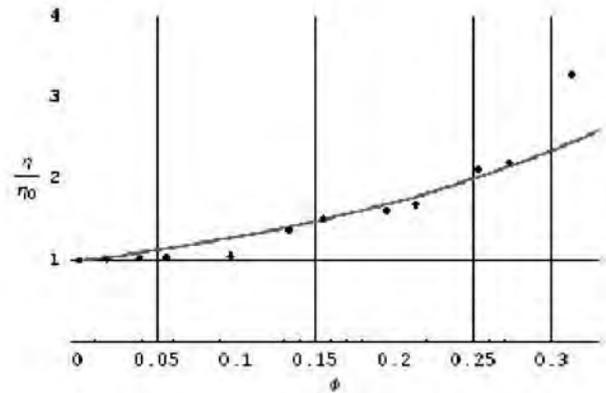


Figure 2:

The interpreted jamming point for the high shear regime can be seen in the dramatic decrease in viscosity at  $\approx 52:3\%$ . The data set is from the 46 $\mu$  beads sheared at 4:0000rad/s.

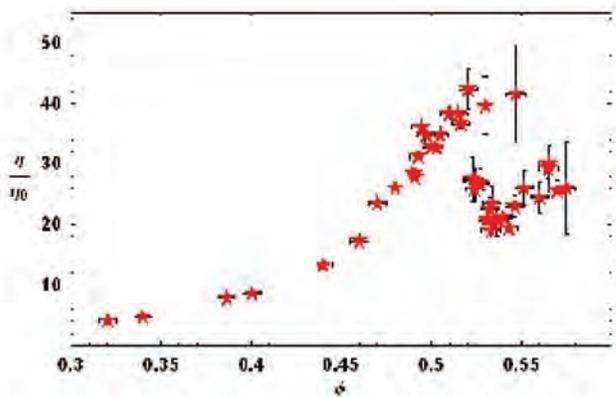
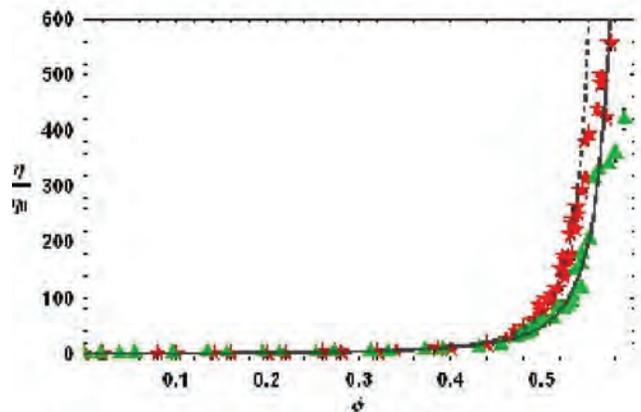


Figure 3:

Stars represent 46 $\mu$  beads and triangles represent 71 $\mu$  beads. The 46 $\mu$  beads demonstrate a larger effect than the 71 $\mu$ , especially at high concentrations. The dotted line is the Krieger-Dougherty fit to the 46 $\mu$ , 0:1000rad/s data. The solid line is the Krieger-Dougherty fit to the 71 $\mu$ , 0:1000rad/s data.



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## Isolation of Purified Vacuoles from *Arabidopsis thaliana*

### Abstract

To understand how plants function, it is necessary to understand the function of the plant cell structures. One important structure is the plant cell vacuole. Vacuoles are involved in water storage, chemical storage and digestion. In order to study how the vacuole performs these functions, it is necessary to isolate purified vacuoles. This paper describes a procedure to isolate vacuoles from the leaves of *Arabidopsis thaliana*, a model genetic organism. A microscopic and enzymatic analysis revealed that the vacuoles isolated in this study were relatively pure and would therefore be suitable for future genetic and biochemical studies.

### Introduction

A prominent part of the plant cell that plays a central role in plant growth and development is the vacuole. Vacuoles are membrane-bound sacs in plant cells that participate in various cell functions. They store most of the water present in a cell and take part in additional functions such as chemical storage, waste disposal, chemical defense, and digestion. To fully understand the functions of the vacuole, scientists need to be able to separate them from the other structures in the cell so that the contents of the vacuole can be observed.

*Arabidopsis thaliana* (thale cress) is a model genetic organism in plant research, just like fruit flies and mice are model organisms in animal research. *Arabidopsis* is widely used because the DNA sequences of all its chromosomes have been determined. Therefore, there are a number of genetic resources available for the study of this organism. Now it is much easier to identify and isolate genes from *Arabidopsis*. In addition, it is easier to determine gene function since there are mutants available for the majority of the identified genes including those coded for transporters that move compounds in and out of the vacuole. Scientists may now be able to compare the contents of vacuoles isolated from a mutant that has a defect in a specific transporter to the contents of the vacuoles from the non-mutant. Any observed differences may provide insight into the role of a specific transporter. For example, assume compound X is present in the vacuole of non-mutant plants but is not present in vacuoles of the mutant. Since we know that the mutant cannot make transporter A, then transporter A might be responsible for moving compound X into the vacuole. However, in order to know what is present in the mutant vacuole and what is present in the non-mutant vacuole, scientists would need to first successfully isolate vacuoles from the plant cell. The goal of this research is to develop a procedure for the isolation of vacuoles from the leaves of *Arabidopsis thaliana*.

### Methods

#### Plant Material

Seeds of *Arabidopsis thaliana* (cultivar Columbia) were obtained from Lehle Seeds (Round Rock, Texas). The seeds were planted in potting soil and grown at 22°C in 8 hours of light and 16 hours of dark. The plants were watered when needed and harvested for vacuole isolations 6 to 8 weeks after germination.

#### Vacuole Isolation

To isolate vacuoles from plant cells, it was first necessary to remove the cell wall. To accomplish this, two grams of leaves were sliced with a razor blade and added to a solution containing the cell wall degrading enzymes Cellulase RS and Macerozyme R-10. The resulting cells without the cell wall were referred to as protoplasts. The protoplasts were filtered through nylon mesh and collected through centrifugation. The vacuoles were then isolated by subjecting the protoplasts to a shearing force through a 12% Ficoll (synthetic sucrose polymer) gradient using ultracentrifugation. The protoplast sample was placed on top of the 12% Ficoll solution and centrifuged at 170,000g for 2 hours. The centrifugal force combined with the viscosity of the Ficoll solution removed all the cellular contents surrounding the vacuole. The vacuoles were collected from the top of the Ficoll layer. This procedure was similar to that used by Guy et al. (1979) to isolate vacuoles from pea plants.

#### Purity of Vacuoles

Vacuolar purity was judged using microscopic examination and marker enzyme analysis. Marker enzymes are enzymes exclusively localized in a particular cellular structure. These enzymes are helpful in determining whether certain structures are present in a preparation. In this experiment, the two marker enzymes that were analyzed were glucose 6-phosphate dehydrogenase and  $\alpha$ -mannosidase. Glucose 6-phosphate dehydrogenase is a marker enzyme for the cytoplasm (cellular material between the vacuole and the cell membrane) and  $\alpha$ -mannosidase is a marker enzyme for vacuoles.

Glucose-6-phosphate dehydrogenase converts nicotinamide adenine dinucleotide phosphate (NADP) to NADPH (reduced form of NADP) in the presence of glucose 6-phosphate. The formation of NADPH was measured at a wavelength of 340 nanometers with a spectrophotometer. The greater the absorbance at 340 nanometers, the more NADPH was formed, which meant that glucose-6-phosphate dehydrogenase activity was occurring. If the absorbance did not change, then the preparation lacked the marker enzyme activity and therefore a cytoplasm. Both the protoplast and vacuole samples were tested for glucose-6-phosphate dehydrogenase activity as described by Simcox et al. (1977).

To test whether the isolated vacuole preparation actually contained vacuoles, a marker enzyme assay for  $\alpha$ -mannosidase activity was performed. This enzyme activity was determined by measuring the release of p-nitrophenol (PNP) from PNP- $\alpha$ -mannose. PNP- $\alpha$ -mannose is colorless, but when p-nitrophenol is released, it forms a color

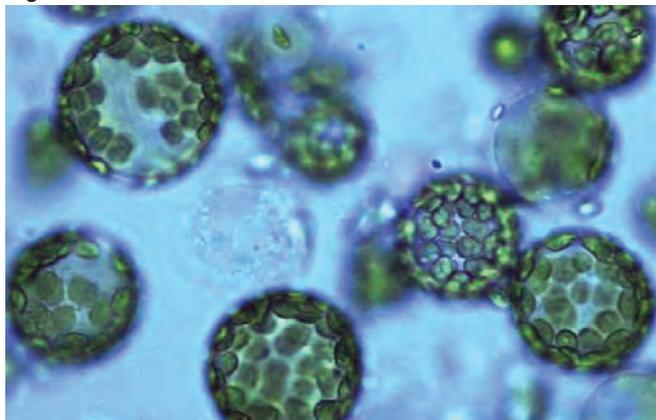
<sup>1</sup> Advisor: Dr. John Dean and A.J. DeLa Cruz, Completed Summer 2008. dfrascar@gmail.com.

that can be measured at a wavelength of 405 nm with a spectrophotometer. A marker enzyme assay for  $\alpha$ -mannosidase was performed for both the vacuole and protoplast samples as described by Boller and Kende (1979).

### Results and Discussion

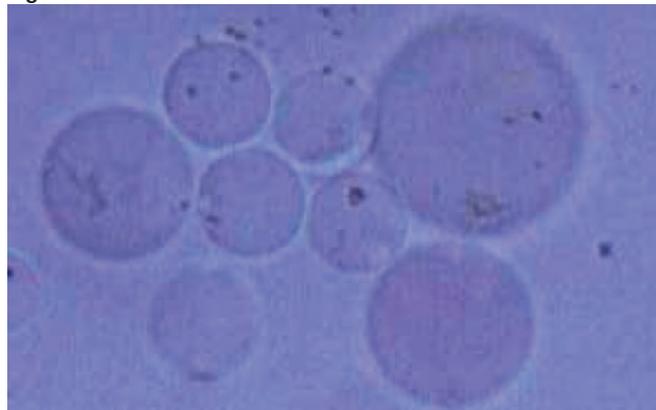
Protoplasts and vacuoles were isolated using the procedure described above as shown in Figures 1A and 1B, respectively. The vacuoles shown in Figure 1B appear to be free of most cellular contaminants. However, the purity of the vacuoles was determined through a marker enzyme analysis. The actual values obtained for the marker enzyme assays were very close to the theoretical values that should be obtained if the preparation contained purified vacuoles. If we assume one vacuole per protoplast and our final preparation consists of vacuoles, then we anticipate the vacuole/protoplast ratio of  $\alpha$ -mannosidase activity to be 100%. We obtained a value of 123% (Table 1). Since purified vacuoles are fragile, we may have lost a few in our sample before we were able to collect our counts. This might have contributed to the higher than expected value. If the vacuole preparation were pure, we would anticipate the vacuole/protoplast ratio of glucose-6-phosphate dehydrogenase activity to be 0%. We obtained a value of 15.9% which indicates that most of the cytoplasm has been removed (Table 1). These results are comparable to vacuolar preparations from other species using procedures developed by other researcher groups (Taguchi et al., 2000).

Figure 1A:



### Microscopic view of protoplasts

Figure 1B:



### Microscopic view of vacuoles

Table 1:

Marker enzyme analysis of protoplasts and vacuoles isolated from *Arabidopsis thaliana*

Type of activity	Protoplast Sample*	Vacuole Sample*	Vacuole/Protoplast x 100
$\alpha$ -mannosidase	2.39 + 0.014	2.95 + 0.069	123%
Glucose-6-Phosphate Dehydrogenase	3.97 + 0.23	0.632 + 0.461	15.9%

\*units nmol min<sup>-1</sup> million<sup>-1</sup>

### Conclusion

We have demonstrated that it is possible to use the procedure described by Guy et al. (1979) to generate highly purified vacuoles from the leaves of *Arabidopsis thaliana*. This procedure can now be used to successfully isolate purified vacuoles from this model genetic organism. This will allow plant biologists to compare the contents of vacuoles isolated from a variety of transport mutants to the contents of vacuoles isolated from non-mutants. Future studies may allow plant biologists to eventually identify the specific transporters involved in the movement of materials in and out of the vacuolar.

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7. Please send one copy of your paper as an e-mail attachment to [rerber@depaul.edu](mailto:rerber@depaul.edu). In addition, send a printed copy along with your faculty advisor's sign-off to:

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