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# Journal of Undergraduate Research

# University of Rochester

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The *Journal of Undergraduate Research (JUR)* is dedicated to providing the student body with intellectual perspectives from various academic disciplines. *JUR* serves as a forum for the presentation of original research, thereby encouraging the pursuit of significant scholarly endeavors.

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# From the Editors

Even as we reach the conclusion of our fifteenth year of publication, the editorial staff of the Journal of Undergraduate Research is consistently amazed, each and every semester, by the quality and breadth of the research conducted by students at the University of Rochester. We are proud to provide these amazing student researchers with a platform for showcasing their hard work and dedication to expanding the scope of our collective knowledge. We also hope that our publication can inspire the next group of budding researchers to pursue their passions and challenge the current boundaries of the scholarly world.

During our interview with Professor Jorgensen, she recounted her early experiences as an undergraduate, pursuing research for the first time. Her memories and reflections call forth many young, aspiring thinkers with vast reservoirs of academic potential waiting to be unleashed. With Professor Jorgensen's words in mind, we hope that the readers of our publication will find inspiration to ask questions they are passionate about and ultimately embark on the enlightening journey of searching for answers.

The path to pursuing knowledge will never end, and new questions will always arise when old questions are answered. Researchers demonstrate a deep curiosity for these new questions, and also a relentless perseverance to appreciate the daunting but rewarding task of exploring the unknown. We believe that the student authors featured in this issue fully exemplify these traits, and we hope that you may appreciate their dedication as much as we have. Perhaps you might even find the inspiration to ask your own questions about the world around us.

And with this, we are proud to present to you our Spring 2017 Issue of JUR, which features research on the history of Cuba and its tourism, a computer-game playing AI, the venom of Nasonia vitripennis, and the positioning of candidates in United States politics. Enjoy!

Sincerely,

*Emily Gore and Victor Zhang*

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## Professor Interview

# Beth E. Jörgensen, PhD
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**JUR**: Could you tell us about your professional background and how you became involved in research?

**Jorgensen**: As a PhD student at the University of Wisconsin-Madison, I had to do research papers and ultimately a dissertation on an original topic that involved extensive research and my own original thought formed by my own research. I chose a writer from Mexico named Elena Poniatowska. She was not very well known in the U.S. and there were very few articles and no books written about her. It gave me an open field to study her work in the way that I wanted to, and I approached it from a feminist perspective.

Her interest coincided with mine - she's very interested in putting out, working on, and creating stories around experiences of oppression and experiences of marginalization, within Mexican society especially. That attracted me because I always liked the social and the political aspect of literature.

I looked at a variety of her texts. There were some interviews and articles I read that had already been done, but mostly, I had free range to say what I wanted to say without repeating work that was already done. Then when I started my position here, I continued - I refined my dissertation and had it published by the University of Texas Press. It was the first book-length study that had been published on her. That was something that she very much appreciated, and brought her work to the attention of many U.S. scholars and students. I continued to be

interested in women writers because they were less studied than most of the male writers from Latin America.

The crónica as a genre was also something I was interested in, and I co-edited a book with a colleague from Ohio State University on the Mexican chronicle. That was interesting because we got some of the "crónistas" (the chronicle writers in Mexico) to contribute short essays about how they view that genre, along with getting scholars from the U.S. to write about different chronicles. Poniatowska and several other crónistas contributed, and I did all the translations of their essays to English.

After that, I authored a book on nonfiction writing in Mexico. When that was done, I undertook another collaborative work with a volume of essays that just came out a year ago on disability approaches to Latin-American literature and film. For that, I collaborated with a colleague in University of Toronto. In 2009, I really started to focus my work and research on disabilities. This came about because of a decision to teach one of Poniatowska's books - a collaborative autobiography of a woman named Gabriela Brimmer. She was born in the late '40s, lived her whole life in Mexico, and had cerebral palsy. Most people could not understand her spoken Spanish.

I decided to teach that book in the context of a course of coming of age stories in Latin America. In the course, I wanted to represent a variety of experiences: coming of age stories by a person of color, an indigenous person, someone early in the 20th century, by

men, by women... Once I decided to teach that book, I realized there's something out there called disabilities studies. So, I started reading just to teach this one text effectively, but I became so engaged that it opened my eyes to viewing disabilities in a completely different way - as issues of stigma and exclusion, and everything we can learn from people who live with disabilities. So, from teaching that one book, my research path changed in one way that I've been very enriched by.

**JUR**: What are some of the specific issues that you studied in state, and why they might be problematic? It seems like you started off with a lot of feminism literature and the trajectory kind of took you to the disability studies.

**Jorgensen**: What I'm looking at now, primarily within Mexican literature, is how characters with disabilities are represented in fiction. The other piece is life writing, or autobiographical writing by people with disabilities. I'm very much interested in the autobiographic representations of disability, as well as the fictional representations. What we found is that, in literature of all kinds, disabled characters have been used to send a message about society, or to serve as a lesson - like Tiny Tim in Christmas Carol. It's not about having disabilities; it's using that character with disability and "the crutch" to make Scrooge a better person. Really, we don't learn very much about disability, and that's pretty common. Another function that has been prevalent throughout literature is the disabled character representing

evil, of ill happening in the society, or an individual defect. So, we have Richard III in the Shakespeare play who has a little bit hunched back. And so, in the Shakespeare play, he's evil because he's deformed. He's failed because he will never find love because of his deform. So, if he can't find love, he'll just try to ruin people. This doesn't tell us about what it is to live with disabilities, but projects our fears onto disabled characters... our fear of the other, who is different.

That's the other thing that really interests me and that's why I love the story "Juan Darien" - because of the way he's not a disabled character but he's different.

People projected their fears of the different onto Juan Darien, onto a blind person, onto whatever. What do we do with racial difference? That's part of what fascinates me about studying disability and also trying to break through those stagnates, and those projections of fear onto the others... to realize that by embracing our diversity, we enrich our lives and move ahead in better ways.

**JUR**: So, your academic focus is literature's implementations on social issues, and now focuses especially on the portraits of disabilities? What inspired you to delve into this field specifically? You talked a lot about the autobiography that Poniatowska wrote.

**Jorgensen**: Yes. The experience of teaching that (gearing up to teach it) has exposed me to this whole field. This is the way that research happens. You start to look into something, and then it just expands infinitely. (chuckle) Because I'll never get to the end of the road in terms of reading the theories and reading the text - there's always something you can do. At a certain point, in order to have a conference presentation or write an article, you have to put some limits on yourself. Then, you work within those limits and you produce something that is what it is. And always, you can go on and do more.

**JUR**: That's a really insightful look into how research works in general. In any field, that's really a good way to look at it.

**Jorgensen**: Often what happens, you know … sometimes it's easy to have this happen, especially if you don't have a deadline, or such a blessing (chuckle) … some of us would never finalize the project. You can just keep reading, keep thinking, keep reading more. Because one thing you read leads to another work that was cited. But if you have deadlines, you have project completion goals. You get something done in the form that is still solid enough to put out there, and then you move on to something else.

**JUR**: Speaking of deadlines and presentations, you recently presented some of your research at a conference in Toronto. Could you tell us more about that project and that experience?

**Jorgensen**: Yeah, that project was kind of what you would call a one-off - something that I think is not going to be a part of a larger project. For that conference, I looked at interviews with criticism of two Mexican writers who have disabilities. I wanted to see if I could find anything interesting in terms of how the instance of disability, the identification of disability in their writing showed up in the critical work. When I write - when most people write - as writers who do not have an identified disability, who appear to be typical, we don't usually say "this writer with blue eyes, who's 5 feet 10 tall…" We don't even pay attention to any of that. We don't talk about their health status, or their physical status, if it's typical or normal. I wanted to see if there's a significant difference in questions that came up in interviews, or comments that came up. One writer who committed suicide in the late 1940s was a poet, and it's not entirely clear what his disability was, but it was psychosocial. Maybe he was very depressed. For a lot of reasons, people have projected all kinds of things onto him. Discourse of disability as mental disturbance - something kind of evil, demonic - comes up all the time. So, I did find some of the interesting things. The other writer's impairment is not a significant disability. She has one eye that doesn't focus (almost blind), but the other eye works quite normally. Everyone asks her about that. I think one eye is a little off to the side. So it becomes the

thing that people are way too preoccupied with, as far as I'm concerned, but it's quite interesting to see how that works in the criticism. That was just a one-time project.

But what I'm more interested in is how critics write about a writer who has disabilities, and critiquing the critics. One of the things that we run into is that there aren't a lot of scholars working in the humanities who are Latin American - who are Mexican or from Chile - who are thinking about issues of disability and disability representations in those societies. I am looking from my North American perspectives at these texts, and it would be very easy to use theories produced in the U.S., or Britain or Canada, to impose on Latin American texts. But that makes me uncomfortable, because they are writing in a different culture and society. What I want to do is to take a theory of a life writing text, (autobiographic novels or autobiography, diaries, or another kind of disability writing) first-person texts, and read them for what they can teach us to theorize - to look at life writing as a theory, rather than looking at them as raw materials. I want to read them for the theoretical insights that a life writing provides, rather than going in the other direction - having theory in mind and seeing in the text.

**JUR**: So, it's sort of letting the writing shape your theory, as opposed to letting the theory shape the writing?

**Jorgensen**: Exactly. Because in reality, that's what the scholars in the U.S. have done. They looked at autobiographies by people with disabilities, and then they created the put-together of what the characteristics are, and they've created a theory out of that. I want to do the same thing, but coming from Mexican texts, and see what differences and similarities there are.

**JUR**: Could you speak more about that? What might some fictional or non-fictional works that you've read tell us about our portrayal of certain people?

**Jorgensen**: Storytelling is a powerful way to communicate experiences that people have and it changes minds sometimes.

That is, if we get more diverse stories out there, the more our minds and our attitudes and the way we live in the world is going to be transformed in positive ways.

That might sound very idealistic, but I really believe it. It's been true for me, it's true for a lot of people. Most writers were avid readers as young people, and continue to be avid readers. They attest to the ways their reading of literature from a variety of places has affected them, their formation of identity, the formation of the way they think about other people and about other cultures. Thinking specifically about our world today, if we read the literature from other countries, some of our views about immigrants might be improved. Right now, our politics seem to be encouraging us to be afraid. To be hostile a bit towards people of other religions, of other countries, immigrants, people of the Muslim faith … or kind of an attack in certain ways in our political discourse. So, reading literature that speaks with different voices can be very important. Stories are an effective way, more than lecturing people, of bridging divides that our politics are trying to widen right now. And that is why I have that poster on my door. It says: "We the People are greater than fear."

**JUR**: So diversifying a perspective can help educate yourself on an issue even if the work is fictional?

**Jorgensen**: Exactly, if it introduces you to a story and an experience that you don't have personally. I know recently there has been a move that young people need stories that reflect their own experiences. And I agree with that. But I also believe that we all need stories that reflect other people's experiences.

I think the problem has been that, for many decades in the history of the U.S., everyone has mostly been reading stories written by white men.

Now that is changing, and it should. But at the same time, just as it wasn't intellectually healthy to grow up only reading literature written by white men mostly about white men, it wouldn't be good for a young African-American student to only read literature written by African-American men. The combination

is what we should strive for… for as much diversity as possible.

We need to read out about ourselves and see our own experiences reflected in literature; it's a way of affirming who we are. And then reading literature produced by people who are different and have different experiences from us is another step, because it expands our idea of who we can be.

**JUR**: You mentioned collaboration, and you mentioned the importance of having deadlines, but what are some traits that you think a good researcher possesses?

**Jorgensen**: Certainly curiosity. Research starts with a question. Everyone talks about that, but it's true. Research starts with something you don't know, that you would like to know more about. Any good research project starts with a question. It may also start with a hypothetical answer that you want to test out, but it has to start with that. Once you have that question, research involves reading - for me, reading things that I think will help me answer that question, some of them because I study literature. Pieces of literature are my primary texts, but then I read theory about literature, critical articles on the books that I am interested in to see how other scholars have read them. If an author is still alive, I might try to get an interview with that person and talk to them about what they've written and how they've done it, and what writing means to them. If the author is not available for that, then you just go on your own reading or other interviews you might find. For people in the sciences, the tools they use are very different, but it all has in common both reading and honoring the work that has already been done and acknowledging the work that has already been done, but also challenging it, trying to expand on it, and offering your own contributions to expand what we know.

**JUR**: Are there any other traits?

**Jorgensen**: Curiosity, being able to form a question, wanting to know something, and then being willing to do the patient work of sifting through what's already there that you have to take into

account… and also knowing when to stop, because you could just keep reading forever. One citation leads to another, to another, to another. Knowing when to reign it in so that you can do something manageable. Younger scholars often fall into the trap of not knowing how to limit what they are doing, because everything seems interesting and one thing leads to another. At a certain point, defining some boundaries, some limits for your study, is really important to learn how to do. One of the ways you can do it is by saying: "Okay, I'm going to set these limits, but in my next project, I'll go into this other direction." Make that promise to yourself. You may not ever get to it, but if you make that promise, it eases the pain of limiting, and understanding you are leaving some things out, because you have to.

**JUR**: Based on your first research experience at University of Wisconsin-Madison, how would you suggest an undergraduate get involved in research?

**Jorgensen**: I went to Oberlin College in Ohio, small liberal arts school. My senior year, I did an honors thesis, which was a research project, on a very famous Mexican novel called Pedro Páramo, by Juan Rulfo. I wrote a thesis on this novel that was longer than the novel. I really got into it. I read the critical articles that other people had written. I thought about it. I did my own analysis, and I was just so happy doing that. I loved every moment I spent doing that.

So my suggestion is, for anyone: identify either some topic you really love or in the case of someone who isn't in humanities, some artwork, or some literature, or some architecture, or whatever, that just really excites you and captures your interest. Then, start to read what other people have said about it as a first step, and think about it yourself, and ask yourself, "Why does this piece appeal to me?" "Why does this novel speak to me in a certain way?" In my honors thesis, what was critical was the professor who sponsored it, who supervised it and worked with me, and the same thing as a graduate student. If students are in one of the sciences - who is that professor who has a lab that is doing work that you are interested in? And

make that connection. In the humanities, sometimes that seems less obvious, but it is just as important, when you are a young scholar, to make that connection with people more experienced - scholars who are working in areas that are exciting to you.

Even when you get to be an old scholar like me, the person in Toronto who I co-edited this book with, had already published books from a disability studies' perspective. She is right up there in the field and very connected, and I was just starting... but she was so generous with me when I suggested that we co-edit a book together. She really was the expert, and I was kind of the beginner. I had co-edited a book before, so I had some of those skills to bring. We just formed a wonderful team, and it was just a wonderful experience. I learned a lot, and I think I helped her out a little bit, too. Do not be afraid to say, "Okay, you have more expertise than I do, but here is what I can bring to a project and what we could come out with by working together."

**JUR**: Based on all of your experiences, do you have any advice for undergraduates in general?

**Jorgensen**: Well, some of them I touched on. Reach out to faculty members who are doing work that you think is interesting. You might have taken a course with them and really liked that course. Seek out a conversation with that faculty member about something that interests you. That is what we are here for, and we welcome students to reach out to us. Or come up with a specific project that you might want to do, whether it's in someone's lab or it's in the humanities, something you might want to do as an independent study, or if you are taking a course, and there is a research component to it… if you have to do some kind of research paper, choose a topic that you are really interested in, and then work with the faculty member to fit it into that course, so that you can be working on something where you are self-directed and self-motivated to do it. That is the most successful way to get involved in research.
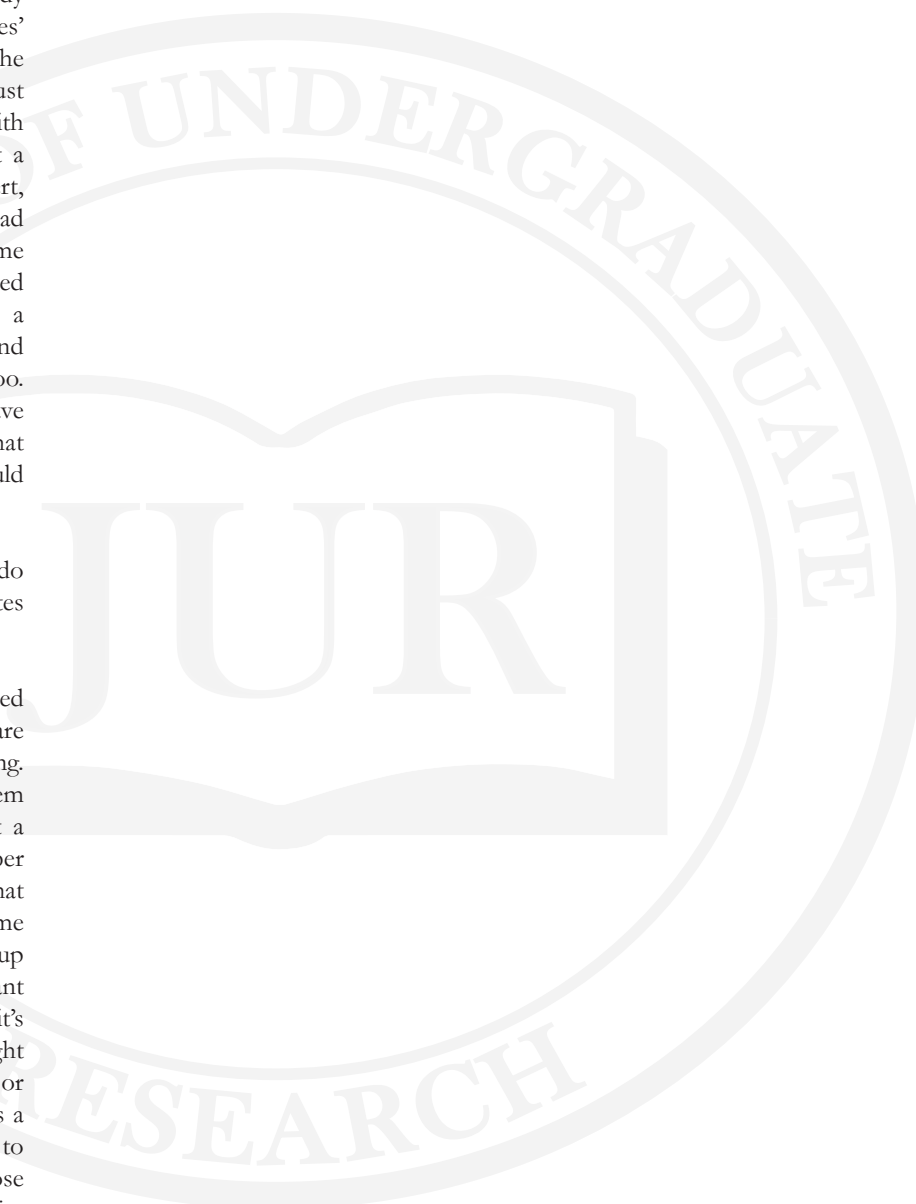
# Guidebooks to Havana: The Tourist Transformation of the Cuban Public Sphere, 1859-1953

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This study examines the tourist influence on Cuba's development from the last century of Spanish Colonial rule to the end of the Cuban Republic in 1959. Havana's urban public spaces acted as the stage upon which tourists and Habaneros interacted for over a century. Attitudes toward Havana's different barrios reveal how tourism impacted the city's physical development, and with this development the nature of the pleasure-seeking Americans' relationship with Cuba. By tracing American tour guides in Cuba back to the mid-nineteenth century, we can better understand the preexisting forms of Habanero public spaces and how tourists reimagined them over time as the spaces physically developed. This paper studies five major public spaces in Havana: El Morro, the Malecón, the Prado, the Plaza de la Catedral and the Plaza de Armas. The tourist influence in Habanero public space is determined through examining the evolution of American guidebooks concerning these cultural spaces. The guidebooks, and their authors, were the means by which generations of American tourists learned to interpret historic spaces in Havana.

This study ultimately argues that guidebooks to Havana during the period examined emphasize three major themes that directly contributed to Havana's physical and social development. The first theme concerns the creation of a Havana that originated in the tourist imagination, wherein tourists placed importance on Colonial period historic sites such as El Morro and the Plaza de la Catedral that conflicted with Cuban rejection of Spanish imperial symbols. The first theme is problematic because the imagined Havana was often realized in the physical development of these public spaces. The second theme elaborates the social development of public spaces like the Prado that were originally places where tourists and the Cuban elites could interact, but evolved to become more cosmopolitan as tourists spent more time in these same spaces. The final theme is the suburbanization of Havana in response to and as a result of American tourism. Havana began as a colonial city populated along the bay but expanded with the growing population creating Centro Habana and eventually the important suburb of Vedado. As tourism expanded, the finest hotels and attractions were built further and further away from Habana Vieja, the colonial barrio, and with these hotels, the tourists and the wealth were pulled away from Centro Habana. As a result, the buildings and roads of the older sections of the city were left to crumble as relics of Cuba's colonial past.

Part of this study's significance is methodological. Cuban historical studies tend to emphasize the year 1959 and the success of the 26 July Movement. While the importance of Cuba's Communist Revolution cannot be denied, there is a certain amount of anachronism in examining and arguing about Republican events in anticipation of the Revolution's victory. This study responds directly to Dennis Merrill's argument that, "Modern tourism so misrepresented Cuban culture and diluted local identity that it… contributed to the rise of Fidel Castro's communist regime."[1] The question of to what extent American tourism really did shape Habanero identity is addressed in this paper's second section by tracing the tourist literature back to the Colonial Period. The reading of tourist sources from Cuba's late Colonial Period in conjunction with sources from

the Republican Period has hitherto not been undertaken, and these later sources must be analyzed via the understanding Americans had of earlier Havana to avoid anachronism. Studying the evolution of public spaces can elucidate important social, economic, or cultural changes given the importance of public spaces, the plaza in particular, in Latin America. This project's thesis thus establishes the topic in both the wider realm of Latin American history and grounds the significance of Cuba as unique within Latin America.

At its core, this study is a history of what American tourists have determined are the most important spaces in Havana. In analyzing the messages that these tourists conveyed to other tourists, we can better understand how American vacationers directly affected Havana's urban development. Havana's uniqueness, exemplified by its gridded formation as denoted by the Law of the Indies but contrasted with its constant depiction as a European metropolis, is integral to understanding Havana's development. When combined with Cuba's unique history as Spain's last remaining New World colony and the effect late emancipation in 1898 had on the modernization movement in Cuba, the need for a closer examination of the late nineteenth through the mid-twentieth century is paramount.

This paper proceeds chronologically through two major periods of study, defined by the dominant political structure of each period. The first period examines guidebooks from the second half of the nineteenth century through the end of Spanish colonial rule in 1898. The US military occupation of Cuba, 1898-1902, is critical to understanding and contextualizing guidebooks after

the end of colonialism, and is examined in the secondary literature. The second period is the age of the Cuban Republic, founded in 1902 via prior agreement between Cuban statesmen and the US government for the end of the occupation. The Republic persisted until 1959, and was marred and demarcated by a second US military occupation in 1906, Gerardo Machado's dictatorship from 1929-1933, and the ouster of Machado by Fulgencio Batista's 1933 Sergeant's Revolt. Democracy was restored until Batista's military coup and dictatorship in 1952, which lasted until 1959 when the Cuban Communist Revolution deposed Batista and ended the Republican Period.[2]

To contextualize this study spatially, some explanation must be given on public space in Latin America and its historical importance to culture. First among the many forms of public space in the Latin American urban sphere is the plaza, a product of the uniform grid plan that all Spanish colonial cities were required to use by the 1542 Leyes de Indias, or Laws of the Indies. Latin American cities have, "a central plaza that is often a locus of civic and religious institutions and public events, but also a range of secondary plazas…linked by major avenues and transit lines, and which can serve as commercial and recreational nodal points."[3] The Plaza de Armas was colonial Havana's center of civic spectacle, demonstrated especially through military exercises. The Plaza de la Catedral, seat of the cathedral, is also critical to this study and oft noted by tourists for the story that Columbus' bones were interred within.

Colonial rule came to an end after the signing of the 1898 Treaty of Paris, effectively replacing Spanish rule with US military occupation. However, the Cuban nationalist *mambises*, the revolutionary guerillas, now found their ambitions for a free Cuba halted by the occupying US army. This created tension between US designs for Cuba, the *mambises*, and lingering elements of Spanish colonial rule. Marial Iglesias Utset elaborates how seemingly innocuous everyday activities acquired explicit political connotations during the US occupation. When a Cubano danced the *danzón* versus the two-step, chose to walk rather than ride a bicycle,

or wore a particular type of clothing, these acts signified where a Cubano stood in the now post-revolutionary Cuba that had seemingly traded Spanish colonialism for US interventionism.

Havana's public spaces became places of inadvertent demonstration, as any action within them could be seen and scrutinized during this period of explicit symbolism. Plazas featured heavily in this period as the traditional spaces where public spectacles occurred and people from all walks of life interacted. As Havana hosted the US military government, the city experienced major renovation and modernization of public streets and state buildings, specifically designed "in line with U.S. architectural styles and patterns of urban development."[4] Utset illustrates the point that from the renovated Malecón to the Prado, much of Havana came to physically reflect the influence of its new imperial protector during

of pleasure and an escape from everyday realities."[5] There is no inherent business or diplomatic purpose to a vacation, only pleasure. In order to maximize pleasure and decrease any stress related to visiting a foreign place, the tourist naturally carried a guidebook.

Guidebooks armed tourists with the knowledge of what spaces they would see and how to value those spaces. This created what Rudy Koshar terms "the optics of tourism,"[6] introducing an active element to the analysis that guidebooks instructed their readers in "what ought to be seen."[7] For Koshar, the active element is the tourist "search for knowledge,"[8] which in the Cuban context helps explain the abundance of guidebooks to Republican Havana. American tourists' apparent need to write guides interpreting and reinterpreting the same Habanero cultural spaces testifies to this tourist search for knowledge. However, this

> *"Havana's public spaces became places of inadvertent demonstration, as any action within them could be seen and scrutinized during this period of explicit symbolism."*

this period. The conflict between Cuban nationalism, the influence of the United States, and the lingering Spanish colonial tradition produced the explicit meaning of normally rote symbols. After the founding of the Cuban Republic in 1902 this conflict remained but transitioned into a tacit phenomenon. American tourists brought with them the cultural baggage of the military occupation. This made their assumptions about space and Habaneros all the more potent as a symbol of the continued American imperial domination over Cuban and Spanish tradition.

In order to examine the message of American tourists in Havana, we must have a working understanding of tourism, both generally and in the Latin American context. This paper uses tourism under the definition given by Eric Zuelow, who states that tourism is "travel in pursuit

search for knowledge also contributed to Havana's physical development according to the spaces that tourists valued the most.

We begin by examining Richard Henry Dana Jr.'s colonial period travel journal, published in 1859. Dana dedicated his guide to the high class "Gentlemen of the Saturday Club,"[9] and set the tone for later guides with his descriptions of what to wear, where to eat, and other details critical to Cuban excursion. Thirty years later, Reau Campbell published his guidebook to Cuba, the latest edition in his series that included Mexico and Puerto Rico.[10] The final guidebook from the colonial period comes from Robert Thomas Hill, who wrote for the US Geological Survey on both Cuba and Puerto Rico. Hill's publication was far from an objective survey, and his commentary on Havana's public spaces
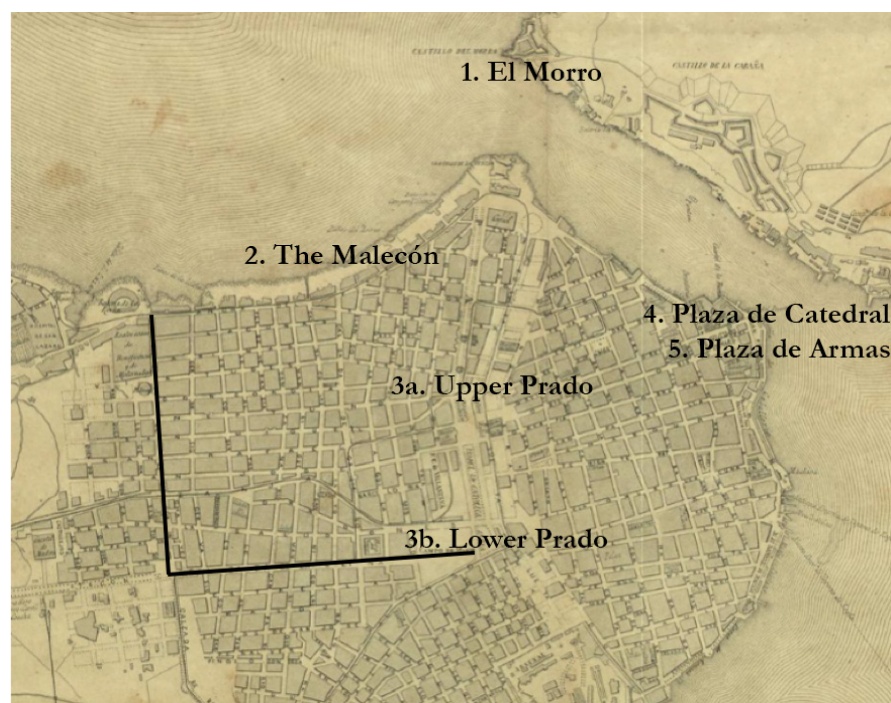
Figure 1: *Plana de la Habana*, 1875, Estéban Pichardo y Tapia, World Digital Library, Library of Congress. The green line is a reference point to mark Havana's expansion, as seen in Figure 3. The vertical is the modern Calle Padre Varela and the horizontal is the modern Calle Simón Bolívar.

and Cuban social conditions classify it as a guidebook.[11]

The Republican Period had a greater number of tourists and consequently more guidebooks to help Americans understand Havana before they got there. Thomas Terry, author of guidebooks to Mexico and Japan, published his first edition in 1926. The purpose of Terry's guide was to fix the problem of Cuba being "…less known than it should be,"[12] a common cliché. Eleanor Early, a career freelance journalist who spent several years living on various islands in the Antilles, published a Caribbean guidebook a decade later with great emphasis on Havana. Early was succeeded several years later by the affluent duo of Consuelo Hermer and Marjorie May, who decided to write their own guide to Havana after many vacations and reinterpret Havana in all the ways they felt other guides failed. As we shall see, they relied on many of the same clichés and interpretations earlier authors used. Five years later Erna Fergusson picked up where Hermer and May left off and continued the theme of reinterpreting the same public spaces, but with the inclusion of a lengthy history of Cuba for context.

Fergusson's history is important in the second section of analysis in revealing the attitudes of tourists towards Cubans in the Republican Period. Finally, this project examines William A. Roberts' Havana specific guidebook, a successor to Roberts' first guidebook to the entire Caribbean.

The analysis of tour guides to Havana will proceed thematically around the cultural spaces that American tourists emphasized most heavily. The spaces in reference possess importance to Cuban history beyond tourism, and the constant need of tourists to reinterpret these spaces in guidebooks reveals the development of these spaces that resulted from of that interaction. The result was that the tourist industry directly affected the urban development of Havana, and the creation of a Havana that existed in the American tourist imagination. This imagined city was neatly packaged and divided by landmarks that came to have as much or more significance to tourists than they did to Habaneros or Cuban history.

We begin by examining El Morro, the fortress at the entrance of Havana bay. El Morro guarded Havana's entrance

and, for over a century, was the first thing most tourists saw upon entering Cuba. El Morro was symbolically important for flying the national flag, which changed over time from that of Spain to the United States, to finally flying the Cuban National Flag in 1902.[13] In 1859 Richard Henry Dana Jr. sailed into Havana at sunrise,[14] past "[t]he steep Morro, with its tall sentinel lighthouse, and its towers and signal staffs and teeth of guns." [15] The Fortress was built in the sixteenth century with the explicit purpose of defending Havana from naval attacks, and Dana's caricature of the teeth of the battlements epitomized the tourist fascination with El Morro's defunct military purpose.[16] For tourists, sites such as El Morro were associated with a feeling of Spanish imperial power that both elicited excitement and upheld a romantic belief that such imperial power was a thing of the past.

Reau Campbell came to Havana thirty years after Dana, and sailed into Havana harbor "under the guns of Morro Castle, with the brightening daylight tinging the eastern sky and showing the frowning walls of Morro" For Campbell, sailing past El Morro signified entering into a world "older than your grandfather," a world where such fortifications were necessary to keep pirates and royal navies from thinking about invading Havana. Whereas for Dana the Fortress was merely a sight to behold, by Campbell's day it had become a tourist attraction. Although the Spanish military still drilled there, tourists could nonetheless gain access by obtaining permits that were offered at hotels in Havana.[17] A ferry ran tourists across the bay from Habana Vieja to El Morro, which indicates how popular trips over to the Fortress became over time.

At the end of the Spanish Colonial Period the Spanish flag was replaced by the American flag of the occupying military. Now firmly in the grasp of the US, El Morro no longer served any military purpose and its function beyond tourist attraction became purely symbolic, especially for the flag flown on the ramparts. During the occupation, El Morro was merely a "picturesque lighthouse and fortifications,"[18] and was inaccessible to tourists and Cubanos

alike. Although Robert Thomas Hill was unable to visit the Fortress as part of his geological survey, El Morro still captured his imagination as the Fortress continued its vigil looking out to sea.

The idyllic vision of El Morro continued well into the Republican Period, as the site was easily recognized as "the most picturesque thing in Cuba."[19] By 1929, the tourist apparatus was fully in place, completing El Morro's journey from defunct fort to idealized symbol of Spanish colonial power in the tourist's imagination. In his self-titled guide, Thomas Terry notes that the sight-seeing tourist need only hire one of innumerable ferries that ushered tourists directly across Havana bay to El Morro. The whole ordeal costed little and took no more than five minutes. In truth, Terry admits that the Fortress itself was little more than, "a rambling confusion of weather-smutched parapets, gun-embrasures, merlons" and a handful of other crumbling bits of military masonry. But it was the idea that El Morro invoked in tourists that made it so exciting, the "romantic memories of bold conquistadores, fighting corsairs, and of many a wild adventure on the Spanish Main."[20]

El Morro did not physically change as a result of all this tourist interaction. The Fortress remained ever taciturn as the "waves beat its old face," and yet El Morro became an integral part in the imagined Havana of the American tourist. El Morro provided a prime example of the way that American tourism affected not merely the actual physical development of Havana, but produced an abstract map to Habanero historical spaces that endured beyond the American blockade. El Morro may have, according to Erna Fergusson, reminded tourists "of the might of imperial Spain," but this paper agrees with Utset's argument that Cubanos symbolically rejected that same Spanish imperialism, and thus did not want constant reminders. The formation of Cuban national identity during the occupation period shifted from evolving out of Spanish colonial identity and became increasingly defined against imperialism, be it Spanish or American.

The Cuban Revolutionaries, the *mambises*, looked to the United States as an exemplar of Republican government

and constitutional principles, but these Revolutionaries fought Spain for the right to establish them in Cuba. These virtues are best exhorted by the apostle of Cuban independence, José Martí, founder of the Cuban Revolutionary Party in 1892 and martyred by his death in battle against Spain in 1895. Martí recognized the nature of US expansionism in Latin America and argued that the revolution of 1895 was not only against Spanish rule but also to, "impede in time…the extension of the United States throughout the Antilles and to prevent its full weight from falling upon [Cuba]."[21] In his essay on "The American Truth," Martí argued that the Revolution must be fought against both Spain and the United States because they were "disdainful of the great masses – the mestiza masses of the country, capable and inspiring, the intelligent and creative masses."[22] These are the same masses, the Cuban *pueblo*, who met the swarms of American tourists during the Republican Period and become reduced to the status of colorful hosts.

Across the harbor from El Morro in Havana proper, the boulevard of the Malecón embedded itself in the tourist mind as the glittering border dividing the city from the sea.[23] The Malecón as it existed during the Republican Period was actually the result of a public works project undertaken by American General Leonard Wood. However, it had a reputation for luxury even before the

boulevard's beautification. The Colonial Period guides make no mention of the passage that existed before the Malecón, but Hill noted in his survey that even while the harbor was fringed only by the sea wall, the street running along the sea had had fine mansions and green spaces.[24] The Malecón served as the sea wall itself (both before and after beautification) and thus it is precisely the handsome buildings and the boulevard that were elevated in the tourist mind.

By 1929, the Malecón had expanded to connect Havana along the coast with the fashionable suburb of Vedado (see Figure 3). Whereas buildings in Old and New Havana bore the distinct marks of their Spanish-Moorish ancestry, Suburban Havana was decidedly North American in contrast.[25]

According to Terry's Guide, the 1929 expansion project solidified the Malecón as "the most popular and delightful of the city resorts."[26]The extension of the boulevard coincided with the construction of "parques, [and] monuments,"[27] including the monument depicting the destruction of the American ship, the *Maine*, which caused the US to declare war on Spain in 1898 and led to the occupation of Cuba. Monuments became one of the primary attractions of the Malecón. Eleanor Early wrote, "every evening we walked from the Prado to the Malecón and along the sea."[28] The idea of wandering "along the



Figure 2: Vedado, showing the earlier Republican period buildings in the foreground and the suburb's modern development in the background. Wikipedia Commons, 22 April 2017.

Malecón," or of shops and restaurants being at "the end of the Malecón" is a common theme across Republican period guides. This was reflective of the way the boulevard was fixed as a landmark on the tourist's compass to Havana. By 1941, the Malecón had achieved an aesthetic fixation in the tourist mind. Hermer and May inscribed a near transcendent beauty to the boulevard when they wrote "the necklace of lights along Malecón, that fabulously beautiful sea-front drive, the silhouettes of royal palms against the sky and the bright star-crowded heavens, give the harbor the unreal quality of a painted backdrop."[29] While romanticizing the Malecón seemed purely aesthetic, the outpouring of sentiment in American tour guides contributed to the physical development of the Malecón through the suburbanization of Havana.

At the end of the Colonial Period, Hill noted that the mansions spanning the length of the boulevard. The primary and most elaborate section of the Malecón runs from the northern terminus of the Prado in Centro Habana westward out to the wealthy suburb of Vedado. In 1930, the Hotel Nacional, the most lavish hotel in Havana, was constructed in Vedado, rising "big and beautiful over the Malecón."[30] In less than a decade the locale had become so populated with tourists that Erna Fergusson explicitly advised "[n]ot choosing the tourist hotels on the Malecón."[31] Although Fergusson preferred to stay in the Packard Hotel in Centro Habana, labeling hotels like the Nacional as tourist hotels enabled tourists to distinguish between places where American customs were the norm, such as speaking English. By advising readers to go to the Habanero suburbs, whether explicitly or by implicitly labeling these parts of the city as less foreign, guidebook authors incentivized the continual movement of the largest capital out of Habana Vieja to where it would be inaccessible to most Habaneros. By the mid-1950s, seeing the sites along the Malecón occupied an essential part of tourist literature, and Roberts recommended to his readers that they walk along that "finest boulevard of its sort in the West Indies" out to see Vedado and then back to the Prado.[32] Roberts distinguishes his preferred barrios of Havana by their orientation to the Prado,
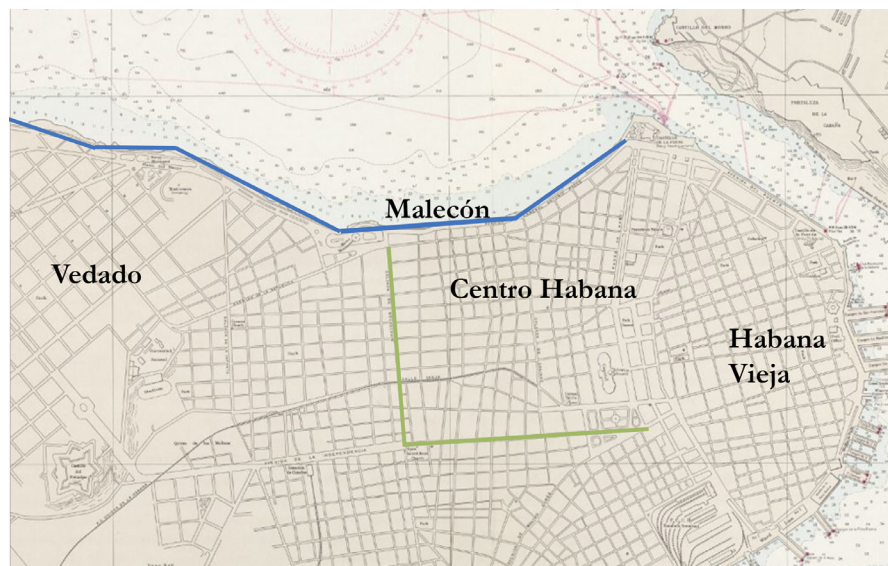


**Figure 3**: "West Indies, North Coast of Cuba, Habana Harbor (Puerto de la Habana)", 1962, United States Hydrographic Office. Harvard Map Collection, Harvard Library. The green line marks the furthest expansion of Havana in 1875 (see Figure 1). The blue line marks the Malecón, beginning at the end of the Prado

saving his highest praises for the newer sections of the city to the west, especially Vedado.

The Prado was an important part of Habanero geography in itself, and it also developed in response to tourism. Names are critical in this section, and it must be noted that the proper name for the Prado is the Paseo de Martí, named after the Cuban apostle in 1904.[33] Before the Prado was named after Martí, it was the Paseo de Isabel II, named after the Spanish queen. Tourists used the terms Prado and Paseo de Martí/Isabel interchangeably. Cubanos tended to almost exclusively refer to the promenade as the Prado, reflecting a refusal to call streets by their Republican Period names.[34] This paper later examines this refusal as a potential source of resistance to tourist geography. This paper reflects the Cuban semantics, and any reference to the Prado should be understood to mean the Paseo de Martí, the name that would appear on a map.

It is also important to note that geographically the Prado separates Habana Vieja from Centro Habana. In the early Colonial Period, a wall surrounded Habana Vieja as part of the city's fortifications against naval attack. The wall was demolished in 1863, but Habaneros continued to refer to Habana Vieja as *intramuros*, within the walls, and everything beyond the original city limits as *extramuros*. The Prado was also divided into Upper and Lower sections.[35] The Upper Prado was the main section of the promenade, lined by trees and buildings. The promenade continued to the Lower Prado, which was bordered by the Parque Central, the Teatro Nacional, and eventually the Capitolio Nacional. Although the former walls and the Prado physically divided the barrios of Havana, this paper argues the Prado acquired geographic importance to tourists, beyond its centrality to Havana's urban plan, as a means of orienting Havana to tourist attractions.

The importance of the Prado to tourists constitutes another way that tourism shifted the development of Havana away from Habana Vieja into Centro Habana and eventually the suburbs. When Dana traveled to Havana in the 1850s, his hotel, one of few tall buildings at the time, was located on the Prado, which at that time was still located *extramuros*, beyond the Puerta de Montserrate.[36] The "grand avenue" of the Upper Prado was already lined by the double rows of trees that remain today, and Dana notes the Teatro Tacón, Havana's magnificent opera house, on the Lower Prado. Dana conducted business with American friends while in Cuba, but he made a concrete geographic separation between the dual purposes of his visit. Business, such as delivering letters to merchants, was strictly conducted "in town," that

is, in Habana Vieja, while pleasurable activities, such as seeing an opera at the Teatro, were conducted along the Prado.[37]

Both Dana and Campbell characterized the Prado as being the place for an evening stroll amongst Havana's finest. The Parque Central, along the Lower Prado and Calle Neptuno, provided an elegant meeting place for "fashionable Havanese", where tourists could observe local customs and hear music from the military band before heading into the Teatro Tacón for the opera.[38] Despite the completely serene atmosphere Campbell describes, he also claimed that tickets to the opera had to be bought from speculators on the sidewalk. This comment in particular foreshadowed the social effect of increased tourism on the Prado, and we will see authors describe the Prado as more cosmopolitan, and thus less elite, over time.

In 1898, the Prado remained a popular attraction and continued to develop despite US military occupation. Hill stayed in the Hotel Inglaterra along the Upper Prado, known at that time as simply the '*Paseo*,' alluding to the rejection of naming the promenade after Isabel II. We learn from Hill that now the entire length of the Prado was lined by two or more story buildings, a far cry from Dana's day. Furthermore, the Teatro Tacón is no longer exclusively the theater of the wealthy. One night Hill attended the theatre and the combination of the class act and the elegant attendance led him to describe the scene as downright Parisian.[39] But the following night the common classes invaded, and the Prado was full of "negresses and mulattos" who took over the Teatro Tacón with the "scum of the male population" and by Hill's account trashed the place.[40] The increasing diversity of Habaneros that tourists encountered on the Prado was well under way by the end of the Colonial Period.

In 1925 the entire Prado was redesigned and beautified by modernist architects led by Jean-Claude Forestier[41]. The result was the widening of the Prado to accommodate both more cars and foot traffic and the marble benches and ornate lamp posts that remain along the promenade today. This was the physical

form of the Prado that our Republican Period authors experienced. The form that modernist architects intended allowed visitors to the Prado to see into the "theaters of public urban life."[42] This description is fitting, as by the mid-Republican Period tourist guidebooks recommended that vacationers spend some time along the Prado, if not to see the actual monuments, then certainly to see the spectacle of Cuban society.

Terry has much to offer his readers regarding the people that can be seen while relaxing in the Parque Central. However, Terry's description also makes it quite clear that tourism is the primary cause for so many spectacles. "From dawn until midnight" the Prado is full of taxis, tourists running from hotels to restaurants, street vendors, lottery ticket salesmen, proselytizers, and so many others. Terry presents this as a meager glimpse of the "kaleidoscopic picture of island life."[43] This description differs sharply from the Colonial Period Prado, which was almost exclusively wealthy clientele out for an evening stroll. Terry refers to the Sevilla-Biltmore Hotel as the reason for the Prado having become a city hub. The Sevilla-Biltmore, built in 1924 on the Lower Prado, was the most lavish hotel in Havana at the time, but became less popular after the construction of the Nacional in Vedado several years later. The Sevilla-Biltmore was effective in continuing to keep the wealth moving out of Habana Vieja. Just as tourists were attracted to the hotels, street vendors and taxi drivers were attracted to the tourists.

The Capitolio Nacional, built in 1929 as the seat of Cuban government, became a major tourist attraction along the Prado, and the construction of the Capitolio itself contributed to the further beautification of the promenade. Terry wrote that the Capitolio was still under construction at the time of writing, but noted that the Parque Central was connected to the adjacent Parque Colón, increasing the green space and allowing for more interaction between both Habaneros and tourists. Hermer and May explicitly referred to the redesigned Parque Central as the "Columbus Circle" of Havana to familiarize readers with the mingling crowds of everyday Cubans and tourists.[44] And yet, the increased

cosmopolitan air of the Prado highlighted the continued suburbanization of Republican Havana. Fergusson detailed the route taken by Cuban tourist chauffeurs across Havana, beginning in the colonial barrio, proceeding down the Prado, and then across the Malecón out to Vedado. As she passes along the Prado, Fergusson comments, "some of the finest houses have descended in the social scale from palace to tenement," a result of the Prado becoming "caught in stone."[45] The Prado was clearly no longer the fashionable place to live.

In contrast, in 1953 Roberts claimed that suburban Havana was full of million dollar palaces suggestive more of California than a colonial capital.[46] Indeed, American architects built some of the finest houses in Vedado, commissioned by Cuban elites.[47] Roberts described these mansions as "abandoning the old romance" of Spanish architecture, reinforcing the idea that the iconic value of the older barrios of Havana was not merely in the colonial architecture, but the sense of colonial days long past that such sites invoked in tourists, much like El Morro.

The final two Habanero spaces under consideration in this section are the oldest plazas in Havana, the Plaza de Catedral and the Plaza de Armas. The Plaza de Catedral, site of the Colón Cathedral, epitomizes the dual character of colonial historical sites in Havana as both physically repurposed for tourists and invoking the air of Spanish Cuba that guidebook authors loved to emphasize. The idea of a grand, colonial Cuba seems to have existed only in the imagination of tourists. The idea was a feeling expressed by tourists like Dana, still very much in the Colonial Period, who described the Cathedral and the Plaza as recalling "the great days of Old Spain."[48] Part of this attraction was the popular story that the body of Christopher Columbus was interred within the Cathedral. The differing stories tour guide authors wrote about the presence of Columbus' tomb emphasized the excitement that was built up around it. Dana, for example, insists that Columbus' body itself is behind a specific wall in the Cathedral, and when tourists entered the Cathedral they immediately looked to that exact wall.[49]

Campbell, however, insists that the ashes of Columbus are interred in the Cathedral beneath a bust of the explorer.[50] Hill presents a synthesis of both stories, with the ashes interred behind the wall.[51] These Colonial Period stories were clearly popular among tourists, as they appear in every Republican Period guidebook.[52]

As more tourists were drawn to the Plaza de Catedral, the physical development of the Plaza became anachronistic. Guidebooks continued to espouse the feeling of a colonial golden age that the Plaza invoked, even as the Plaza became host to tourists' favorite bars and restaurants. Hermer and May are first to note that across the Plaza, facing the Cathedral, is a "fine old palace", built in 1720, that houses the Havana Club Rum Company's free bar.[53] Tourists were thus attracted to the Plaza de Catedral out of a desire for free Cuban rum. If that was not enough attraction, Hermer and May also patronize the Paris Restaurant, adjacent to the Cathedral itself, which was claimed to be the best and most popular spot in Havana.[54] The anachronisms compounded in the Plaza de Catedral as tourists ate French haute cuisine and drank Cuban rum while imagining themselves in old imperial Spain.

When Fergusson visited the Plaza de Catedral to enjoy the free rum bar, the Havana Rum Company had upgraded to serving free daiquiris to tourists.[55] In the pages of these guidebooks, the Plaza had come to embody a status of "come for the rum, stay for the Cathedral." Despite this tourist infrastructure the Plaza de Catedral somehow continued to evoke "the atmosphere of bygone centuries."[56] Here a contrast must be drawn between the Plaza de Catedral and El Morro in order to appreciate the anachronisms presented by the development of the Plaza. El Morro was significant in the tourist literature for evoking a similar air of Spanish imperialism in the tourist's imagination, but the Fortress itself was never physically developed in response to tourism; it was only made more accessible over time while the same tropes continued to be applied. This evocation of Spanish imperialism was problematic with the developing Cuban nationalism and with the founding of the Republic, because tourists continued to rely on Colonial

Period descriptions that took conflict with Cuban autonomy from Spain. The Plaza de Catedral also evoked an imagined golden age of Spanish imperialism in tourists, but was also physically developed for tourists in the form of free rum bars and five-star restaurants housed in seventeenth century palaces. This takes the Plaza de Catedral a step further than El Morro in making Habaneros complicit in the formation of an imagined Havana tourists could more easily orient themselves around. Tourist perception of Habanero agency is explored more closely in the next section. For now, it is important to understand that the Plaza de Catedral was physically developed over time for tourists, but catered to tourist imaginations by retaining the power to evoke an air of grand Spanish imperial times.

The Plaza de Armas is unique among the public spaces reviewed in this study because it was not physically changed by tourism and was not socially repurposed like the Prado. The Plaza de Armas' importance to this study is founded upon the simple premise that it appears over and over again in Republican Period guidebooks to Havana. The Plaza acted as a physical placeholder for tourists, a sort of center point around which they oriented themselves to Habana Vieja. As Havana continued to suburbanize, largely as a result of increased tourism, Habana Vieja stuck in tourists' sightseeing agendas primarily because it was old. The Plaza de Armas, being the oldest public space in Havana, thus became characterized universally as the starting point from which tourists could explore and discover other entities, such as the free rum bar and the evocation of Spanish imperialism in the Plaza de Catedral.

The Colonial Period guidebooks are valuable to understanding the Republican concept of the Plaza de Armas because the earlier authors give us a glimpse at the original function of the Plaza.[57] The purpose of the Plaza de Armas was to display spectacles and symbols of Spanish civic and military authority. The Plaza featured the palace of the Captain-General and various military processions to demonstrate Spanish rule of Cuba. Dana described seeing a military *retreta* in the Plaza, which he claims occurred every

evening at eight o'clock.[58] After the end of Spanish colonialism, the Plaza became merely a relic of this past place of spectacle and physically just a "restricted quadrilateral space marked by a few trees and flowers."[59] Despite shared guidebook knowledge that the Plaza de Armas had had, at one point, an important colonial function, it lacked the charm of El Morro or of the Plaza de Catedral in evoking a sense of a colonial golden age. The Plaza's presence in tourist literature and the picture drawn of the Plaza in the tourist imagination characterizes the Plaza as a box to check off on an agenda. Unlike El Morro, which made tourists feel like conquistadors, or the Plaza de Catedral, which at least had free rum, the Plaza de Armas was only mildly interesting mainly because it was old. The fact that generations of guidebook authors felt the need to interpret the Plaza and encourage readers to visit it cements the Plaza's presence in the tourist picture of Habana Vieja, but because authors provided no further elaboration on the attraction of the Plaza de Armas, it never developed beyond the cobbled square where Dana heard the military band play in 1859.

In the course of discussing the effect of tourism on public space in Havana offered some argument that Habaneros responded to tourism by shifting the important places of Havana in their own minds. This would seem to suggest a correlation, that tourists and Habaneros both ascribed greater importance to the same spaces over time and the modern map of Havana developed out of this unity. However, in this next section I analyze the attitudes of tourists towards Habaneros, and conclude that while the map of Havana that tourists imagined and disseminated through tour guides may have become real over time, tourists always maintained a paternal attitude towards Habaneros. This paternal attitude denied Cubans autonomy, and reflected the belief that Cubans were underdeveloped, and so could not define the important places of their own capital city. Tourists understood themselves to be not only as vacationers, but as ambassadors of modern American culture. When tourists oriented themselves to certain public spaces they not only changed the physical fabric of Havana over time, but they also

imposed their own meanings onto these spaces. However, Habaneros were still able to maneuver within their own urban spaces, and even resist tourists in some small ways.

Paternalism in this section refers to the tourist attitude towards Cubanos, and describes the phenomenon whereby American tourists viewed Cubanos' existence in urban cultural spaces as contingent. This means that tourists understood Habaneros only in so far as Habaneros were perceived to need the cultural sophistication and economic capital of their gracious and cultured visitors. Paternalism was heightened by the overarching US imperial relationship with Cuba. For Cuba, Spain's last colony in the New World, US imperialism was attached to the annexationist movement in the late 1800s, the US declaration of war on Spain in 1898, two military occupations of Cuba in the span of a decade, and the Platt Amendment that justified any and all US state interference into Cuban political autonomy until its annulment in 1934. The Colonial Period guidebooks present a strong sense of ownership over Cuba that is reflected in the Republic Period guidebooks.

All guidebooks examined in this study were interested in giving an overview and explanation of Cuban culture and society, often accompanied by a brief review of Cuban history. In the scope of this project, the roots of the American tourists' paternal relationship to Cuba can be traced all the way back to Dana. Dana was certain that Cuba would only ever exist as a colony, because Cubans had experienced neither political autonomy nor self-government.[60] In the scope of this project, Dana was one of the only authors that experienced first hand Spanish military spectacles in the Plaza de Armas. Dana bought into these spectacles as a display of the Spanish, not Cuban, rule of Cuba, and was convinced that being ruled was Cuba's natural state of being.

Campbell, visiting Havana thirty years after Dana, was not explicitly interested in the state of political affairs in Cuba, but nonetheless managed to convey a clear picture of the tourist's power in Havana. For Campbell, geographic vicinity to the United States meant that Cuba

"belong[ed] to the domain of the tourist – at least since it has been shown that it only requires a ferry-boat to cross over."[61] The more accessible Cuba became to tourists, the more Cuba belonged to tourists, and as the steamboat lines from the United States expanded, Cuba only continued to become more accessible. For example, Havana was already unrestricted to tourists by 1889, as evidenced by Campbell's trip to El Morro. Despite the Spanish military actively using the fort, a day pass obtained at one's hotel was all a tourist needed to visit the fortress.[62]

When Spanish rule ended in 1898, American authors were still certain of the foreign nature of Cuba and its need for a new imperial power. In his study for the US Geological Survey, Hill characterizes Cuban culture based on the premise that Cubans were unable to govern themselves. It is precisely because of "the peculiarities of [Cuban] government, which offers no paths of ambition to

its underdeveloped citizenry, describing Havana as "a picturesque and beautiful place, presenting, even in the midst of the most horrible tragedy of the century, the gay appearance of a European city."[63] Havana could be disconnected from the colonial conflict and revolutions and still remain the idealized vacation city for tourists. This underlies the critical point about the disconnect between tourist paternal attitudes and the perception of Cuban colonial dependency. The tourist gaze separated Havana from Habaneros, meaning American tourists could still view the Plaza de Armas and the Catedral as mere objects of historical importance, relics of a bygone time. Havana only had the appearance of a European metropolis for the American tourist, but for the Habanero spaces that formerly had specific Spanish colonial functions needed reinterpretation because of rejection of Spanish colonial tradition, either in favor of mambise nationalism or

> *"The Plaza acted as a physical placeholder for tourists, a sort of center point around which they oriented themselves to Habana Vieja."*

the aspiring youth, the [Cuban] men are generally listless." These same listless men could then become objects that tourists could observe along the Prado, or that tourists could directly engage with as taxi drivers or street vendors.

The foreign perception and deserved colonial status of Cuba was all but complete in the American mind in 1898. The US military occupation ended in 1902 but the Platt Amendment ensured that the US government had the legal right to suspend the democratic Cuban government at any time. The same Cuban government that Americans were convinced would end in failure to begin with would endure under a watchful imperial eye. All that was needed was a way of reconciling this new Cuba with the tourist land of pleasure left over from the Colonial period. This was readily available in the familiar streets and plaza of Havana. Hill elevates the capital above

acceptance of US hegemony.[64]

Americans perceived the end of Spanish power in the Americas differently. In 1904, Hezekiah Butterworth published his "popular illustrated history" of all the Latin American republics, focused on the liberation movements that had created the republics that exist today. The importance of undertaking such a study is that it recognized that the nations of South America seemed "about to shock the world by [their] industrial achievements."[65] Cuba was presented as the youngest of these rising nations, connected to Venezuela, Colombia, and other republics by revolutionary tradition traced back to Bolivar. Butterworth presents his work as an introductory history, a primarily empirical account based off the documentary research of other scholars, but with the overarching teleological assumption that Latin America was about to become heavily

industrialized and ready to assume geopolitical importance on the world stage. This assumption excludes the reality that the industrialization was carried out largely by foreign companies with great exploitation and social turmoil.[66]

Terry's guide gives the reader a sense of Havana's new landscape, that had been built to accommodate the twentieth-century American tourist. In particular, Terry qualifies the hotels based on their similarity to their American counterparts, likely a result of being "patronized by the cream of Cuban wealth and aristocracy."[67] These same wealthy Cubans patronizing the Hotel Nacional were likely also moving out of Centro Habana and building elaborate mansions in Vedado. This Cuban aristocracy chose to throw in their lot with the American hotel managers contributing to the suburbanization of Havana, thus allowing us to problematize Terry's commentary on the Cuban people he describes for his tourist audience.

Terry assured his readers that Americanization was good for Cuba, but his way of answering allows us to interpret a negative response from Cubanos. In order to propose Cubans played an active and approving role in the imperial reconstruction of their capital, Terry creates the character of the "honest, thoughtful, grateful Cuban of the old régime."[68] This Cuban caricature is the native defender of US imperialism, who harasses the Cuban nationalist with the loaded question: What would have happened to Cuba if the US did not declare war on Spain in 1898? One can only assume the answer is continued oppression by Spain. The Cuban of the old régime remembers this oppression, and thus proclaims the US to be "a generous fountain whence Cuba has drawn unthinkable benefits."[69] The US was not merely providing a paternal example for Habaneros to follow; they were actively forcing their way into Havana and rearranging it under an American model, inconsistent with the desires of the Cuban nationalists.

But did Americanization negatively affect Cubans? Terry's paternal attitude emphasizes that American tourists felt their understanding of Habanero public space was completely valid, and because Cubans were seen as inferior, the tourist

understanding of public space was the only valid view. However, this does not preclude the possibility that Cubans were able to continue using their own city spaces and craft new meanings for them after the end of Spanish colonialism. In fact, the social evolution of the Prado towards cosmopolitanism demonstrates that Habaneros did impose their own meanings onto public space. The street culture that developed along El Prado in the Republican Period, with Terry's description of street vendors and taxis and all types of people crowding the promenade from dawn until after dusk, was Habaneros repurposing a public space that was formerly the province of the city elites. When the modernist architecture movement beautified El Prado in 1925 to make a theater of public life, Cubans and tourists continued to share the space in greater numbers. These Habaneros were often broadcasted as a spectacles in the guidebooks, but this is still an example of Cubans using a Cuban space in a Cuban way.

Cubans possessing their own understanding of Habanero public space separate from tourists' raises a valuable point. Tourism directly contributed to the social transformation of the Prado, which in turn eased tensions created by explicit symbolism during the US occupation. In effect, cultural symbolism became implicit over time because of tourism. Tourists imposed their own meanings on Habanero public space, and Cubans were thus able to express some autonomy, as Cuban use of public space was perceived as spectacle by tourists, instead of an explicit support of a particular type of modernization.

Early implicitly defined tourist spaces by their level of accessibility to foreign visitors, which demonstrated how guidebooks privileged tourist understanding of space and reduced Habanero autonomy within their own spaces. Early describes an ideal tour of the city, which for some might involve hiring a car and a guide, but he warned, "Cuban drivers generally are dumb in history and deficient in English, so pick your guide with care."[70] The paternal semantics of this statement are blatant: tourists cannot expect Cubanos to know their own history, so they must rely on

another American's descriptions of Cuban spaces. Even deeper is Early's assertion that some Cuban drivers not only do not know English, but that this constitutes a deficiency. Furthermore, there is a level of financial accessibility dividing tourist and Cuban space, because, "Havana is an expensive place…from a visitor's viewpoint. Natives can live well on very little money."[71] Early draws a severe contrast between the tourist parts of Havana and everywhere else, and almost explicitly denotes the tourist areas as monetarily inaccessible to Habaneros. So while the Prado may have remained accessible to Cubans, Vedado and the wealthy suburbs became increasingly isolated from local Habaneros. Hermer and May heap praise upon the hotel system that pampered the wealthy tourists who would read such travel guides.[72]

Fergusson's paternal attitude is evident in the central questions to her guide. Fergusson imagines Habaneros as remarkably similar to Americans, and explicitly puts this idea into the minds of her readers by asking, "Why are these Cubans like us in so many ways?" But Fergusson also asks, "What are [Cubans] to us? And why?"[73] To her, the people of Cuba must possess some distinct relation to Americans; they cannot merely be people living their lives in a particular country. By including a brief history in her travel guide, Fergusson asserted for her countrymen that Cubans exist only in relation to the experience of American tourists. Fergusson's history inscribes youthfulness to Cuban culture in the context of Cuban republicanism, which only succeeds in ingratiating an imperial mindset that the US must continue to keep a hand on its Caribbean neighbor's shoulder and steer it towards progress.[74]

And Yet even in the context of Fergusson's paternal language towards Cubans, we see more evidence that Habaneros used public spaces distinct from tourists. In Habana Vieja, Fergusson describes the narrow streets of the colonial barrio as "jammed not only with vendors and walkers but with talkers who know no better place for gesticulative discussions, impeding traffic."[75] Similar to Terry, Fergusson chalks this up as an attraction of sorts, a spectacle of Cuban culture for tourists to observe.

But Fergusson adds a paternal gloss by qualifying "[t]he Cuban who jokes and plays, irresponsible and complaining, is the descendant of the colonial who had no rights."[76] While Fergusson understands Cubans as inferior, we see the endurance of Cuban street culture in Habana Vieja along the Prado, even as tourists reduced the colonial barrio to a place to drink and remember old colonial days. Roberts also raises a possible way that Cubans resisted the tourist understanding of Habanero public space. Streets in Havana often have two or three different names; a result of having a Colonial Period name that was often changed during the Republic Period, and sometimes a colloquial name in addition. Although the Republican government had been attempting to rename city avenues since its formation in 1902, Habaneros refused to use the new street names despite the passage of time. Case in point, the Paseo de Martí, formerly known as the Paseo de Isabel, but known to Cubans only as the Prado. Similarly, the Malecón was renamed after a national hero to the Avenida de Antonio Maceo, but again even naming the street after a national hero did not mean Habaneros used that new name.[77] Roberts examines the result of this local practice with a tourist's attempt to navigate the city: "A taxi driver will throw you a puzzled glance if you mention an appellation that has been staring him in the face for years, and at last will mutter, 'oh, you mean so-and-so!'"[78] Refusing to call streets by the names that the government gave them was a possible way for Habaneros to resist the government action towards uniformity. It is perhaps interpreted as another encroachment on traditional understandings of public space and can at least be established as unwelcome by most Habaneros.

Tourism directly affected Havana's physical and social development from the last half-century of Spanish Colonial Rule to the end of the Cuban Republic. A century of American guidebooks constantly emphasized five public spaces in Havana, and examining tourists' accounts of these spaces (El Morro, Malecón, El Prado, Plaza de Armas, Plaza de Catedral) revealed that tourists repurposed and indirectly developed

Havana in three major ways. Tourists often imagined Havana, and especially early colonial sites like El Morro and the Plaza de Catedral, in ways that conflicted with Cuban nationalism and the rejection of Colonial Spain, but the tourist interpretation of historical spaces was the one that endured to the end of the Republic. Tourists also socially developed spaces like the Prado as more hotels and attractions were built, drawing tourists to these spaces and drawing Habaneros to the tourists. Finally, tourism contributed to the suburbanization of Havana by patronizing the grandest hotels and expensive clubs and restaurants in Vedado, pulling the wealth away from the center city.

Havana's colonial sites were not physically developed because of tourism, but were repurposed because of tourists' constant visitation and admiration. The Plaza de Catedral and El Morro were praised for the feeling they invoked in tourists, described as the air of Old Spain or Colonial Cuba. El Morro was recognized for its original military purpose but mainly favored by tourists because they could stand atop the battlements and feel like a conquistador. Similarly, the Plaza de Catedral invoked this feeling of a bygone colonial era in tourists, even as the Plaza became home to Habana Vieja's finest restaurants. In essence, the Plaza de Catedral became anachronistic as tourists continued to share the same stories about Columbus being buried in the Colón Catedral while drinking cocktails in posh outdoor cafés. The tourist conception of El Morro was more problematic for Cubans because of the Fortress' symbolic connection to Spanish oppression. The fact that tourists continued to express the same colonial sentiment over time highlights the power that tourists had in shaping Havana. The Plaza de Armas emphasizes this power in the reverse. The Plaza de Armas was omnipresent in guidebooks to Havana, yet it failed to invoke the same feeling in tourists as the Plaza de Catedral. Tourists only passively considered the Plaza de Armas because of its historic status as Havana's first public space, and because the Plaza was not emphasized in greater detail, it was never physically developed.

The Prado and the Malecón changed

both socially and physically because of tourism and consequently contributed to the suburbanization of Havana. As the Prado developed, the Malecón developed in concert, transforming the latter into the avenue to the suburbs. The guidebooks make it clear that as the Prado urbanized, the architecture became distinctly more American, especially the hotels. The Malecón was expanded to connect the Prado with Vedado, and tourists then wandered down the Malecón to the newer, more extravagant hotels in the suburbs, where the everyday Cubans who interacted with tourists on the Prado could not follow. Vedado was consequently developed in a distinctly American style and was full of palaces and high rises as befitting its wealth in comparison to the older parts of Havana.

The physical development of Havana by tourism was mediated through a lens of paternalism, as vacationing Americans understood Cubans to be less developed and thus privileged the American interpretation of Habanero space. This paternal attitude towards Cubans was produced by American imperialism, as exemplified by the US military occupations at the turn of the twentieth century. Tourists then internalized US imperial power over Cuba, reflected in the language of ownership the guidebooks use when describing Habanero public space. In particular, tourists bought into the idea that Cubans had no experience with political autonomy or governance and thus needed a paternal presence.

Despite the widespread tourist reinterpretation of Habanero public space, Habaneros themselves were able to repurpose city spaces for distinctly Cuban purposes. Even though the tourist gaze reduced Cuban use of public space to mere spectacle, Habaneros retained some autonomy and helped contribute to the evolution of the Prado into a cosmopolitan space. El Prado had formerly been the promenade for elites but was transformed into a social space for Habaneros of every station to meet and discuss the affairs of the day. Furthermore, Habaneros resisted the tourist repurposing of public space in some small ways, especially by continuing to use colloquial names for city streets, despite government attempts to rename

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these streets after national heroes. This act constituted a small resistance to tourists' ability to reconcile a map of Havana with the metropolis they read about in guidebooks. Even as Habaneros found ways to maneuver within their own public spaces, it was ultimately the tourist developments of Havana that endured through the Republican Period.

But what happened to Havana after the victory of the Communist Revolution? Tourism virtually ceased to exist, and Havana ceased to physically develop. Instead of tearing down the symbols of Spanish and American oppression, the Revolution renamed and repurposed Havana on an egalitarian model harmonious with the spirit of Communism. Case in point, the Plaza Cívica, which was renamed the Plaza de la Revolucion.

Although the Revolution did not physically develop Havana in any of the ways that tourism did, the Revolution did socially develop Habanero public space, imbuing it with an egalitarian atmosphere. The finest example of this is Havana's *Parque Coppelia*, in the heart of Vedado, home to the Coppelia *heladería,* world-famous socialist ice cream.[79] Despite the Parque being in Vedado and not Habana Vieja, James Curtis argues that the Parque Coppelia can be conceived as a traditional Latin American plaza because of its physical location in the urban grid and its ability to function as a social space.[80] The Parque Coppelia provides a physical respite from the close quarters of urban life and a convenient place to meet comrades, similar to the Colonial Plaza de Armas, where Habaneros would convene to watch military parades.

The Parque Coppelia continues to be a truly egalitarian place. The heladería's many patrons include the "squeaky-clean Communist youth", "young people who have long hair", as well as homosexuals and black marketers. After Cuba reopened the tourist industry in the 1990s, tourists, too, frequented the Parque, and the space thus developed into "the ultimate democratic ice-cream emporium."[81] Unlike the social development of El Prado, where Cubans were able to socialize only under the paternal tourist gaze, in the Parque Coppelia tourists and Habaneros are united by the singular goal of buying and eating ice cream. Any socializing between groups is merely the result of waiting in very long lines.

The Parque Coppelia's location in Vedado suggests that the Revolution was in some ways able to transcend the boundaries, real or imagined, that tourists placed upon different barrios of Havana, and that Habaneros were able to use their own public spaces without the objectification of tourist eyes. As we enter an uncertain future in regards to US-Cuba relations, it is unclear what will become of the physical fabric of Havana. The US embargo will end eventually, and American tourists may one day be able to travel to Cuba as quickly and easily as their comrades a century earlier. If this project can provide any insight, the public spaces of Havana may once again become classified and divided by their accessibility to tourists, and consequently reimagined and repurposed to serve the desires of tourists over Cubans.

## Footnotes

1. Dennis Merrill, *Negotiating Paradise: US Tourism and Empire in Twentieth-Century Latin America*, (Chapel Hill: UNC Press, 2009), 4.
2. Louis A. Pérez, Jr., *Cuba: Between Reform and Revolution*, (New York: Oxford University Press, 2011), 236.
3. Anton Rosenthal, "Spectacle, Fear, and Protest: A Guide to the History of Urban Public Space in Latin America", *Social Science History* 24, no. 1 (2000), 46.
4. Marial Iglesias Utset, *A Cultural History of Cuba During the U.S. Occupation, 1898-1902*, (Chapel Hill: University of North Carolina Press, 2011), 5.
5. Eric G. E. Zuelow, *A History of Modern Tourism*, (New York: Palgrave, 2015), 9. Zuelow is Associate Professor of History at the University of New England, and studies tourism as it relates to national identity.
6. Rudy Koshar, "'What Ought to Be Seen': Tourists' Guidebooks and National Identities in Modern Germany and Europe.", *Journal of Contemporary History* 33, no. 3 (1998): 323-40, 325.
7. Zuelow, *A History of Modern Tourism*, 76.
8. Koshar, "What Ought to Be Seen", 325.
9. Richard Henry Dana Jr., *To Cuba and Back: A Vacation Voyage*, (Boston: Ticknor and Fields, 1859), dedication page.
10. Reau Campbell, *Around the Corner to Cuba*, (New York: C. G. Crawford, 1889).
11. Robert Thomas Hill, *Cuba and Porto Rico, With the Other Islands of the West Indies; Their Topography, Climate, Flora, Products, Industries, Cities, People, Political Conditions, etc.*, (New York: The Century co., 1898).
12. Thomas Philip Terry, *Terry's Guide to Cuba, including the Isle of Pines, with a chapter on the airways and the ocean routes to the island; a handbook for travelers, with 3 specially drawn maps and 7 plans*, revised edition, (Boston: Houghton-Mifflin, 1929), iii.
13. Terry, *Terry's Guide to Cuba*, 204. Terry's guide claimed to be the best resource for this new flow of tourists because it updates regularly, out of recognition that, "Cuba is progressing so rapidly that a guidebook which is not changed frequently will quickly become obsolete." (v) Thus, it is cyclical when the nation that drives Cuba's modernization is the same one that produces the tourists and the guidebooks.
14. According to Campbell, any ship not flying the Spanish flag was prohibited from entering the port during the day, and restricted to entering at dawn and dusk.
15. Dana Jr., *To Cuba and Back*, 29.
16. Alejandro de la Fuente, *Havana and the Atlantic in the Sixteenth Century*, (Chapel Hill: University of North Carolina Press, 2008), 71. From atop El Morro is was possible to see any approaching ships, friend or foe.
17. Campbell, *Around the Corner to Cuba*, 18, 19.
18. Hill, *Cuba and Porto Rico*, 108.
19. Terry, *Terry's Guide to Cuba,* 203.
20. Ibid., 204.
21. Robert H. Holden and Eric Zolov, *Latin America and the United States: A Documentary History*, (New York: Oxford University Press, 2000), 63.
22. Ibid., 63.
23. Beyond tourist metaphors, Malecón translates as 'embankment'.
24. Hill, *Cuba and Porto Rico*, 109, 110.
25. Ibid., 6.
26. Terry, *Terry's Guide to Cuba*, 299.
27. Ibid., 191.
28. Eleanor Early, *Ports of the Sun: a Guide to the Caribbean, Bermuda, Nassau, Havana, and Panama*, (Boston: Houghton-Mifflin, 1937), 286.
29. Consuelo Kamholz Hermer and Marjorie May, *Havana Manaña*, (New York: Random House, 1941), 46.
30. Early, *Ports of the Sun*, 290.
31. Erna Fergusson, *Cuba*, (New York: Knopf, 1946), 5.
32. W. Adolphe Roberts, *Havana: Portrait of a City*, (New York: Coward-McCann, 1953), 153.
33. The word 'prado' refers to a central promenade, and is a typical feature of Spanish cities (i.e there is a Prado in Madrid). In the Cuban sense there is a linguistic conflict over whether a person referred to the street by its proper name, which changed over time, or simply as 'El Prado'.
34. Many street names in Centro and Habana Vieja were changed after emancipation from Spain, most of them named after mambise leaders, like Martí.
35. See Figure 1.
36. Dana, *To Cuba and Back*, 37, 38. The Puerta was one of several gates allowing passage through the walls.
37. Ibid., 44.
38. Campbell, *Around the Corner to Cuba*, 11.
39. Hill, *Cuba and Porto Rico*, 112.
40. Ibid.
41. A French landscape architect famous for curating the promenades in Paris, Forestier also influenced the ideals of the International Congresses of Modern Architecture (CIAM).
42. Timothy Hyde, *Constitutional Modernism: Architecture and Civil Society in Cuba, 1933-1959*, (Minneapolis: University of Minnesota Press, 2013), 120.
43. Terry, *Terry's Guide to Cuba*, 112.
44. Hermer and May, *Havana Manaña*, 96.
45. Fergusson, *Cuba*, 7. The question of preservation of Cuban urban historic sites is one that persists today.
46. Roberts, *Havana: Portrait of a City*, 6.
47. José A. Gelabert-Navia, "American Architects in Cuba: 1900-1930", *The Journal of Decorative and Propaganda Arts* 22 (1996): 133-49. Gelabert-Navia gives a specific example of the Marqueses de Avilés, who commissioned American architect Thomas Hastings to build their palaces in downtown Vedado.
48. Dana, *To Cuba and Back*, 55.
49. Ibid., 56.
50. Campbell, *Around the Corner to Cuba,* 17.
51. Hill, *Cuba and Porto Rico*, 112.
52. At no point are any of the guidebook authors in either period clear on whether or not Columbus was actually ever interred in the Colón Cathedral. The story goes that after the end of Spanish rule, the withdrawing Spanish government took the body of Columbus back with them to Spain, making the famous site in the Cathedral, whether real or not, into the 'former site of Columbus' body.'
53. Hermer and May, *Havana Manaña*, 97.
54. Ibid., 129.
55. Fergusson, *Cuba*, 5. The daiquiri is important symbolically as being a quintessentially Cuban cocktail. Thus the example of Cubans giving away free daiquiris to tourists seeking 'authentic Cuban experience' can be seen as a strategy of disseminating a piece of Cuban identity.
56. Roberts, *Havana: Portrait of a City*, 162.
57. It should be noted that all Spanish colonial cities featured a plaza de armas as the center of civic and military authority. The physical form and function is not unique to Havana or Cuba, it is how the form and function of Havana's Plaza de Armas became cemented in Republic period tourists' imaginations and guidebooks that is important.
58. Dana, *To Cuba and Back*, 48. A performance of military music by the colonial military band.
59. Terry, *Terry's Guide to Cuba*, 253.
60. Dana, *To Cuba and Back*, 171.
61. Campbell, *Around the Corner to Cuba*, 30.
62. See note 17.
63. Hill, *Cuba and Porto Rico*, 108.
64. Utset, *A Cultural History of Cuba*, 3.
65. Hezekiah Butterworth, *South America; A Popular Illustrated History of the South American Republics, Cuba, and Panama*, (New York: Doubleday, Page, & Company, 1904), vii.
66. See Anton Rosenthal, "The Arrival of the Electric Streetcar and the Conflict over Progress in Early Twentieth-Century Montevideo", *Journal of Latin American Studies* 27, no. 2 (1995): 319-41.
67. Terry, *Terry's Guide*, 22. It seems intuitive that grand Havana hotels such as the Hotel Nacional should rank among the grand American hotels, considering that they were constructed by the American firms McKim, Mead and White, and Purdy Henderson Company.
68. Ibid., 36.
69. Ibid.
70. Early, *Ports of the Sun*, 300.
71. Ibid., 302.
72. Hermer and May, *Havana Manaña*, 13.
73. Fergusson, *Cuba*, 9.
74. Fergusson stated that because Cuba "…remained dependent some eighty years longer than most of Spain's American empire...", Cuba suffered from a "colonial complex." *Cuba*, 118, 119.
75. Ibid., 7.
76. Ibid., 134.
77. Roberts, *Havana: Portrait of a City*, 158.
78. Ibid., 155.
79. James R. Curtis. (1993). *Havana - Havana's Parque Coppelia: Public Space Traditions in Socialist Cuba.* Places, 8(3). Coppelia is the Cuban ice cream national brand name, and the Parque is named after the brand.
80. Ibid., 65.
81. Ibid., 67.

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# *Nasonia* Venom Research

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The venom of *Nasonia vitripennis*, a parasitic wasp, has been found to induce developmental arrest, changes in gene expressions, and metabolic cascades in Sarcophaga bullata fly hosts. Yet the venom itself, a cocktail of proteins and small molecules, has not been fully characterized. In this research, I investigated the proteins and small molecules in *Nasonia vitripennis* venom. Total venom was compared to multiple RNAi venom protein knockdown samples via protein gel electrophoresis to identify the functional size of individual novel venom proteins. In particular, venom Y protein, one of the most highly expressed venom proteins, was found to be post-transcriptionally processed and shown to contain a peptide motif that is conserved among related but diverging venom proteins. Size fractionation of *Nasonia vitripennis* venom was performed using 3 kDa filters to separate small molecule components from large protein components. By injecting different fractions into hosts, the large protein components were found to be sufficient for inducing developmental arrest in the fly. In prior results, small polar molecule(s) from *Nasonia vitripennis* venom were implicated in venom-induced sorbitol elevation in both fly hosts and human renal cells. Since sorbitol accumulation is one of the major causes of cellular damage in diabetes, identifying the sorbitol-elevating small molecule and understanding its mechanism could provide valuable therapeutic and pharmaceutical insights. In collaboration with Kyle Rugg and Dr. Robert K. Boeckman (UR Chemists), the small molecule fraction was analyzed using mass spectrometry. Unfortunately, size fractionation failed to separate the small molecule of interest; hence, the molecule of interest has not yet been identified.

## INTRODUCTION

*Nasonia vitripennis* (*N. vitripennis*) is a parasitic wasp that injects venom into its insect hosts to manipulate host physiology, arrest development, and utilize the envenomated host as an improved environment and food source for the offspring.[1,2,3] *N. vitripennis* is a model parasitoid[4] with at least 79 venom proteins.[5]. Yet, *N. vitripennis* venom is not well characterized. Based on previous research, venom of *N. vitripennis* induces changes in gene expression levels[6] and manipulates host metabolism[7] when comparing envenomated and normally developing hosts. Surprisingly, *N. vitripennis* venom induces sorbitol elevation in both fly hosts[7] and in human renal cells, most likely by changing the non-canonical aldo-keto reductase (AKR1C).[8] Sorbitol elevation is a cause of diabetes complications, such as loss of eyesight, nerve damage, and kidney failure in type II diabetic patients. Through Siebert's previous analysis, this effect is believed to be caused by a small polar molecule within the *N. vitripennis* venom.[9] In this study, I attempted to separate the small molecule of interest from full *N. vitripennis* venom using 3 kDa filters coupled with the mass spectrometry analysis of the filtration samples. Unfortunately, I failed to find consistent results indicating the proper separations of venom components. To further study novel venom proteins, I used RNA interference with knocked-down novel venom protein and found that most of the venom proteins were post-transcriptionally modified. In particular, I closely examined venom Y, one of the most highly expressed venom proteins in *N. vitripennis*,[10] and confirmed its post-transcriptional processing which shortened the protein from a predicted size of 11.4 kDa to a functional size of 5.5 kDa.

## BACKGROUND

### *General Venom System, Parasitic Venom, and Their Potential Use in Drug Design*

Venoms of many species are cocktails of proteins and other natural products, giving rise to great potential pharmaceutical and therapeutic uses.[11] Small molecules within venoms have been a major focus for developing pharmaceutical products and research tools.[12] For example, snake venoms contain numerous small molecules and peptides/proteins, displaying various bioactivities such as neurotoxic, cytotoxic, cardiotoxic, myotoxic, and different enzymatic activities.[13] Fatal snake venom toxins raise significant health issues but also have profound potential as diagnostic tools, therapeutic agents, or drug leads with anti-tumor, anti-microbial, anti-coagulating, and analgesic activities. A similar application has recently been found in the cone snail whose venom peptides, which facilitate the capture of prey by inducing rapid hypoglycemic shock, are similar to human insulin.[14] Such small insulin-like peptides can bind to human insulin receptors with a greater affinity than human insulins can and activate receptor signaling, potentially impacting the design of therapeutic insulins.

Parasitic wasps, both endoparasitic and ectoparasitic, utilize hosts during reproduction to provide suitable environments for their offspring. Endoparasitic wasps lay their eggs within their hosts, whereas ectoparasitc wasps lay their eggs on their hosts. *N. vitripennis* is an ectoparasitic wasp that injects its venoms into the fly hosts through the ovipositor before the flies lay their eggs.[15,16,5] The eggs are laid on the envenomated hosts between the puparial wall and the surface of the fly pupae. The developing larvae consume the hosts as sources of nutrition until pupation and emergence, ultimately resulting in the death of the hosts. Although the primary purpose of the parasitic venom system is to manipulate the physiology, development, and immunity of the hosts,[3] venoms of parasitic wasps also exhibit potential pharmaceutical and therapeutic use. Venom serine proteases with potent anticoagulant effects from wasps (including *N. vitripennis*) and bees can inhibit platelet aggregation and degrade the β-chain of fibrinogen.[17,5,18] promoting a potential treatment for thrombotic disorders.

### *N. Vitripennis Venom Induces Pheotypic, Gene Expression and Metabolic Changes in Fly Hosts*

*N. vitripennis* has been broadly used as a model for biological study.[4,19] The venom of *N. vitripennis* has been found to cause developmental arrest of envenomated hosts,[1] including the failure of eye pigment deposition, body bristle formation, and melanization in the cuticle.[2] Despite the obvious phenotypic differences between envenomated hosts compared with normally developing hosts, changes in gene expression were also found via high-throughput RNA sequencing.[6] Overall, 1217 genes were differentially expressed between normally developing and envenomated hosts. Most of these genes showed dramatic and sudden changes in expressions between 36 hours to 72 hours post-envenomation. After 36h, genes associated with normal development were not upregulated in envenomated hosts compared to normally developing genes. Between 72h and 120h post-envenomation, a sudden 55% upregulation of developmental arrest-associated genes occurred in normally developing hosts, but not in envenomated flies. In 72h envenomated hosts, expression of cuticular protein genes had some of the largest decreases, with ten transcripts ranging from 100-fold to 2072-fold decreases compared to normally developing flies. In contrast, there was a strong upregulation of *enhancer of split* complex genes between 4h and 72h in envenomated hosts compared to normally developing hosts, indicating a potential molecular mechanism of apoptosis of neural cells and developmental arrest (Figure 1).[6] These typical gene expression changes
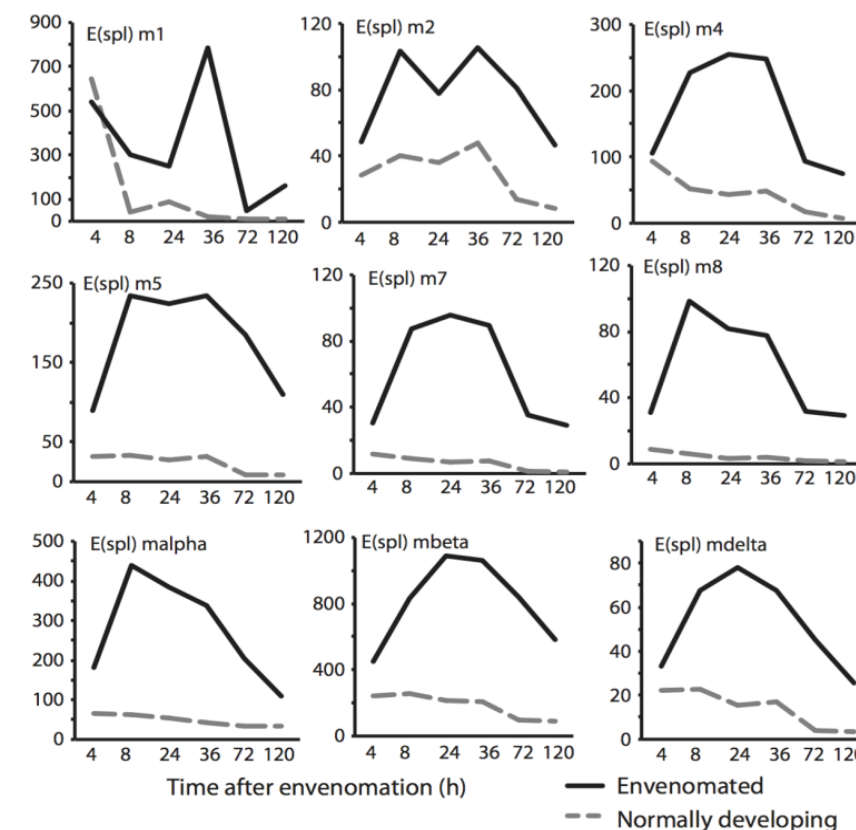


**Figure 1**: Differential gene expression of *enhancer of split* of envenomated (solid line) and normally developing hosts.[6]

induced by *N. vitripennis* venom can serve as biomarkers to quantitatively analyze host developmental stages using PCR. By standardizing host developmental stages, researchers can better measure the developmental changes instead of subjectively observing phenotypic changes of envenomated hosts, thus avoiding huge variances among the observers.

The venom of *N. vitripennis* has also been found to induce metabolic cascades in fly hosts, keeping the host alive for at least five days after the envenomation of fly hosts.[7] The *N. vitripennis* venom causes depression in respiration,[2] suppresses the host immune response,[20,21] targets the sugar metabolism, glycolysis, phospholipid degradation, carbohydrate metabolism, and amino acid metabolism,[7] and triggers the hosts to change into a similar stage as cold treatment, diapause and hypoxia.[2,22,7]

### *N. Vitripennis Venom Induces Sorbitol Elevation in Fly Hosts and Human Renal Cells*

One of the outstanding metabolic effects of *N. vitripennis* venom is its ability to activate the sorbitol pathway under stable glucose conditions in both envenomated flies[7] and human renal mesangial cells (HRMCs).[8] By venom component separation using high-performance liquid chromatography (HPLC) and testing each fraction for sorbitol elevation, a highly polar small molecule (small peptide or chemical) was implicated as the responsible compound.[9]

Sorbitol is a 6-carbon sugar alcohol and is considered a major cause of diabetic microvascular damages in insulin-independent tissues (like kidney, retinal, and nerve systems) once accumulated in humans.[23] In humans, sorbitol is synthesized through the sorbitol pathway, where glucose is converted into sorbitol and then to fructose. Aldose reductase (AR) is the first and rate-controlling enzyme in the pathway, transferring glucose and NADPH into sorbitol and NADP+. Sorbitol dehydrogenase (SDH) is then converted into sorbitol and

NAD+ into fructose and NADH.[24] Since AR has a low affinity for glucose (high Km) in the human body, the proportion of glucose transformed into sorbitol is small in normal human cells. However, in a hyperglycemic condition, the high intracellular glucose level results in an increase of the enzymatic conversion of sorbitol and a decrease of the NADPH

wasps, adult females of *N. vitripennis* and *N. giraulti* (1-2 days after emergence) were exposed to *S. bullata* pupae (3 females per tube with 3 host pupae) for 48 hours in cotton-plugged glass vials at 25°C (Rearing of *S. bullata* was as per Werren and Loehlin 2009b).[19] After 48 hours, the fly hosts were removed. The adult females were put on ice to limit their

*"Sorbitol is considered a major cause of diabetic microvascular damage in insulin-independent tissues once accumulated in humans."*

in insulin-independent tissues in humans [25]. Consequently, the consumption of NADPH by AR causes inhibition of antioxidant capacity and glutathione peroxidase activity. Such sorbitol accumulation also induces osmotic stress, damages proteins via oxidations, and affects ATP synthesis by providing the mitochondrial electron transport chain with excess NADPH.[23] Since the gene sets in sorbitol synthesis are highly conserved between humans and flies, research was done in both HRMCs and fly hosts.[8]

By giving HRMCs a low dosage of venom from *N. vitripennis*, Siebert[8] found that total venom induces sorbitol elevation without changing the levels of glucose and fructose. An upregulation of the non-canonical aldo-keto reductase (AKR1C*) family in envenomated cells was also found after envenomation or high glucose levels, suggesting the roles of AKR1C* in sorbitol pathway regulation. Venom from *N. vitripennis* uncouples sorbitol elevation from hyperglycemia and therefore potentially provides new insights into the mechanisms and pathological impacts of sorbitol elevation in human cells.[8] To reveal the small molecule of interest, I attempted to develop a size-fractionation method using 3 kDa filters to separate the small molecule components from the large venom components.

**Methods**
*Venom Sample Collection and Venom Sample Preparation*
To collect venom samples from Nasonia

activities. Venom reservoirs of the adult females were then collected on 1X PBS by venom dissection and stored on dry ice during dissection. If not processed immediately, venom samples were then stored under -80 °C. The concentration of the venom samples was one venom reservoir per 1 µL of 1X PBS or 1 µL of UltraPure Water. The venom samples were centrifuged at 12,000g for 15 minutes under 4 °C to release the venom components from the reservoir. The samples were then filtered through 0.22 µm filters to remove the membrane and bacteria with centrifugation at 12,000g for 4 minutes under 4 °C. The processed venom proteins were stored in -80 °C in between experiments.

*Venom Protein Quantification Using BCA Assay and Mass Estimates*
To better characterize the venom proteins and the overall mass, venom protein estimates and mass estimates were done. 175 venom reservoirs were collected and processed using the above procedures, making venom samples with 1 venom reservoir equivalent (VRE). 100 µL of such samples were added into a pre-tired 0.65 µL, followed by a 6-hour lyophilization on a Labconco FreeZone freeze-drying apparatus using a belt-driven oil vacuum pump to remove all the solvent (i.e. water). The sample was then weighed on the same microbalance, and the mass of 100 venom reservoirs was recorded by Rugg, a chemist at the University of Rochester.

The venom protein concentration is estimated using the PierceTM BCA Protein Assay Kit (Thermo Scientific). This assay allows total colorimetric detection and quantitation of total venom protein. Considering our small sample size, the assay was done based on the microplate procedure. 25 µL of each standard or venom sample with 1 VRE replicate were added into a 96-well plate. 200 µL of the working reagent, which contains BCA reagents A and BCA reagents B from the kit, was added into each well, followed by thorough shaking for 30 seconds. The plate was then covered and incubated at 37 °C for 30 minutes. After incubation, the plate was cooled to room temperature, and the absorbance of each well was measured at 562nm on a plate reader.

*Knockdown of Nasonia Vitripennis Larvae with RNA Interference*
RNA interference has been shown to effectively knockdown gene expressions in *N. vitripennis*.[19] Here, RNAi was used to knockdown the most abundant venom proteins including venom V, X, Y, and Z in *N. vitripennis*. Non-virgin *N. vitripennis* females were hosted with *S. bullata* pupae and kept at 25 °C for 6 days. After hosting, the hosts were carefully opened, and the larvae of *N. vitripennis* were collected and kept on 1X PBS plates (100 larvae per plates) during and after dsRNA injection.[26] *N. vitripennis* venom dsRNA was synthesized by Edwards from genomic DNA using the MEGAScript RNAi Kit [Life Technologies, Grand Island NY], according to the manufacturer protocol. Complementary dsRNA at a final concentration of 0.36 g/µL in ddH2O with 0.5 µL of green food coloring per 10 µL dsRNA solution was loaded into a capillary needle using microloader pipette tips. The filled needle was mounted in a microinjection pump for injections. dsRNA targeting venom V, X, Y, Z proteins were injected at the posterior end of the larvae.[26] Control wasps were injected with dsRNA complementary to the E. coli LacZ gene, since the *N. vitripennis* genome lacks a Lac operon. An additional plate of 100 larvae was collected as a control for uninjected samples. The larvae continued to develop on the 1X PBS plates at 25 °C. When
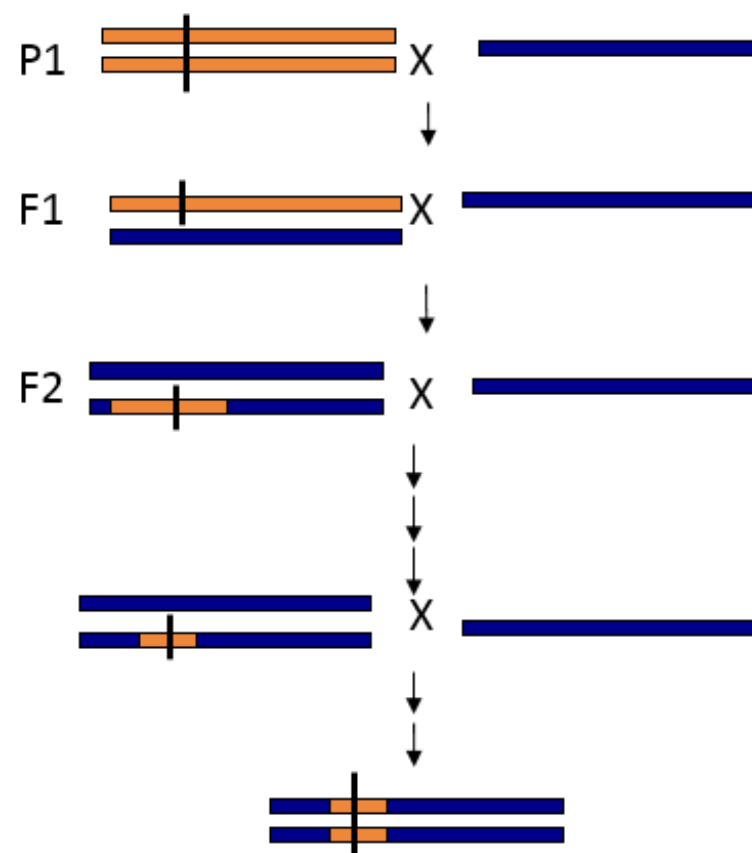


Figure 2: Process of generating a venom Y introgression line by Doucette. *N. vitripennis* male (diploid, navy) was first crossed with a *N. giraulti* female (haploid, orange) to generate F1. F1 was then crossed with *N. vitripennis* male.Due to recombination, regions in *N. vitripennis* chromosome will be replaced by homologous regions from *N. giraulti*. PCR was used to select the venom Y replaced offspring. F2 containing *N. giraulti* venom Y homologous region was then back-crossed with *N. vitripennis* to refine the recombination region. After multiple generations of crossing, the venom Y region of *N. vitripennis* is replaced and is refined. Finally, homozygous femalers were generated to be venom Y introgression line.

the injected larvae were developed to the second or third pupae stage, the *N. vitripennis* pupae were transferred into cotton-plugged glass vials and continued to develop at 25 °C. After the enclosure of the injected *N. vitripennis*, females were exposed to fresh *S. bullata* pupae for 48 hours and venoms were collected following the protocol for venom sample collection and venom sample preparation as described above. The collected venom samples were analyzed using venom protein gels to confirm the knockdown at the protein level. In addition, such dsRNA knockdown was confirmed in RNA level by Edwards. All venom samples were stored at -80 °C between experiments.

*Venom Y Introgression Line Generation*
As an alternative way to study venom Y

protein - one of the most highly expressed venom proteins in *N. vitripennis*[10] - a venom Y introgression line was generated to knockout venom Y protein.[27] Within the venom Y introgression line, the venom Y region of *N. vitripennis* was replaced by the homologous region in *Nasonia giraulti* (*N. giraulti*), a sister species of *N. vitripennis* that does not produce venom Y protein. A *N. vitripennis* female was crossed with a *N. giraulti* male. The F1 generation was then back-crossed with *N. vitripennis*. PCR with primers targeting multiple genes was used to monitor the size of the recombination region and confirm the replacement of the venom Y region. The F1 offspring with the venom Y region replaced was then back-crossed with *N. vitripennis* to refine the recombination region. After multiple generations of back-crossing,

the offspring with the recombination region only near venom Y were crossed with themselves to generate homozygous wasps (Figure. 2). Confirmed by PCR,[28] the venom Y introgression line has a venom Y region of *N. vitripennis* with the venom Y homologous region of *N. giraulti*. The resulting introgression line was tested using venom protein gel to check for the presence of the venom Y protein.

*Venom Protein Gels*
To study the venom protein components and identify the knockdown venom proteins, a 1D protein gel was performed with lightened bands indicating the targeted knockdown proteins. Collected venoms of double stranded RNA knockdown of *N. vitripennis* in Venom X, Venom Y, Venom Z, Venom V, Metalloproteinase (Met), GT/GC, hypothetical protein, LacZ (control), and uninjected *N. vitripennis* (control) were used for protein gel analysis. Additionally, *N. giraulti*, a species closely related to *N. vitripennis* that does not have venom Y homologous genes, and a venom Y introgression line that was created by replacing the venom Y region in the *N. vitripennis* genome with the homologous region of *N. giraulti*, were run on the gel to further study venom Y protein. 5 µL of each venom sample were thoroughly mixed with 5 µL of NuPAGE® LDS Sample Buffer (4X) and 2 µL of NuPAGE® Reducing Agent (10X), producing total volume of 12 µL for all venom samples. Then, venom samples were heated at 70 °C for 10 minutes to completely reduce disulfide bonds in the proteins. XCell SureLock® was used and both Upper (200 mL) Buffer Chamber and Lower (600 mL) Buffer Chamber were filled with 1X Buffer of 50 mL 20X NuPAGE® MES Running Buffer mixed with 950 mL UltraPure water and 500 µL of NuPAGE® Antioxidant in the Upper Buffer Chamber. Venom samples were loaded onto the gel using pipette tips. Page Ruler Low Range Unstained Protein Ladder was used as a standard on the leftmost column . The gel was run at 200 V constant voltage, 80 mA/gel (start) and 60-80 mA/gel (end) using a power supply for approximately one hour and 15 minutes. The gel was then removed from

the chambers and fix of 50% ethanol, 7% acetic acid and dH2O was added to cover the gel and microwaved for 1 minute. Stain/Destain containing 5% ethanol, 7.5% acetic acid and dH2O was added to the gel along with 1.5 mL of Coomassie Blue Stain. The gel was left on a shaker overnight, and a picture of the gel was taken after.

*Venom Y Peptide Sequencing*

To confirm the introgression in the venom Y introgression line, and hence to further study venom Y, the band of venom Y on the protein gel was cut and submitted for peptide sequencing at the Mass Spectrometry Resources Laboratory at the University of Rochester. The venom protein gel was run based on the protocol discussed above. After staining and destaining the gel with Coomassie Blue Stain, the band of venom Y protein from N. vitripennis was cut out from the gel and diced into small pieces by Welle from the Mass Spectrometry Resources Laboratory at the University of Rochester to sequence venom Y protein (protocol provided by K. Welle). Those pieces were then placed in a Lobin tube, and 100 µL of 50 mM Ammonium Bicarbonate were added into the tube. After shaking for 10 minutes, the supernatant was removed. An additional 100 µL of 25 mM Ammonium Bicarbonate in 50% Acetonitrile were added, followed by proper shaking for 10 minutes and removal of the supernatant. This step was then repeated once more. The resulting sample was rinsed with 100 µL of 100% Acetonitrile for 5 minutes while shaking, followed by removal of the supernatant. The processed gel pieces were then placed in Speed Vac for 5 minutes. 5 µL of 10 mM DTT in 50 mM Ammonium Bicarbonate were added to the sample to completely cover the gel pieces, followed by an incubation in 55 °C sand bath for 1 hour. After removing the supernatant, 100 µL of 50 mM IAA in 50 mM Ammonium Bicarbonate were added to completely cover the gel piece, followed by incubation in the dark for 30 minutes. The supernatant was then removed. The sample was rinsed with 100 µL of 25 mM Ammonium Bicarbonate and shaken for 10 minutes. After removal of the supernatant, the sample was rinsed with 100 µL of 25 mM Ammonium Bicarbonate with 50% ACN and shaken for 10 minutes. The resulting supernatant was then removed, and the resulting sample was rinsed with 100 µL of 100% Acetonitrile and shaken for 5 minutes. After drying down in Speed Vac for 5 minutes, the gel pieces were mixed with a minimal amount of trypsin aliquot (10ng/µL with 50 mM Ammonium Bicarbonate) and were left at room temperature for 1 hour for rehydration. The sample was then incubated at 38 °C overnight. The resulting supernatant was transferred into a clean 0.5 mL Lobind Tube, followed by an addition of 50% CAN or 0.1% TFA to cover the gel. After 25 minutes of shaking, the supernatant was extracted and pooled with previously extracted supernatant. Then 50 µL of 100% ACN were added with 1 minute shaking. The resulting supernatant was pooled with the extracted supernatant. The pooled extract was then frozen and dried for Mass Spectrometry analysis. After digestion, the sample was desalted with a C18 column. The desalted sample was then injected onto the Q Exactive Plus mass spectrometry, operating in data dependent mode, to generate reads of peptide sequences. Then, the data was blasted against a customized database containing Nasonia transcriptome data. Hence, the digested peptides within the venom Y were mapped back onto the transcripts and to the N. vitripennis genome. The posttranscriptional processed sequence of venom Y was identified.

*Size Fractionation of N. Vitripennis Proteins Using 3 KDA Filters*

In an attempt to separate the small molecule component from the large venom protein component, venom samples were further filtered through 3 kDa filtration [Merck Millipore]. Each filter was pre-rinsed twice using 100 µl UltraPure Water followed by centrifugation at 14,000g for 30 minutes at 4 °C. 100 µl of venom samples were added into each filter, whereas 100 µL of UltraPure Water were used for the control. Both the venom sample filtration and the control were run in replicates of two. Samples were then centrifuged at 14,000g for 30 minutes at 4 °C. Filtrates were individually transferred into 1.7mL Eppendorf tubes. In addition, 100 µL of UltraPure Water were added into each filter followed by centrifugation at 14,000g for 30 minutes at 4 °C, to rinse the filter and hence to collect more materials. The rinses were transferred into new 1.7ml Eppendorf tubes individually and were then collected. To collect the concentrate of the fractions that did not go through the filters, the filters were flipped and centrifuged at 1,000g for 2 minutes at 4 °C. All samples were stored at -80 °C before further analysis.

During the process of method development, glycerol contamination from the filters was found to be a problem for our experiment. In order to eliminate the glycerol contaminant, excessive pre-rinsing of up to 6 rinses with 100 µL UltraPure Water was performed prior to the filtration of venom samples. However, the excessive pre-rinsing seemed to prevent proper filtration of the venom sample. Hence, we decided not to incorporate it into our protocol.

*Mass Spectrometry Analysis of Different Venom Fractions*

To identify the small molecule of interest, different fractions of venom samples generated from the filtration were lyophilized and reconstituted for Mass Spectrometry analysis. An initial low-resolution mass spectra were acquired on a Thermo Scientific LTQ Velos Ion Trap liquid chromatography-mass spectrometry (LC-MS) under both electrospray ionization (ESI) in positive and negative modes (by Kyle Rugg and Robert Boeckman at Department of Chemistry, University of Rochester). After this initial mass spectrometry analysis, high-resolution mass spectra at University of Illinois at Urbana-Champaign (UIUC) were acquired on a Wasters Q-TOF Ultima mass spectrometer in electrospray (ESI) positive ionization mode. The resulting peak numbers in each spectrum were then inputted into an Excel spreadsheet, sorted, and aligned to look for peaks of interest.

*Injection of S. Bullata Pupae With Different Venom Fractions and Serial Diluted from Venom*

To analyze the effect of venom samples on host development, filtered venom samples and serially diluted full venom samples were injected into S. bullata pupae to test for developmental phenotypes. Full venom samples were diluted to 1:1, 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, and 1:128 VRE using 1X PBS as buffer. 5 µL of each venom samples were then mixed with green food dye thoroughly to help visualize the injection. The anterior ends of the fresh S. bullata puparial wall were removed and placed on a PCR plate. The venom samples were stored on ice during the injection. Approximately 2 µL of each venom sample were loaded onto the capillary needles with pipettes and injected equally into the anterior ends of 10 fly pupae. Additional injections with 1X PBS were conducted as controls, along with uninjected, needle-poked, and cool-killed host pupae. For each set of injections, 10 host pupae were used. Photos were taken daily after day 1 to record the phenotypic developmental changes of the hosts.

## RESULTS
*The Venom Protein Components Inducing Host Developmental Arrest*

To study the developmental arrest effect of serial diluted N. vitripennis venoms, total venom samples were diluted to 1:1, 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, and 1:128 VRE and injected into hosts with ten replicates for each dose. Since the approximate protein concentration of one VRE is 600 µg, roughly 120 µg, 60 µg, 30 µg, 15 µg, 7.5 µg, 3.75 µg, 1.875 µg, and 0.94 µg of total venom proteins were injected into the fly hosts respectively. By subjectively identifying developmental phenotypes, like eye pigmentation and bristle formation of each envenomated host, hosts with 120 µg and 60 µg showed developmental arrests. Hosts with 30 µg,15 µg, and 7.5 µg total venom proteins seemed to experience developmental delay. Hosts with 3.75 µg, 1.875 µg, and 0.94 µg showed no developmental arrest phenotypes, suggesting that the induced developmental delay or arrest was related to the quantity of venom proteins present in the envenomated hosts (Table 1).

Size-fractionated venom was used to further study the effect of venom components on host development. 3 kDa size fractionation was performed to separate the protein components (>3kDa) from small molecules within the venom samples. Two fractions generated from the filtrations - concentrate (containing all the protein components) and filtrate (containing the small molecule components)- were injected into the hosts. After observations from day 1 to day 8, the large venom components induced a developmental arrest effect similar to full venom, suggesting that the venom protein components were sufficient to cause arrest (Figure 3). The small molecule components contained no protein and showed no obvious effect on host development.

*Post-transcriptional Modification of Venom Y Protein*

Venom proteins were knocked down using RNA interference. Double-stranded RNA targeting specific venom proteins was injected into N. vitripennis larvae.[19] Venom of each knocked-down N. vitripennis female was then

**Table 1**. Daily observation of the development of injected hosts

| Samples Injected into Each Host | | Day 3 | Day 5 | Day 6 | Day 7 | Day 8 | Dead | Developmental Arrest |
|---|---|---|---|---|---|---|---|---|
| 1 VRE (120 µg) | Eye | | 1 | 1 | 1 | | 0 | 9 |
| | Bristle | | | | | 1 | | |
| 1/2 VRE (60 µg) | Eye | 1 | 1 | 1 | 2 | 1 | 1 | 8 |
| | Bristle | | | | | 1 | | |
| 1/4 VRE (30 µg) | Eye | | 1 | 5 | 6 | 3 | 1 | 6 |
| | Bristle | | | | | 1 | | |
| 1/8 VRE (15 µg) | Eye | | 3 | 10 | 10 | 5 | 0 | 0 |
| | Bristle | | | | | 5 | | |
| 1/16 VRE (7.5 µg) | Eye | 9 | 10 | 10 | 5 | | 0 | 0 |
| | Bristle | | | | | 5 | | |
| 1/32 VRE (3.75 µg) | Eye | 8 | 10 | 10 | 3 | | 0 | 0 |
| | Bristle | | | | | 7 | | |
| 1/64 VRE (1.875 µg) | Eye | 8 | 9 | 10 | 1 | | 0 | 0 |
| | Bristle | | | | | 9 | | |
| 1/128 VRE (0.94 µg) | Eye | 6 | 10 | 10 | 1 | | 0 | 0 |
| | Bristle | | | | | 9 | | |
| Water | Eye | 9 | 10 | 9 | | | 0 | 0 |
| | Bristle | | | | 1 | 10 | | |
| 1xPBS | Eye | 8 | 10 | 10 | 1 | | 0 | 0 |
| | Bristle | | | | | 9 | | |
| 0.5xPBS | Eye | 8 | 10 | 9 | 2 | | 0 | 0 |
| | Bristle | | | | 1 | 8 | | |
| Needle-Poked Hosts | Eye | | 10 | 10 | 10 | | 0 | 0 |
| | Bristle | | | | | 10 | | |
| Anterior Cap Removed Hosts | Eye | 9 | 9 | 8 | 1 | | 0 | 0 |
| | Bristle | | | | 1 | 9 | | |
| Cool Killed Hosts | Eye | | | | | | 10 | 0 |
| | Bristle | | | | | | | |

Table 1: Daily observation of the development of injected hosts. The developmental stages of injected fly hosts and controls were evaluated subjectively. Two major changes-eye pigmentation (Eye) and bristle formation (Bristle)-were evaluated every day. The number of hosts with the described phenotypes was recorded in the table. 10 hosts were injected with each venom sample. Day 1 and day 2 showed no development in all hosts, hence the data is not shown. 1VRE and ½ VRE venom samples induced developmental arrests in hosts. 1/4 VRE, 1/8 VRE, 1/16 VRE induced developmental delay in hosts, evidenced by a relative smaller number of bristle formation on day 8. 1/32 VRE, 1/64 VRE, and 1/128 VRE showed no significant effect in host development. In addition, water, 1xPBS, and 0.5xPBS were injected into hosts as controls for venom samples. Needle-poked, anterior cap removed and cool killed hosts were used as control for the technology.

collected via dissection. The knockdown was confirmed using SDS-PAGE gel. Successful knockdowns showed different banding patterns with absent or significantly lightened bands compared to controls (Figure 4). Interestingly, venom proteins, including Metalloproteinase (Met), venom V, venom Y, and venom Z, were found to have smaller molecular masses compared to predicted sizes derived from transcriptome data.[29]

We then specifically looked at venom Y, one of the most highly expressed venom proteins.[10] A knockdown of venom Y gave a completely missing band around 5 kDa when comparing the venom knockdown to wild type (Figure 4, boxed in green). However, the predicted size of venom Y was 11.4 kDa, whereas the actual venom Y band was 5 kDa, indicating further processing of the protein after transcription. Processed venom Y protein was not found in the venom Y introgression line (Figure 4, boxed in green), where the venom Y gene region in *N. vitripennis* was replaced by its homologous region in *N. giraulti*, which does not have venom Y protein (Figure 5). As a method of knocking-out venom Y, the comparison of the banding patterns between the venom Y introgression line and wild-type *N. vitripennis* further confirmed the functional size of venom Y and its posttranscriptional processing.

With the aim of identifying the processed nucleotide sequence of venom Y, protein sequencing using mass spectrometry was then performed at the URMC Mass Spectrometry Resource Laboratory. Mass spectrometry data showed two unique peptides mapped back to predicted venom Y nucleotide sequences (Figure 6, highlighted in yellow), framing a polypeptide with a molecular weight of 5.55 kDa, which is a close approximation of the size of the venom Y band identified in previous protein gel analysis. These results suggested that the processed venom Y is about 5.55 kDa with the sequence shown in Figure 6. Werren[30] has identified a region in venom Y that is highly conserved in diverse venom proteins characterized by the "FIEN" amino acid sequence. We hypothesized that the conserved "FIEN" region may have significant biological functions. Hence, a future direction of
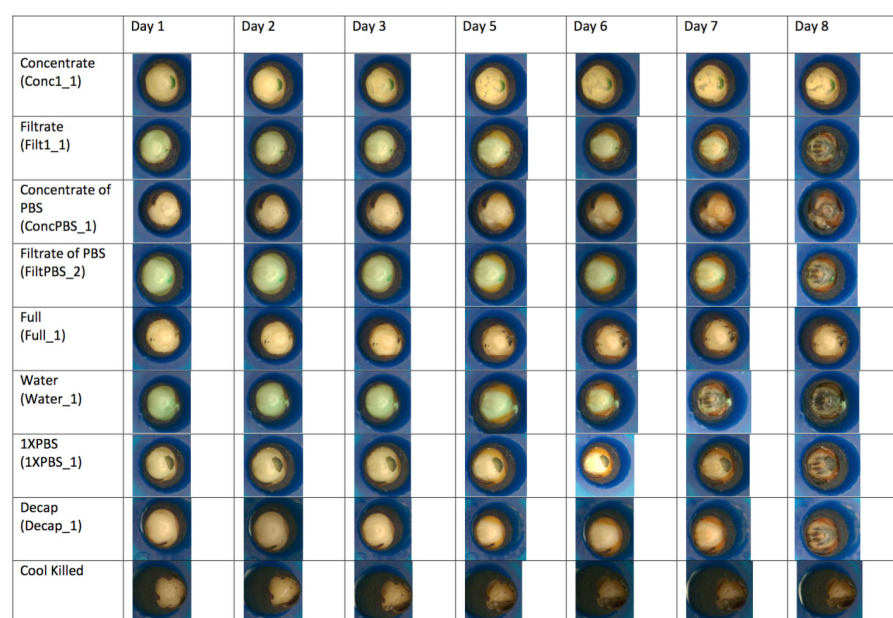


**Figure 3**: Pictures of injected hosts were taken daily to observe the developmental changes. Concentrate of 3kDa filtration and full venom induce developmental arrest.
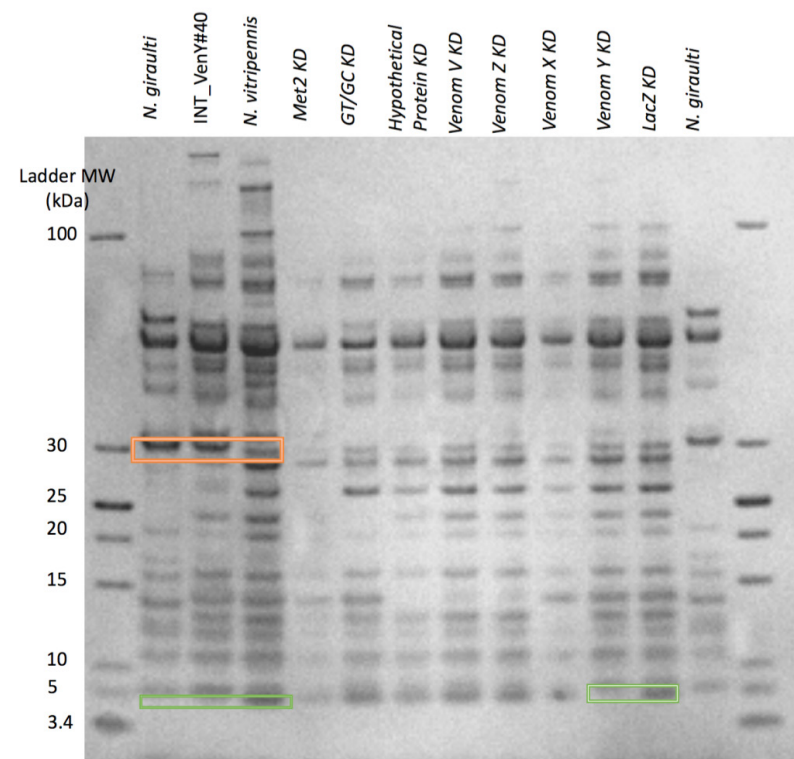


**Figure 4**: SDS PAGE, size separation of venom proteins. Venom Y (green) is the smallest protein visible on the gel, with a molecular weight around 5kDa.

studying venom Y would be focusing on the functionality of the protein.

A 30 kDa venom protein gene seemed to be incorporated into the introgression line along with venom Y gene from *N. giraulti* (Figure 4 boxed in orange). By analyzing the sequencing data of this band and comparing those
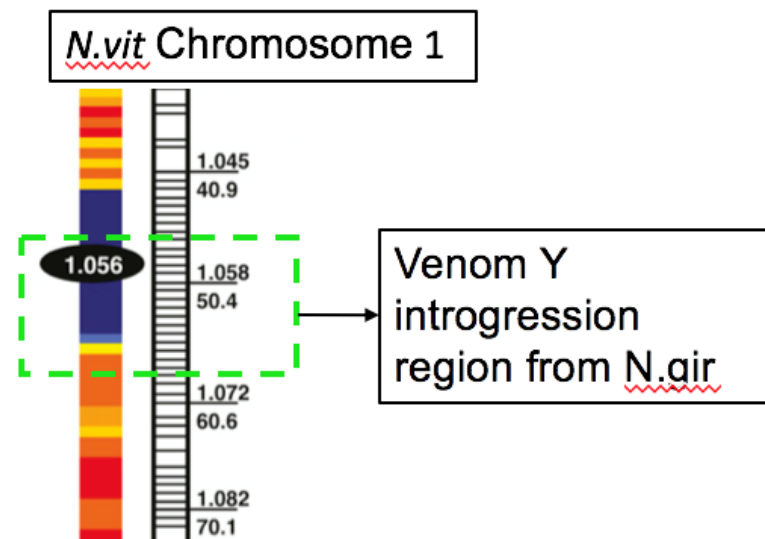


**Figure 5**: An introgression line was created by replacing the venom Y region in the *N. vitripennis* genome with the homologous region from *N. giraulti (N.gir)*, which lacks venom Y.
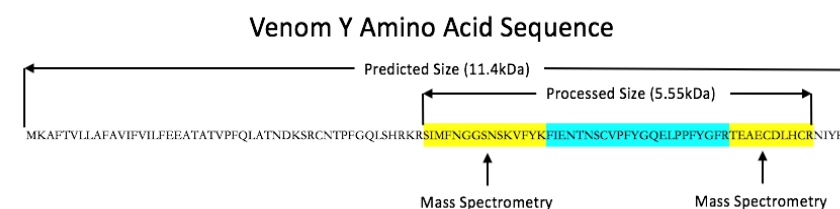


**Figure 6**: Venom Y Amino Acid Sequence, where the predicted size of the protein is 11.4kDa. Mass spectrometry data contains the peptide sequences in yellow, framing a sequence with the size of 5.55kDa, indicating the processed size of venom Y.

sequences to the annotated genome and to venom transcription data of both *N. vitripennis* and *N. giraulti*, my colleague Guo identified several genes that might correspond to the 30 kDa venom protein. Furthermore, he located the genes on the Nasonia chromosomes and found that the majority of those genes were located in the centromere regions of chromosomes 1, 3, and 5.[31] Since the venom Y region is located near the centromere of chromosome 1, this supports our hypothesis that this region is incorporated into the introgression line due to its close proximity to the venom Y gene during recombination.

*Method Development of Size Fractionation: Attempting to Separate the Small Venom*

*Molecule of Interest*

The study of small venom molecules was initiated by Siebert's striking finding[8] that a small and highly polar venom component may cause sorbitol elevations in human renal cells. 82 venom fractions were generated at the University of Utah using HPLC systems followed by C18 columns to separate the venom samples with 125 VRE by both molecular size and polarity. Based on Siebert's preliminary results, fractions 1 through 6, the smallest and the most polar fractions, showed sorbitol elevations in human renal cells. High-resolution mass spectrometry analysis of Siebert's fraction 1 at the UIUC showed no mass over 2,000 m/z, indicating the absence of protein within the samples. Learning that sorbitol

elevation has profound impact in type II diabetic patients, I decided to further study the small molecule of interest. Since a similar venom fractionation method is currently unavailable, I have started the project with method development of venom size fractionation using filters [Merck Millipore].

During the initial stage of method development, 30 kDa filters were first used to test for separation of venom proteins, and then followed by venom protein gel electrophoresis. We were hoping to see different banding patterns between the filtrate (materials that had gone through the filters) and the concentrate (materials that were retained in the filters). Since *N. vitripennis* venom contains proteins from 160 kDa to 5 kDa (Figure 4), size separation at 30 kDa should produce a separation of bands at 30 kDa. However, our initial testing of filtration did not show promising venom component separations due to different concentrations between the filtrate and the concentrate.

Attempting to identify the small molecules responsible for sorbitol elevation, 3 kDa size filtration was done on *N. vitripennis* venom samples. The filtrate was lyophilized and reconstituted for a low-resolution LC-MS. LC-MS under both ESI positive and negative modes was run on the filtrate (by Kyle Rugg and Robert Boeckman in the Department of Chemistry, University of Rochester). The spectrum of the sample contained a hit at 437.5 m/z, suspected to be the small molecule of interest, and an additional hit at 528.6 m/z, suspected to be an adduct of the small molecule and the glycerol. This initial analysis encouraged us to keep developing a filtration method for size fractionation. A 'milder' ionization method (APCI) was also performed on the same sample. Fraction 1 sample with confirmed bioactivity from Siebert [8] was also analyzed. Both samples showed similar peaks of masses, 408 m/z and 426 m/z, where the difference of 18 m/z was probably accounted for the appearance of water. Such similar hits between Siebert's fraction 1 and the filtrate encouraged further investigation using 3 kDa filtration since size fractionation seemed to be able to capture the small molecule of interest and separate it from

large venom components, providing more materials for further analysis.

After 3 kDa size filtration of a *N. vitripennis* venom sample, different fractions were sent to Boeckman lab, University of Rochester, for lyophilization and Liquid Chromatography-Mass Spectrometry (LC-MS) aimed at identifying the chemical structure of the small molecule responsible for sorbitol elevation. However, as mentioned above, glycerol contamination was found in our filtered samples after lyophilization; this was problematic for this experiment since the glycerol retains water molecules during lyophilization, interfering with the mass detection of the small molecule of interest. Nonetheless, glycerol may interact with the small molecules, impacting the bioactivity of the small molecules. According to the manufacturer of the filters [Merck Millipore], the glycerol contamination is common and they proposed using a 0.1N NaOH solution to elimination such contamination. Attempting to eliminate glycerol contamination, 500 μL and 100 μL of 0.1N NaOH as well as just UltraPure Water followed by excessive rinses were used. All rinses were then lyophilized and observed under a microscope, looking for liquid (indicating glycerol contamination) and/or white pellets (indicating NaOH contamination). We found that more than 6 UltraPure water rinses or 100μl of 0.1N NaOH followed by 4 UltraPure water rinses were sufficient to remove glycerol contamination. Hence, we decided to use more than 6 rinses of UltraPure prior to the sample size separation to eliminate glycerol contaminations. The resulting samples were again sent to Beockman Lab, University of Rochester for LC-MS analysis, but unfortunately, no unique peak was identified. Therefore, the excessive rinses eliminating glycerol may change some critical characteristics of the filters that prevent proper filtrations.

To further test the size fractionation sample, the 3 kDa filtration samples with no excessive rinses along with HPLC generated samples (Siebert, unpublished) were sent to UIUC for a high-resolution LC-MS analysis. Peaks that were present within the mass spectrum were recorded into an Excel file. The peaks were aligned among different samples to see whether a peak was present or absent in a particular sample. Three peaks, 629 m/z, 718 m/z and 911 m/z were found in the rinses of the 3 kDa filtration without excessive rinses, as well as in some of the HPLC generated samples that showed biological activity, but they were not present in any of the controls (Table 2). To further confirm such candidates and generate samples with cleaner background, a replication of the filtration was done. However, replicating the experiment showed these two peaks among several venom samples as well as controls. Hence, we did not have enough evidence to conclude that those two peaks were from the venom samples. Due to the inconsistency of the results, size fractionation using filters was considered to be an inefficient way of separating small molecules of interest from large venom components.

## Discussion

*The Venom Protein Component is Sufficient for Inducing Host Developmental Arrest*

After size fractionation of the *N. vitripennis* venom at 3kDa via filtrations, both the concentrate and the filtrate were injected into hosts. Based on high-resolution mass spectrometry analysis from UIUC, no mass above 2000 m/z was identified in the filtrates, indicating a lack of protein components. As a result, the concentrate induced host developmental arrest whereas the filtrate did not. This suggests that the venom protein component is sufficient for inducing host developmental arrest. This also supports the hypothesis that venom manipulates host metabolism directly, for example, via protein-protein interactions6.

In addition, full venom was diluted in a series and injected into hosts. By focusing on developmental features, like eye pigmentation and bristle formation, hosts with 120 μg and 60 μg showed developmental arrests. Hosts with 30 μg,15 μg, and 7.5 μg total venom proteins seemed to experience developmental delay (Table 1). Hosts with 3.75 μg, 1.875 μg, and 0.94 μg showed no developmental arrest phenotypes, suggesting that the induced developmental delay or arrest was related to the amount of venom proteins present in the envenomated hosts.

However, the developmental delay was quantified subjectively. Such bias could be induced during the identification process of host developmental stages. Based on the information of venom-induced host gene expression changes, biomarkers could be designed to standardize the host developmental stages. With the knowledge that a cluster of cuticle genes was not upregulated in envenomated hosts at 36h after envenomation compared to normally developing hosts, primers targeting these cuticle genes will be designed. PCR with these primers followed by DNA gels will reveal the gene expression levels of the cuticle genes. By measuring the cuticle gene expression levels, the host's developmental stages can be well-defined. Thus, by monitoring gene expression levels instead of time after envenomation, we can properly identify developmental delays.

*Venom Y Protein is Post-transcriptionally Processed*

Venom Y knockdown via RNA interference, followed by venom dissection and protein gel electrophoresis, revealed the functional size of the venom Y protein to be approximately 5 kDa. Coupled with MS-based peptide sequencing, the functional sequence of venom Y was found (Figure 5). According to the transcriptome data, venom Y protein was predicted to be 11.4 kDa. However, both the protein gel and the mass spectrometry data indicated that the venom Y protein is 5.5 kDa, suggesting that venom Y protein is post-transcriptionally processed. Particularly, the venom Y peptide sequence deduced from mass spectrometry data showed that venom Y contains an amino acid sequence, characterized by four amino acids "FIEN", that is conserved among multiple functionally diverse venom proteins. Werren first identified this "FIEN" region, suspecting its biological significance. Our data suggests that the "FIEN" exists in venom Y. Therefore, venom Y can be used as a model to further study the functionality of the "FIEN" region. In addition, we confirmed that the 30 kDa band, incorporated along with venom Y from *N. giraulti* into *N. vitripennis* during recombination, is located near the venom Y region at the centromere of chromosome 1.[31]

*Small Molecule Method Development*

Attempting to separate the small molecule components from large protein components in *N. vitripennis* venom, 3 kDa filtrations were done on multiple venom samples followed by high-resolution mass spectrometry (UIUC). Although initial analysis indicated that the filtration separated the small molecules, the lack of consistent evidence among various replicates suggested that filtration is not an efficient method to size fractionate Nasonia venom samples. The shared peaks among both venom samples and controls could be due to the lack of the blanks when running the samples through the mass spectrometry at UIUC. Since mass spectrometry is very sensitive, the leftover molecules from the previous samples could result in overlapping peaks. On the other hand, problems could occur during filtration. Considering the amount of large proteins within the venom, it is possible that the large molecules clog up the filters and therefore prevent the small molecules traveling through the filters. Hence, using filters with larger pore size may be an alternative approach to separate venom components. From his preliminary results, Siebert separated the venom samples based on both polarity and size. Therefore, size may not be a critical parameter for separation. Rather, since the small molecule(s) of interest are highly polar, it may be more efficient to fractionate the venom components based on the polarity.

## Conclusion

In this research, I attempted to separate the small molecule that was predicted to be responsible for inducing sorbitol elevations in both fly hosts and human renal cells by developing a filtration-based method to size-fractionate Nasonia venom. However, by analyzing the mass spectrometry data of the filtered samples, there is no consistent evidence of proper separation. Hence, filtration is not an efficient way of size-fractioning venom samples. On the other hand, using RNAi to knockdown novel proteins and identifying the functional size of venom protein on a protein gel suggested that many venom proteins are post-transcriptionally processed, especially venom Y protein. Venom Y protein is significantly shortened when compared to transcriptome data. A serially diluted venom protein was injected into fly hosts. Full venom and 1/2 diluted venom induced developmental arrest, whereas 1/4, 1/16 and 1/32 diluted venom induced developmental delay, supporting the conclusion that venom induces hosts developmental arrest via protein-protein interactions.

**Table 2**. Summary of the 619, 708, and 911 peaks

| Samples | Peaks of Interest (m/z) | | |
|---|---|---|---|
| Pooled venom filtrate with excessive pre-rinses | 629 | 708 | 911 |
| Pooled H2O control filtrate with excessive rinses | | | |
| Venom filtrate without excessive pre-rinses | + | + | + |
| Pooled venom rinses without excessive pre-rinses | + | + | + |
| H2O control filtrate without excessive pre-rinses | | | |
| Pooled H2O control rinses without excessive pre-rinses | | | |
| UltraPure H2O in PP Eppendorf tube | | | |
| UltraPure H2O in glass vial | | | |
| Siebert's Sample Fraction 2 | | + | |
| Siebert's Sample Fraction 3 | | + | + |
| Siebert's Sample Fraction 4 | | | + |
| Siebert's Sample Fraction 5 | | | |
| Siebert's Sample Fraction 6 | + | | |
| Siebert's Sample Fraction 7 | | | |
| Siebert's Sample Fraction 8 | | | |
| Siebert's Sample Fraction 9 | | | |
| Siebert's Sample Fraction 10 | | | |
| Siebert's Sample Fraction 11 | | | |
| Siebert's Sample Fraction 12 | | | |
| Replicate 2: Venom #1 Filtrate | | + | |
| Replicate 2: Venom #1 Rinse 1 | | + | |
| Replicate 2: Venom #1 Rinse 2 | | + | |
| Replicate 2: Venom #1 Rinse 3 | | + | |
| Replicate 2: Venom #1 Concentrate | | | |
| Replicate 2: Venom #2 Filtrate | | + | |
| Replicate 2: Venom #2 Rinse 1 | | + | |
| Replicate 2: Venom #2 Rinse 2 | | + | |
| Replicate 2: Venom #2 Rinse 3 | | + | |
| Replicate 2: Venom #2 Concentrate | | | |
| Replicate 2: H2O Control #1 Filtrate | | | |
| Replicate 2: H2O Control #1 Rinse 1 | | | |
| Replicate 2: H2O Control #1 Rinse 2 | | | |
| Replicate 2: H2O Control #1 Rinse 3 | | | |
| Replicate 2: H2O Control #1 Concentrate | | | |
| Replicate 2: Newly opened UltraPure H20 | | + | |
| Replicate 2: Old UltraPure H2O | | + | |

**Table 2**: Summary of the 619, 708 and 911 peaks showed in all the samples submitted for LC/MS analysis at UIUC. In replicated 1, the peaks of 629 m/z, 708 m/z and 911 m/z were shown only in venom filtration samples without excessive pre-rinses for glycerol elimination. These three peaks were also shared with Siebert's biologically active samples (fraction 2-6). However, 708 m/z was shown in among multiple venom samples as well as the water filtration control and the UltraPure water controls, hence the inconsistency.

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# Candidate Positioning in U.S. House Elections: The Case of Donald Trump

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On May 31st, 2016, Congressman John Shimkus of Illinois' 15th District announced he would support his party's presidential nominee, Donald Trump.[1] In an average election year, a Republican congressman supporting a Republican nominee would likely have drawn little interest. In 2012, for example, only four Republican congress members refused to unequivocally support presidential candidate Mitt Romney.[2] None said they would vote for President Obama over their party's nominee. Yet in 2016, John Shimkus' statement appeared as a full article in local papers and as part of several national stories in support of the Republican candidate.

Republican Congresswoman Ileana Ros-Lehtinen of Florida's 27th District took a very different stance on the presidential nominee. Three weeks before Congressman Shimkus' statement, Ros-Lehtinen told reporters that she would not support Trump and would instead vote for someone from a different party.[3] Publications and websites, including the Washington Examiner, Miami Herald, Bloomberg, and FiveThirtyEight carried this public pronouncement, just like they would Congressman Shimkus.'

President-Elect Donald Trump's rise to the White House should raise many questions for political scientists interested in American elections, but one topic that should receive particular attention is his effect on congressional elections and the strategic positioning of the representatives running in them. Specifically, attention should be focused on exploring how congresspeople pivot from the primary to the general election, and why they decide to signal movement towards, or away from their party base.

Each Representative decides to move closer to or further from their primary constituency based on a variety of factors. For those in heavily conservative or liberal districts, aligning with the base may be the best way to secure the majority of voters. In other districts, especially those with fully competitive inter-party conflict, the decision to distance from the base may be necessary to secure the voters in the middle. These questions revolve around whether to pivot away from the primary constituency during the general election or directly appeal to it. Oftentimes, the positions necessary to maximize the primary vote share will conflict with the ones necessary to maximize the general election vote share. Additionally, the personal characteristics and ideology of the congressperson in question will, naturally, have sway over his or her thoughts and actions. Evidence in the literature is mixed regarding whether congresspeople position themselves based on the opinions of their primary constituency in the general election, and whether their acquiescence to or rebuke of primary voters significantly impacts their final vote share. This paper offers a chance to test these competing theories.

This research addresses the question by examining the case of Donald Trump. In 2016, Donald Trump took the political scene by storm and became the presidential nominee for the Republican Party. For decades, public support of the respective party nominee was a nearly universal expectation for congresspeople.[4] Yet, Donald Trump's unique positions, experience, and personality forced Republican congressional incumbents to decide whether they would publicly support or rebuke their own party's presidential candidate. This presented a fundamental strategic choice: would they position themselves towards or away from their party? The results were striking; many Representatives remained neutral on, or even directly opposed, the Republican Party nominee. Others supported him, but often distanced themselves by stating serious criticism of him as a candidate and as a person. In either case, the decisions were very public and heavily covered by local and national newspapers.

In this paper, I will be reviewing the endorsements and non-endorsements of Donald Trump in two parts. First, I will assess Donald Trump's primary vote-share in congressional Republican incumbents' districts. These results will be compared to Republican incumbents' subsequent endorsement levels of Trump after the primary to potentially identify a relationship between Donald Trump's primary success in their district and subsequent decisions on whether to endorse. An important point of contention is whether candidates endorsed Trump out of personal feeling, were reacting to the responses of their voters, or identified with a mix of the two. If the results were to show that an increase in Trump's primary vote-share is associated with increased levels of support from congresspeople, it would suggest that congresspeople do react to their primary constituency when positioning in the general election. If the results were to show no correlation, it would suggest that candidates pivot from the primary voters to the general electorate without paying outsized attention to the signaled opinions of the former.

Second, I will look at how each congressperson's support for Mr. Trump affected his or her vote share in the general election. If the results show that congresspeople who endorsed Trump more highly in moderate districts earned a lower vote share, controlling for other factors, this would suggest that embracing the primary constituency is a poor choice in swing-districts. Additionally, if it is found that congresspeople who endorsed Trump more highly in safer Republican districts garnered a higher vote share, it would suggest that that embracing the primary voters in more Republican areas is a good decision. If the results show the opposite - that swing-district Republicans did better when embracing Trump, or safe-district Republicans did worse when embracing Trump, or that there was no correlation - there would be evidence opposing the above hypotheses. This would be interesting, as it would contest the idea that an individual congressperson's positioning has a significant effect on their final vote total.

My analysis found that Republican congressional incumbents were more likely to endorse Trump highly when their district supported him. This effect was robust and lasted even when accounting for factors like candidate ideology, incumbency, the economic conditions in the district, the quality of the congressperson's primary challenger, and the competition within the district. This finding supported the idea that candidates are in fact responsive to the opinions of their core constituency. I also studied the relationship of these endorsements by incumbents to their general election performance. Once again, accounting for elements that might confound a study of the Trump endorsement effect on general election vote share, I was unable to show if a congressperson's endorsement level of Donald Trump had an effect on his or her general election vote total.

## HISTORICAL BACKGROUND

For much of its existence, the nomination system for selecting candidates for President was both murky and difficult for the public to influence. Now, it is just murky.[5] From the 17th century far into the late 20th century, the primaries that existed were advisory at best. Voters would give their preference at meetings, caucuses, or polls, and delegates from the state would take that into consideration when deciding whom to make the party nominee. Delegates from all states would meet at the convention to talk, receive promises, and eventually make the big decision on the convention floor.[6]

In 1968, despite not winning a single state's primary, Vice President Hubert Humphrey received the Democratic nomination.[7] The ensuing uproar, made even louder following his loss, forced a complete reform of the Democratic Party nomination process. In 1972, new national rules established that primaries would have binding value on delegates and that candidates would have to consistently compete for the favor of the primary voters. Similar reforms were approved shortly thereafter by Republicans. Even so, neither side has its nominee process fully controlled by the people's votes. Democrats still have delegates at-large who are not bound to anyone else's vote and can swing the nomination to their favored candidate. Republicans have esoteric rules that allow the primary votes to be thrown out if the convention decides, on a majority basis, to do so. Regardless, there is far more citizen control since the reform and the vote of the primary voters has never been overturned by party officials post-reform.[6]

Since the middle of the 20th century, it has been rare for congresspeople to oppose their party's Presidential nominee. In 1964, a group of Republicans, mostly consisting of party officials, defected from Senator Barry Goldwater, fearing his conservatism and temperament.[8] Very few congresspeople were involved. In 1972, some Democrats abandoned Senator McGovern under the banner, "Democrats for Nixon," but once again, very few House members joined in.[9] In both cases, governors, former cabinet officials, and other non-legislative partisans formed the bulk of the movement. Thus, the only two noteworthy movements against a party's own Presidential nominee between the 1950 and the 2014 cycle had perhaps a dozen congresspeople publicly involved. Other than these two examples, it has been extraordinarily rare for congresspeople to openly abandon their nominee. Although they might not campaign with them, as was the case with President Obama in 2012,[10] there have rarely been public rebukes in the period between 1950 and 2014.

The rise of Donald Trump in 2015 and 2016 broke that trend. Fiercely opposed by much of the Republican Party from the very beginning, Donald Trump did not grab the nearly unconditional support traditionally afforded to incoming nominees. When it looked as if he would win the nomination, there was even talk of a contested convention.[11] Thus, when he was then successfully nominated, he faced widespread opposition and half-hearted endorsements from Republican Party members across the country.[12]

The unique rise of President-elect Donald Trump from reality television star to Republican President justifies study on a wide-range of issues. In this paper, however, I will focus on what has been explored above: the uniquely disjointed support for Donald Trump by House members and the effect of this support on the candidates. This exploration should not only tell us about the 2016 election and its ramifications on electoral politics, but should also illuminate the complicated and ambiguous strategy behind candidate positioning.

## THEORY

If politicians care about the demonstrated interest of their primary constituency, I will observe Trump's primary vote share increase a House member's endorsement level of Trump. If constituents care about their

> *"For much of its existence, the nomination system for selecting candidates for President was both murky and difficult for the public to influence. Now, it is just murky."*

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congressperson's choice, I will observe endorsement-based betrayal of Donald Trump in strongly Republican districts adversely affect candidate vote share. Alternatively, I may find that voters are indifferent and that Trump support from politicians is not of importance to voters and their decision-making. Regardless of the answer, these outcomes directly relate to the strategy of candidate positioning and how these positions affect voters' decisions on whether to reward, or punish, their incumbent with their vote.

H1: In Part 1, I look at the congressperson's focus on being elected. If his or her core constituents support Trump, then I expect he or she will be more willing to endorse him to remain in the good grace of the core constituency. If I find results to this end, it will support the results of scholars like Poole, Bafumi, and Clinton. If I find no relationship, then it will serve to rebut their assertions.

H2: In Part 2, I look at the outcome of the endorsement-level decision. Specifically, I review whether congresspeople who highly endorse Trump face repercussions, whether they be good or bad. I expect that congresspeople in more competitive districts will face blowback from highly endorsing Trump, while those who do so in safe districts will improve their general election vote share.

### Data

The sample includes every Republican House incumbent that ran for reelection in 2016 and faced both primary and general election challengers. The state must use a traditional intra-party primary system in order for their congresspeople to be eligible to be a part of the sample. Specifically, this means that voters must be able to choose the candidate they like from their chosen party, and their chosen party only. This can be an open, closed, or semi-closed primary format, as long as the eligible voters are only voting for candidates from one party. This is opposed to top two, or other unusual primary systems, where people vote for candidates from multiple parties at once, or vote for delegates who then pick the nominee. There were 76 congresspeople that met these full requirements in 2016. This sample is less than a third of the 246 total Republican congressional

incumbents up for reelection in 2016.

I do not focus on all Republican congressional elections because this paper is specifically about strategic positioning following the primary with an eye towards the general election. To ensure that the congresspeople studied care about their primary and general election constituencies, I must only look at those who have seen the demonstrated interests of both their primary and general constituencies during that election cycle. This means that the congresspeople must face a primary and general election challenge, and they must know that the voters in the primary specifically identify with the Republican Party. Only then will I be able to measure the positioning decisions related to these two groups.

There were two significant data collection and classification components to this particular study: first, the collection and classification of House members' endorsement levels for Donald Trump, and second, the collection and classification of Donald Trump's primary vote share in each congressional district. Both of these components required substantial original research, and it was important to fully explore the methodology and reliability of these two elements to ensure that they could be convincingly used in this analysis.

I will start by discussing Donald Trump's endorsement level, that is, the level of support Donald Trump publicly received from congresspeople. I classified each congressperson's support on a numerical scale, from 0-4, with each integer representing a different general category of support.

Clearly, endorsement level is not just as simple as a number listed on a candidate's website. To create this variable, I reviewed news reports dating from the end of the primary to November 8, 2016. I used Google News as my aggregator and primarily looked through local papers for comments on Donald Trump made by the congressperson. To ensure that my review does not merely lead to an arbitrary assignment of numbers, I have tried to define clear categories of how strongly a candidate has supported, or not supported, Donald Trump.

The endorsement level variable measures the level of support given by

the Republican incumbent to Donald Trump during the general election. It is a discrete variable ranging from 0 to 4.

A congressperson who actively attacked Donald Trump, or stated his or her plan to vote for an alternative in the general election received a score of 0. Such was the case for Will Hurd, from the 23rd district of Texas, who actively and consistently called for Donald Trump to drop out of the presidential race.[13]

A congressperson who expressed significant public dislike of Donald Trump, such as refusing to vote for him, without having actively attacked him, was given a score of 1. Such was the case for Tom Rooney, from the 17th district of Florida, who refused to vote for Trump or Clinton, and openly discussed this.[14]

A congressperson who stayed neutral on Donald Trump, most often made evident by refusing to comment throughout the race or having said that he or she would "vote for the party's nominee" without mentioning the name "Trump," was scored as a 2. An example of such a congressperson was Bruce Poliquin, from the 2nd district of Maine, who did not give a firm comment on Donald Trump until the election was over.[15]

A congressperson who supported Donald Trump, but expressed reservations, as well, was scored as a 3. For example, Paul Ryan, from the 1st district of Wisconsin, continually said he would support Donald Trump, while simultaneously criticizing the scandals and temperament of his party's candidate.[16]

A congress person who expressed near, or complete, unattested support for Donald Trump was given a score of a 4. For example, Kevin Yoder, from the 3rd district of Kansas, strongly defended Donald Trump throughout the election and unequivocally supported him.[17]

One obvious difficulty for this variable is that some congresspeople actually changed their endorsement levels of Donald Trump over the course of the 2016 campaign. For example, on October 7th, 2016, an old Access Hollywood tape was leaked to the press with footage of Mr. Trump making controversial comments about women, and a number of Republicans who had previously supported Trump denounced their party's
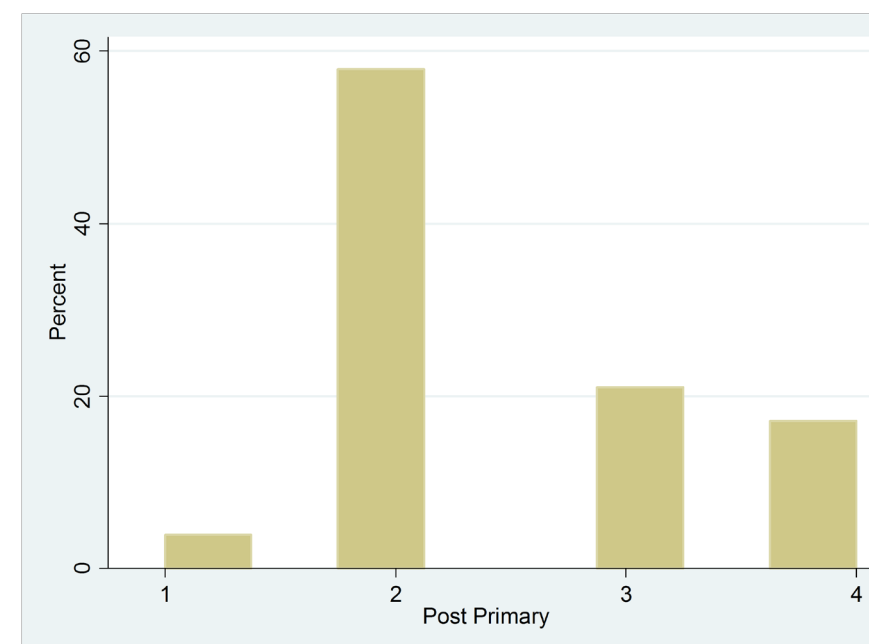


**Figure 1**: Trump Endorsement Level Post-Primary

candidate and withdrew their support.[18]

This is a valid concern, especially considering that a number of congresspeople in this sample did in fact alter their positions over the course of the campaign. To remedy this issue, I will be using two measures of endorsement level for each candidate. For part I of the analysis, where I attempt to measure the candidate positioning directly related to the primary, I will use the endorsement level expressed shortly after the primary. For part II of the analysis, where I attempt to ascertain how general election constituencies reacted to the congressperson's endorsement level of Donald Trump, I will use the support level clearly expressed shortly before the general election.

In the interest of fully exploring these endorsement levels, I have prepared a histogram (Figure 1) of congresspeople's endorsement levels for Donald Trump (scored from 0 to 4) in the sample directly after the primary.

Over half of the congresspeople were classified as having an endorsement level of two, with the remaining 43% split between scores of one, three, and four. At this point, no congressperson in the sample had expressed that they planned on voting for an alternative to Donald Trump come Election Day, and none

actively attacked him. Only a handful of congresspeople, specifically those given a score of a one, were explicitly (or overtly) refusing to support Mr. Trump at this time.

This distribution and attitude changed following negative developments during the 2016 election season, particularly with the release of the Access Hollywood tapes.[19] By the time Election Day arrived, a number of congresspeople had altered their positions on Donald Trump, and many had moved downwards on the zero to four numeric scale. The histogram below (Figure 2), shows pre-general election Trump endorsement levels.

In Figure 2, the zero level of endorsement makes an appearance, with nearly 10% of the sample electing not to support Donald Trump and simultaneously campaigning against him - even going as far to explicitly endorse an alternative candidate. In total, roughly 16% of the sample directly opposed Donald Trump. At the same time, around 34% of the sample continued to explicitly support Mr. Trump, with or without reservations, and 50% expressed a neutral position, oftentimes referring to their fear of a Clinton Presidency. One quote from congressman Rodney Frelinghuysen, of New Jersey's 11th congressional district, well represents the

general public statements of those who expressed a neutral position before the general election. Congressman Russell stated, "Donald Trump was not my first choice, perhaps not my second or third choice… not my fifth choice. I did make a commitment, as a Republican, and 14 million people voted for Trump."[20] He further stated that a President Hillary Clinton would be far worse for the nation.

The second significant data collection and classification component involved putting together the Trump primary vote share broken down by congressional district. This was particularly challenging due to the fact that few states actually collect the Presidential primary vote share in terms of congressional districts. Instead, the publicly available information usually focuses solely on the state as a whole and the counties in that state. In an effort to accurately assess support for Trump in each district, as a congressperson would know, I attempted to accurately compile a representation of the district's primary vote for Donald Trump using county voting information with a district field operation and knowledge of the underlying forces.

To gather this data, I used a combination of the Associated Press Elections Database and the Politico Election Archive. The data for the few states that measured Presidential primary vote by congressional district were taken from the Associated Press Elections Database. For districts in which the data were not already compiled, data were manually compiled by taking county by county vote totals and using them to estimate district vote counts. Unfortunately, not all of these districts were neatly designed. Some districts had a mix of counties - some that were fully in the district and others that were partially in the district. Others had zero, or only a couple of counties that fully fell within the district borders. As such, the primary vote totals for many districts became approximations.

The districts created can be broadly placed into three categories. The first includes districts where the Associated Press had district-level Presidential primary data, or where all counties that make up the district are fully in its bounds. These districts required no approximation. The last two include districts where there
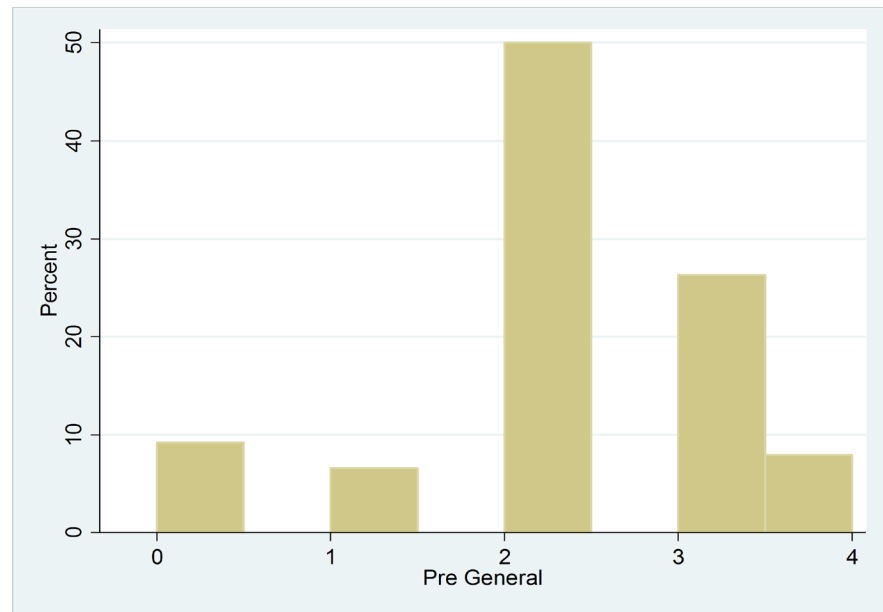
**Figure 2**: Trump Endorsement Level Pre-General

are a mix of counties which are fully in the district and counties which are partially in the district. If at least 35% of the full district population could be found in the counties fully in the district, I used the results of those counties' presidential primaries to approximate the district-level results. For districts where less than 35% of the full district population is located in counties which are fully in the district, I was forced to use counties which are only partially in the district to approximate the Trump primary vote share in the district as a whole.

Figure 3, presented below, is a histogram of the final Trump primary percentages used in this analysis.

The vast majority of districts saw Trump receive less than 50% of the Presidential primary vote, with only 15% of sampled districts voting for Trump by majority. This could help explain why so many congresspeople stayed fairly neutral after the primary (i.e. at an endorsement level of 2).

Information on primary and general election results for congresspeople is taken from Ballotpedia, along with any necessary personal characteristics, such as years of incumbency. Ideological record is sourced from the DW-Nominate database.

Information on Romney's 2012 general election vote share in the district came from Daily Kos, which has compiled an approximation of the Romney and Obama vote share for each congressional district.

The breakdown of the partisanship of districts is taken from FiveThirtyEight in conjunction with the Cook Partisan Voting Index. The index measures how closely a congressional district leans towards either the Republican Party or the Democratic Party. It uses the district level two party vote in past elections and compares it to the national two party vote to uncover how the district leans in overall disposition to the two parties.

Poverty statistics are from the U.S. Census Bureau and their American Community Survey.

## Part I
### Research Design

In the first part of my analysis, the dependent variable is the endorsement level of Trump and the treatment variable is Donald Trump's primary vote share in each congressperson's district.

When studying the relationship in Part 1, I will be using a number of covariates to eliminate confounding factors. The main limit to my analysis involves the direct relationships between candidates supporting Trump, their own personal brand, and the characteristics of their district. I have incorporated the likely top factors that would intertwine support for Donald Trump and the primary vote share for Trump, or the congressperson's own success.

In Part 1, the covariates are the natural log of years of incumbency, whether they faced a high quality primary challenger, their ideological record, the percentage of families in poverty in the district, and Romney's 2012 general election vote share in the district.

- Years of incumbency are used as a measure because longer-serving representatives might, by virtue of their long-tenure, have districts less likely to support Trump. They themselves might be less likely to endorse him given their long incumbency, or more likely to support him to simply to protect themselves from anti-Washington rage. Years of incumbency are transformed into a logarithmic function because I expect there to be a greater effect when a congressperson moves from the 5th year to the 6th year compared to the effect when moving from the 28th year to the 29th year.

- The high quality primary challenger is a binary variable, scoring 0 if the top primary challenger received less than 20% of the final vote, or 1 if he or she received greater than 20% of the vote. Given that congresspeople are worried about reelection, a primary challenger of 20% or more offers a real fear that some significant part of the primary base does not like the candidate. Districts with such a strong primary challenge should be more likely to vote for Donald Trump and have their respective congressperson more likely to endorse Trump strongly to win them back.

- The ideological record of the congressperson falls on a scale from -1 to +1, ranging from liberal to conservative ideology. It will be based on the DW-NOMINATE database kept by Jeff Lewis at UCLA. It uses the roll call votes in the House of Representatives, and scales them according to how liberal or how conservative the underlying legislation is. The legislator estimates created by the DW-NOMINATE score try to accurately model the public ideological profile of a candidate. I am using this figure in the paper to best estimate a legislator's real and expressed ideological disposition. This ties directly into how congresspeople express their positions to constituents back home. So, I expect that those who display a more conservative ideological profile are more likely to support Donald Trump, and thus, the district should be less likely to support the insurgent presidential nominee.

- The percentage of families in poverty is used as a measure because economic hardship in a particular district would likely make it more probable for a congressperson to support a populist candidate, like Donald Trump, to signal his or her understanding of the change needed to combat that economic hardship, and his or her understanding that the district would be more likely to support a candidate like Mr. Trump. At the same time, a district doing well may be less likely to vote for Mr. Trump to maintain the positive status quo, and the congressperson
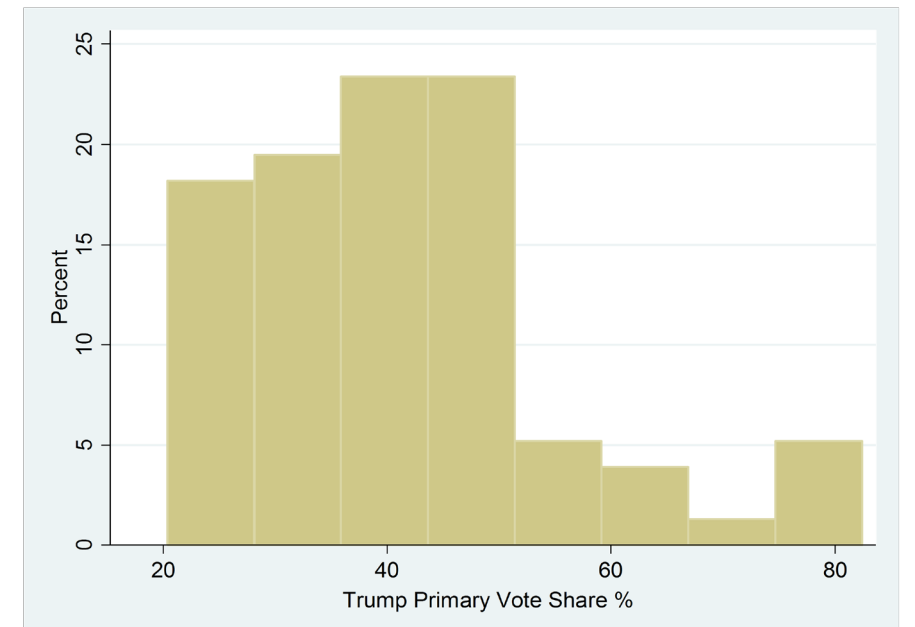


**Figure 3**: Trump Primary Vote Share in Approximated Congressional Districts

would be less likely to support Donald Trump to signal his or her satisfaction with the district's economic situation.

- Romney's 2012 general election vote share is useful to measure the partisan leanings of the district. Generally,

more conservative districts are expected to support Donald Trump more, and less conservative districts are expected to support him less. Thus, the congresspeople in more conservative districts could feel pressured to support the nominee more readily than congresspeople in more moderate districts. This variable should also control for the competitiveness of the district. I have also added a column where Romney vote share is squared to account for a potentially nonlinear relationship between district ideology and the endorsement level for Donald Trump. This is a method used in both Burden (2004) and Ansolabehere (2001).

### Results

In Part 1, I am reviewing the primary vote share earned by Donald Trump in a particular congressional district and the subsequent endorsement level of Mr. Trump by the congressperson from that particular district.

Table 1 displays the correlation between Trump's in-district vote share and the congressperson's endorsement level for Donald Trump using OLS regressions. Column 1 only includes the main covariate of interest, Trump's

**Table 1**. Trump Vote Share in the Primary and Endorsement Level

| Trump Primary Vote Share | 2.442*** (0.673) | 2.850*** (.515) | 2.770*** (.528) |
|---|---|---|---|
| Romney 2012 Vote Share | -------------- | .0316** (.0149) | .154 (.159) |
| Romney 2012 Vote Share Squared | -------------- | -------------- | -.00101 (.00134) |
| Log of Years in Office | -------------- | -.113** (.0497) | -.109** (.0496) |
| High Quality Primary Challenger | -------------- | .312 (.176) | .319* (.177) |
| Ideological Record | -------------- | .900 (.637) | .810 (.651) |
| Poverty | | -.0587*** | -.0607*** |
| Constant | 1.517*** (.263) | -.895 (.885) | -4.466 (4.561) |
| Number of Cases | 73 | 73 | 73 |
| Adjusted R^2 | 0.179 | 0.360 | 0.365 |

**Table 1**: DV: Endorsement level. *p<0.10, **p<0.05, ***p<0.01, two-tailed test.

primary vote share, and column 2 adds the covariates described above. Column 3 adds Romney vote share squared.

Table 1 supports the hypothesis that an increase of Trump vote share in a congressperson's district increases his or her subsequent support of the candidate. In Table 1, there is a positive coefficient estimate for Trump vote share on the endorsement level decisions of congressional Republican incumbents. This exists not only before controlling for a variety of confounding factors, but afterwards, as well, along with an increase in the magnitude. Both of these results were statistically significant to the one point level, which bodes well for the likely strength of the estimated effect.

Table 1 suggests that if a congressperson's district were to go from exactly zero voters supporting Donald Trump's primary candidacy to all voters supporting his candidacy, the congressperson would go up roughly three levels in his or her public support for Donald Trump. This would mean a congressperson who is predisposed to actively attacking Trump and calling for him to "drop out" (an endorsement level of 0) would instead support him with reservations (an endorsement level of 3).

A more intuitive example might involve the percentage of the primary vote share that the regression predicts Donald Trump would need in order to move a congressperson up one endorsement level. This regression analysis predicts that an increase in a district's Trump support from 0% to roughly 35% would cause a congressperson to increase his or her endorsement level by one. A congressperson who would normally withhold support for Trump (an endorsement level of 1) would instead pledge to "support the Republican nominee over Hillary Clinton" (an endorsement level of 2).

It is important, however, to keep in mind the actual limitations of this analysis when attempting to predict the real magnitude of the effect. The 0-4 scale for endorsement level is, in many ways, arbitrary. It is uncertain whether a movement from an endorsement level of 2 to an endorsement level of 3, for example, actually requires the same primary vote share as a move

**Table 2**. Trump Vote Share in the Primary and Endorsement Level for Districts with Full Colonies

| | | | |
|---|---|---|---|
| Trump Primary Vote Share | 2.442*** (0.673) | 2.850*** (.515) | 2.770*** (.528) |
| Romney 2012 Vote Share | -------------- | .0316** (.0149) | .154 (.159) |
| Romney 2012 Vote Share Squared | -------------- | -------------- | -.00101 (.00134) |
| Log of Years in Office | -------------- | -.113** (.0497) | -.109** (.0496) |
| High Quality Primary Challenger | -------------- | .312 (.176) | .319* (.177) |
| Ideological Record | -------------- | .900 (.637) | .810 (.651) |
| Poverty | | -.0587*** | -.0607*** |
| Constant | 1.517*** (.263) | -.895 (.885) | -4.466 (4.561) |
| Number of Cases | 73 | 73 | 73 |
| Adjusted R^2 | 0.179 | 0.360 | 0.365 |

**Table 2**: DV: Endorsement level. *p<0.10, **p<0.05, ***p<0.01, two-tailed test.

from an endorsement level of 3 to an endorsement level of 4. Thus, the magnitude may not accurately reflect the exact Trump vote share necessary to change a congressperson's position.

To confirm that the linear regression used fits the data, I have plotted the residuals for the regression (this can be found in the Appendix). The residual plot does appear to show a random distribution.

There are, however, two notable weaknesses in this analysis.

The first revolves around the question of how well Donald Trump is suited for tests of partisan loyalty. Part of the purpose of this paper is to try to understand the role of candidate positioning in future elections. However, Donald Trump occupied a rather unique position in popular culture and electoral media during the 2016 election. This paper assumes that voters' thoughts on Donald Trump are substantially similar in nature to their thoughts on various other partisan issues. It also assumes that congresspeople viewed the issue of supporting or condemning Donald Trump in a substantially similar way to

those same traditional partisan issues. If views on Donald Trump do, in fact, match this assumption, meaning that voters and congresspeople looked at the endorsement levels of Donald Trump like they did other issues, then this paper will accurately show how candidates position themselves. If, however, the case of Donald Trump is a special circumstance, where endorsement levels do not signal traditional positioning by the congressperson, then this paper will not reflect the true nature of voter choice on grounds of party loyalty.

Additionally, there is concern about the way congressional district vote totals were constructed for the purposes of this analysis. As was mentioned previously, I had to personally create congressional district vote totals by combining counties that were wholly, or partly, available. For districts where there was a mix of partial and whole counties within them, I tried to only consider the counties that were fully in the district. However, some districts only contained a number of partial counties, or few full counties, and in these cases I used partial counties. Several districts were impossible to recreate due

to one or two very segmented counties making up the entirety of the district. To test whether this was a significant issue, I have created a table where all districts made up of partial counties were stricken.

Table 2, above, shows that even when all partial county districts have been dropped, the result remains consistent with the original conclusion and continues to be statistically significant. In fact, the predicted magnitude increases between the analyses.

Overall, the strength of the above results is clear. This analysis is consistent with H1, showing that stronger within-district support for Trump covaries with congresspeople demonstrating a higher level of Trump endorsement, and thus, moving closer to their primary constituency. Controlling for personal and district factors, including competitiveness, the substantial statistical significance and magnitude of the results suggests that in the 2016 election, Republican congresspeople positioned their public opinions on Donald Trump based on the demonstrated interests of their primary base. Some congresspeople who were naturally opposed to Trump learned to put out neutral statements. Others who were indifferent to Trump learned to support him with reservations. Another segment of congresspeople, who were ready to support him with reservations, learned to embrace him wholeheartedly. And other congresspeople, in districts where Mr. Trump performed poorly, did not change their natural positions at all, or perhaps even lowered their public support level of the candidate.

## Part II
*Research Design*

In the second part of my analysis, I evaluate a congressperson's endorsement level of Donald Trump right before the general election and his or her subsequent general election vote share. In order to find this, I reviewed the in-district general election vote share of the Republican congressperson with the endorsement level as my treatment. In this portion, I also break down the candidates in terms of their district partisanship to better understand how swing district candidates differ from Republican safe district candidates. District partisanship

is measured by the Cook Political Report Partisan Voting Index, which uses results from past elections to estimate district partisanship.

When studying the relationship in part 2, I will once again be using a number of covariates to eliminate confounding factors. In this section, I am most concerned about other factors that would affect both the Trump endorsement level and the general election vote share for a given district's congressperson. I have incorporated both personal factors, such as the natural log of years and ideology, and the characteristics of the district, such as the percentage of families in poverty and the 2012 Romney vote, which was used in Part I.

- The log of years of incumbency will take the same form as above, but the logic is that older members are more, or less, likely to endorse Trump, while older members are also more likely to do well, or poorly, in their general elections as a result of their long tenure.
- The ideological record will take the same form as above, but the logic is that more, or less, conservative candidates will endorse Trump more, or less, based on personal factors, while also receiving a higher, or lower, vote share from their constituents.

- The percentage of families in poverty will take the same form as it did above, but the logic is that poor economic conditions will likely lead to voter punishment of their congressperson, while once again, the congressperson will likely be more or less inclined to support the populist Donald Trump based on how his or her district is doing financially.
- The Romney vote share will take the same form as above, but the logic is, instead, that more Republican leaning districts are more likely to vote for their Republican candidates, and that congresspeople from more Republican leaning districts are inclined to support the Republican nominee for President. I again included a squared version of this variable in case there is a non-linear relationship.

*Results*

Table 3, below, displays the correlation between a congressperson's endorsement level of Donald Trump and the general election vote share for that congressperson using OLS regressions. Column 1 only includes the main covariate of interest (Trump's primary vote share), and column 2 adds the covariates described above. Column 3 adds the squared version of

**Table 3**. Endorsement Level of Trump and General Election Vote Share

| | | | |
|---|---|---|---|
| Trump Endorsement Level | 2.883** (1.197) | .524 (.840) | .565 (.933) |
| Poverty | -------------- | 0.0211 (.0894) | .0268 (.0908) |
| Log of Years in Office | -------------- | -0.734 (0.426) | -.747* (.435) |
| Ideological Record | -------------- | 9.809 (4.878) | -9.617* (5.200) |
| Romney 2012 Vote Share | -------------- | .835*** (.105) | .521 (1.342) |
| Romney 2012 Vote Share Squared | -------------- | -------------- | .00258 (.0106) |
| Constant | 54.72*** (2.851) | 17.60*** (4.872) | 26.83 (39.48) |
| Number of cases | 76 | 76 | 76 |
| Adjusted R^2 | 0.113 | 0.529 | 0.529 |

**Table 3**: DV: General election vote share. *p<0.10, **p<0.05, ***p<0.01, two-tailed test.

Romney vote share.

Without covariates, Table 3 predicts a substantial effect from each increase in Trump's general election vote share. Specifically, it predicts that going from a neutral statement on Donald Trump to a statement of full support for Donald Trump would mean a roughly 5.5% increase in the congressperson's general election vote total. However, this effect disappears when the covariates are applied to the regression. In fact, following the addition of the district poverty, the natural log of years in office, the ideological record, and the district's 2012 Romney vote share, the magnitude of the predicted effect drops to almost nothing, and there is no statistical significance assigned to the magnitude. The standard error of this new estimated effect is more than double the actual predicted magnitude, thus highlighting the uncertainty of the prediction. Further, even if there were statistical significance, the magnitude predicts that moving up an endorsement level would net the congressperson only a half a point increase in general election vote share.

However, it is important to recognize that the above table does intermix highly Republican districts and more moderate districts. My original hypothesis predicted that once broken down into moderate and more partisan districts, the resulting analyses would show that supporting Donald Trump in more Republican districts helped congresspeople, and supporting him in more moderate districts hurt congresspeople. A potential reason for the mixed result above would be that, once covariates are added, these two effects cancel each other out. Table 4 below explores the predicted effects in both more Republican districts and less Republican districts. The cutoff for more and/or less Republican districts is the Cook Political Report designation of R+10 partisanship.

Table 4 mirrors the results found in Table 3. Here, the more Republican districts are shown to have a significant magnitude without the covariates added. However, following the addition of the control variables, any statistical significance completely disappears, along with the predicted magnitude. At

the same time, the regression fails to assign any statistical significance to the predicted general election vote share for congresspeople from moderate districts, both before and after controls are added.

There are a couple potential explanations for this result.

One potential factor is the rather low sample size. There are only 46 more partisan districts and 30 less partisan districts to analyze, given the limited number of congresspeople in the original sample. As the sample size decreases, it becomes harder to find a statistically significant result, especially if the actual relationship is weak to begin with.

Another potential factor is that R+10 is not the correct point to distinguish moderate districts. Perhaps moderate districts have even lower Cook Partisan Voting Index scores. Unfortunately, using a lower cut off point would exacerbate the potential problem of small sample size even more. Just in case the cutoff point is, in fact, a significant issue, I have examined this in Table 5, which uses cutoff points at R+7 and R+4.

Table 5 displays no statistically

**Table 4.** Endorsement Level of Trump and General Election Vote Share for Highly Partisan and Less Partisan Districts

| | R+10 and higher districts | R+10 and higher districts | R+9 and lower districts | R+9 and lower districts |
|---|---|---|---|---|
| Trump Endorsement Level | 3.951*<br>(2.104) | 1.561<br>(1.394) | .906<br>(1.298) | -.527<br>(1.093) |
| Poverty | ------------------ | .0274<br>(.128) | ------------------ | 10.89<br>(39.39) |
| Log of Years in Office | ------------------ | -.314<br>(.923) | ------------------ | -.650<br>(.474) |
| Ideological Record | ------------------ | -6.491<br>(8.175) | ------------------ | -13.20<br>(9.415) |
| Romney 2012 Vote Share | ------------------ | .861***<br>(.128) | ------------------ | 1.184***<br>(.255) |
| Constant | 54.51***<br>(5.216) | 10.74<br>(9.973) | 55.16***<br>(9.973) | 2.054<br>(11.94) |
| Number of cases | 46 | 46 | 30 | 30 |
| Adjusted R^2 | 0.170 | 0.450 | 0.021 | 0.529 |

**Table 4**: DV: General election vote share. *p<0.10, **p<0.05, ***p<0.01, two-tailed test.

**Table 5.** Endorsement Level of Trump and General Election Vote Share for R+7 and Lower and R+4 and Lower

| | R+7 and lower districts | R+7 and lower districts | R+4 and lower districts | R+4 and lower districts |
|---|---|---|---|---|
| Trump Endorsement Level | .731<br>(1.594) | -.735<br>(1.128) | -.513<br>(1.758) | -.870<br>(1.162) |
| Poverty | ------------------ | -15.68<br>(64.82) | ------------------ | -104.1<br>(98.81) |
| Log of Years in Office | ------------------ | -.846<br>(1.273) | ------------------ | -2.136<br>(1.174) |
| Ideological Record | ------------------ | -18.22<br>(21.11) | ------------------ | -3.239<br>(19.45) |
| Romney 2012 Vote Share | ------------------ | 1.223**<br>(.481) | ------------------ | 1.043<br>(1.202) |
| Constant | 54.11***<br>(2.900) | 4.692<br>(23.97) | 54.37***<br>(2.953) | 19.48<br>(61.94) |
| Number of cases | 19 | 19 | 12 | 12 |
| Adjusted R^2 | 0.013 | 0.383 | 0.008 | 0.585 |

**Table 4**: DV: General election vote share. *p<0.10, **p<0.05, ***p<0.01, two-tailed test.

significant relationship between endorsement level and general election vote share in the less partisan districts analyzed. This result may, once again, be due to the lower sample size, or may be due to an actual lack of correlation between endorsement level and general election vote share. Either way, the second part of H2, concerning the effect of endorsement level on general election vote share for Republican incumbents in districts of different levels of partisanship, cannot be supported.

The simplest explanation for this continued failure to find an effective correlation is that the positions of congresspeople regarding Donald Trump actually had no real impact on the final general election vote share of each congressperson. It is a possibility that is not easily discounted. It is entirely intuitive that the general election constituency did not particularly care about how their congressperson spoke in regards to Donald Trump, or perhaps, they were not even paying attention to such a position. There were a number

of issues during the 2016 election that received significant attention - issues that may have overridden any thoughts to base one's personal voting decision on one's congressperson's voting decision regarding Donald Trump.

If a Republican voter were trying to decide whether to vote for Congressman Jason Chaffetz from Utah, for example, he or she may have considered that the congressman was the first sitting Republican member of Congress to pull his support from Donald Trump following the release of the Access Hollywood Tapes.[21] At the same time, this voter would also be able to consider a number of the firmly Republican, and even particularly pro-Trump, positions that the congressman had. As the House Oversight Committee chairman, Chaffetz held hearings investigating Hillary Clinton's email server. He was also not a long-time member of Washington, just finishing up his fourth term during the 2016 elections. He even supported many of Donald Trump's more public positions, like non-interventionism and a

repeal of the Affordable Care Act.

Certainly, a Republican Trump supporter could be looking at all of the positions and characteristics that a congressman like Mr. Chaffetz had publicly expressed, and could be deciding whether Congressman Chaffetz supporting, or not supporting, Donald Trump was important enough to risk electing a Democrat with the opposite policy disposition.

Overall, my analysis was not able to find any effect on a congressperson's general election vote share based on his or her endorsement level of Donald Trump. This provides some evidence to dispute the current literature arguing that voters actually punish congresspeople based on their individual actions. However, most of that literature is primarily focused on partisan policy behavior and candidate positioning. This result may simply be due to voters actually focusing on partisan policy positions above all else, causing them to potentially view the endorsement level of Donald Trump as noncontributory in their final choice.

## Conclusion

As I have explored, for congressional candidates, each election offers the potential to make many strategic choices. Should candidates highlight their experience in the party, or their maverick status? Should they strategically vote for party-bills to signal loyalty, or vote against them to signal independence? Should they campaign with a talk radio host, or the party whip? Each choice allows candidates to more or less align themselves with their primary, versus general, constituency.

The choice of endorsement for Republican House members with regards to Donald Trump - a high profile and well documented decision - suggests that congresspeople do move in order to capture their primary constituencies. This could be for any number of reasons. Perhaps congresspeople worry about losing their core voters and believe they can make up any lost ground with swing voters. Perhaps they worry about losing the party activists who pass out fliers, donate small-dollars, and perform other traditional tasks necessary for a successful campaign. Perhaps they fear losing a primary challenge two years down the line. Future scholars may want to survey House members to discover these underlying reasons. Furthermore, additional research investigating the gap between Trump votes and votes for defecting Republican Congresspeople, or on Senators and their reactions to Trump, could also shed further light on this fascinating topic.

Further, I was unable to find whether Trump's endorsement level affected a congressperson's general election vote share, and could not uncover the reason for this lack of statistical correlation. It is possible that this was due to statistical methodology or an actual lack of correlation. Even if the lack of correlation were due to the underlying reality, however, that would still not tell the full story. It is possible, for example, that positioning oneself closer to the primary constituency increases one's base voters, but loses one the general election voters. Another explanation for the lack of relationship is that partisans in more competitive districts know that their vote

matters more in deciding the outcome of an election, and will vote for their party's congressional candidate whether or not they are very aligned with the party nominee. Whatever the reason, political scientists should further evaluate general election voting behavior in congressional races to uncover the possible effects of partisan positioning. With the end of the judicial filibuster and the continuing partisan position-taking in Congress, such research promises to be fruitful.

President Donald Trump entered the White House as President on January 20th, 2017. Understanding the issues surrounding his candidacy and the effects they had on the positioning of the Republican Party is both prudent and necessary for electoral scholarship and Political Science in totality.
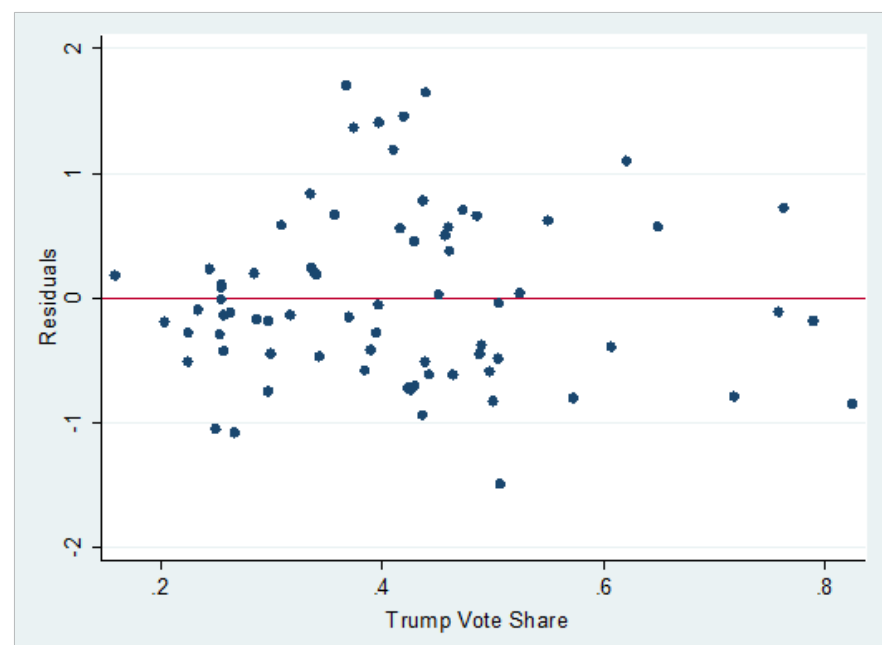
## Appendix

Figure 1 appears to display a roughly random pattern of residuals plotted against the Trump Vote Share variable. The residuals plot thus supports the validity of the Part I linear regression.

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**Appendix Figure 1**: Residuals Plot from Part I

# Role-Playing Game AI

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## 1. INTRODUCTION

From Go to CS:GO,[1] humans have never lost their passion for games. With the development of artificial intelligence and especially machine learning, humans have started to make machines that could learn how to play games themselves. Having seen the triumph of Alpha Go, we cannot help but wonder: can we also make an agent that can learn to play one of our favorite games?

In this project, we aimed to design an agent, using reinforcement learning, for a game called 'NetHack,' which is a single player dungeon exploration game, and then compare its performance to that of hard-coded agents. NetHack looks quite simple, but in reality, is a very complicated game. Therefore, we had to modify the game to make it a little simpler for our agents. To accomplish this, we used the Python library TensorFlow, an open-source library by Google, for creating neural networks. By the end of 20-hour training session, the reinforcement learning agent could not reach the same performance as the best hard-coded agent could; however, its performance greatly improved during the training session, and the agent performed better than some human players who were unfamiliar with the game.

## 2. RELATED WORK

### 2.1 ALPHAGO[5]

AlphaGo is a system designed by Google DeepMind to play Go. The goal of this agent was to play Go better than even the best human players could. The techniques primarily used for AlphaGo are Monte Carlo Tree Search, Supervised Learning, and Deep Reinforcement Learning.

Monte Carlo Tree Search (MCTS) is an approach involving a search of the game tree. The idea behind this is to run many game simulations while performing this tree search. At first, the simulations for both players are completely random at each game state. Some values, such as how often each node has been traversed and how often this has led to a win, will be stored in each simulation. These numbers will change in the later simulations when selecting actions (simulations will seem less random). The more simulations that are executed, the more accurate the system becomes at selecting winning moves.

AlphaGo also learned from games played by humans in the past using supervised learning (labeled examples). These labeled examples can tell what actions might lead to winning.

Unlike supervised learning, deep reinforcement learning has the AlphaGo play against itself. There are rewards (win the game) and punishments (lose the game) included in the reinforcement learning, and the network trained in AlphaGo is a neural network. That is why the technique is named Deep Reinforcement Learning. Overall, AlphaGo is an agent that includes Monte Carlo Tree Search, supervised learning, and reinforcement learning.

### 2.2 FROZEN LAKE[4]

Frozen Lake is one of the game environments from OpenAI gym and consists of 4 by 4 grid blocks. Each of these blocks is either the start block, the goal block, a safe frozen block, or a dangerous hole. The agent's movements are limited to up, down, left, or right. Wind is a feature of the game that works against the agent; occasionally, wind will blow the agent to a space that it did not choose. Nevertheless, avoiding holes and reaching the goal is possible. At every step, the agent gets 0 as reward, but if the agent enters the goal, the reward is 1.

This is a game where Q-learning works well, since we will need an algorithm that learns long-term expected rewards. Q-learning, very simply, involves a table of values for every state and action. For this game, we have 16 possible states, since each block has 4 variations and 4 possible actions - the 4 ways to move around. This gives us, in total, a 16 by 4 table of Q-values. When updating our Q-table, we use the Bellman equation, which says that expected long-term reward for a given action is equal to the immediate reward from the current action combined with the expected reward from the best future action taken at the following state.

For the Frozen Lake game, an on-layer network takes the state encoded in a one-hot vector and outputs a vector of 4 Q-values for each action. After that, more layers, activation functions, and different input types can be added with the help of TensorFlow. When updating the table, back propagation and a loss function are used, instead of directly accessing the table. However, it turns out that this is not very efficient, so, to get greater performance and more robust learning, two other tricks called Experience Replay and Freezing Target Networks are used.

### 2.3 DEEP MIND[2]

Deep Q-network (DQN) is a system made by Google DeepMind that can learn classic Atari video games, and this one system can play all of the different games. The goal of the agent is to achieve higher scores, and DQN is an example of an agent that can learn by reinforcement learning from little starting information. It also expresses data in abstract ways using Deep Neural Networks. The purpose of the system is to implement human-like logic in its learning process.

In many Atari games, the DQN plays better than humans, but it needs to run many game sessions beforehand to learn. For example, in the game 'Break Bricks,' the DQN learned that it had to hit the ball back after 100 playing sessions, and learned how to break efficiently to win against the player after 600 playing sessions. Researchers also found that there are certain types of games that it cannot play better than humans can, including 'Battle Zone' and 'Bowling.'

## 3. PROBLEM STATEMENT

For this project, we plan on building different types of agents to play 'Nethack,' a single-player dungeon exploration game. Since Nethack is a relatively complicated game, we implement some modifications to make it simpler for agents to learn and connect to the game server. We expect the agents to start gaining some knowledge of the game and making adjustments based on the situations they encounter. At the end of the report, we compare the performance of two different types of agents: hard-coded strategies agents and reinforcement learning agents.

## 4. NETHACK

NetHack is an old rogue-like RPG (role-playing game) video game that uses graphics of only ASCII characters. Just like modern RPGs, NetHack has multiple levels, and a variety of items for the player to use. Originally released in 1987, it has been continually receiving updates since. The most recent version and the version we used was 3.6.0. Many of today's RPG games, such as Diablo[2], are derived from NetHack.

### 4.1 INSIDE THE GAME

The character is chosen from the god and is asked to get the Amulet of Yendor from the dungeon. The player's objective in NetHack is to fight monsters and become stronger to eventually retrieve the Amulet of Yendor from the lowest level of the dungeon.
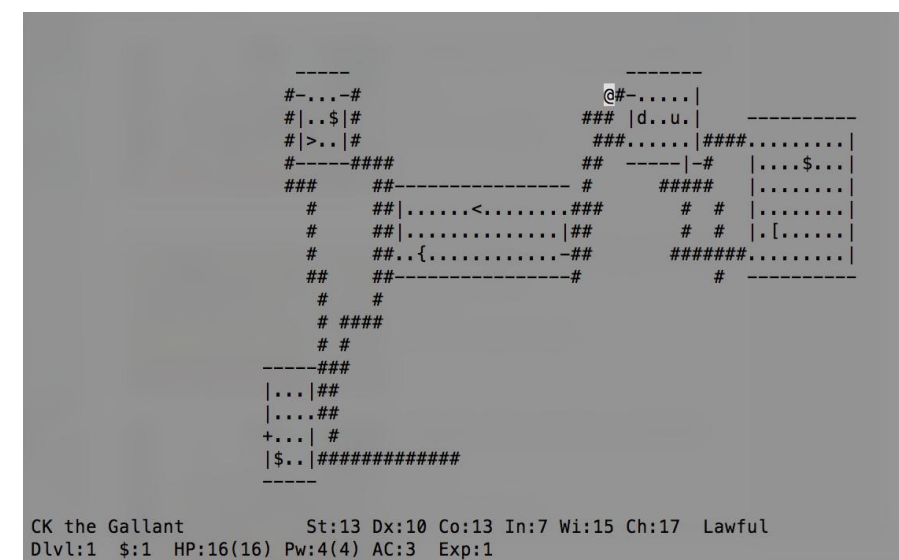


**Figure 1**: Screenshot of NetHack

Players may choose their character's role and gender. There are more than 10 roles, including knight, wizard, rogue, and samurai. The dungeon levels range from 0 to 50. The character also has levels ranging from 1 to 30. However, it is quite hard to reach level 30 because the experience necessary to level up increases exponentially with the character's level. While playing the game, one may die by a monster, by starvation, by drowning, etc. Like in today's RPGs, there are statistics like strength, health points (HP), and intelligence. One may improve these figures by performing certain actions. For example, one can train strength by pushing a rock or carrying heavy things. There are many items, ranging from potions to armor, that can be bought from stores or retrieved from monsters killed.

Although this game is old and has text-based graphics, it is very well made and difficult. We have played this game several times but have never reached the final stage.

### 4.2 GAME MODIFICATION

Given the difficulty and complexity of the game, we decided that in order to have a more realistic goal for our AI, we would modify the game. Originally, there were too many possible actions that a player could take at any point to make any kind of effective player in the amount of time we had. There were also too many objects and monsters that could be encountered for the algorithm to learn anything significant. We got rid of all the monsters except for two of them, the Grid Bug and the Floating Eye. To do this,we ensured that the other monsters did not show up until the seventh level or later, based on the reasonable assumption that our players would never reach these levels. The reason we kept two particular monsters is that the Grid Bug is fairly easy to kill, so the player should try to kill it if possible, and the Floating Eye freezes the player, so the player should avoid it. We attempted to make the Floating Eye immortal, so that the neural network would learn to always avoid the floating eye, but the source code for NetHack is very complicated and we were unable to figure out how to accomplish this.

We also eliminated most of the objects in the game other than food and money. The player still begins the game with various other objects, but now the player will never encounter anything besides the objects it began with. This reduces the ways that a player can die (for example, by being poisoned). We kept food so that the network could be punished for idle moves, and we kept coins to serve as a possible incentive, even though we have not used coins as part of the reward function. By making these modifications, we encountered a bug where the player could now eat any object that it had,
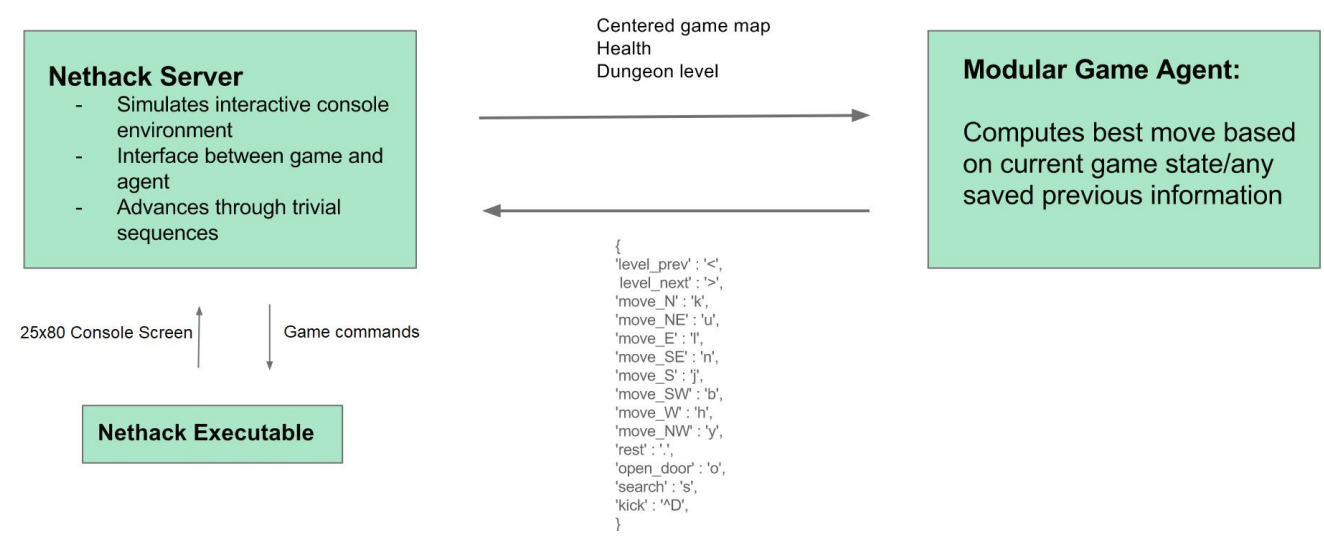
**Nethack Server**
- Simulates interactive console environment
- Interface between game and agent
- Advances through trivial sequences

25x80 Console Screen

Game commands

**Nethack Executable**

Centered game map
Health
Dungeon level

**Modular Game Agent:**

Computes best move based on current game state/any saved previous information

```
{
'level_prev' : '<',
'level_next' : '>',
'move_N' : 'k',
'move_NE' : 'u',
'move_E' : 'l',
'move_SE' : 'n',
'move_S' : 'j',
'move_SW' : 'b',
'move_W' : 'h',
'move_NW' : 'y',
'rest' : '.',
'open_door' : 'o',
'search' : 's',
'kick' : '^D',
}
```

**Figure 2**: The structure of our server

including what it had at the beginning, including its sword. We handled this by excluding eating as a valid agent input later.

### 5. GAME SERVER

The server is a Python script which runs both the Nethack executable and the agent script as sub-processes and passes inputs between them. Nethack is run in a terminal emulator so that the screen is simulated in the correct dimensions. In order to reduce the dimensionality of the action space, the list of possible actions was trimmed down from nearly the entire keyboard to just the following 14 commands:

| > | previous level |
|---|---|
| < | next level |
| k | move N |
| u | move NE |
| l | move E |
| h | move SE |
| j | move S |
| b | move SW |
| h | move W |
| y | move NW |
| . | rest |
| o | open door |
| s | search |
| ^D | kick |

These limited commands are enough to advance through the vast majority of levels despite not handling complex game mechanics, like weapons, armor, food, text-based commands, shopkeepers, and other inventory items. The server

automatically advances through all dialog options and selects the locations of doors for opening and kicking. When the server needs a move, it sends a 9x9 player-centered board, the player's health, and the player's current level to the agent and receives one of the fourteen moves from the list. Since this is the only interaction between the server and the agent program, the agent can be swapped out for a deep learning agent or a hard-coded one.

Figure 2 outlines our server. The server runs the NetHack executable, providing it with game inputs and receiving back the console screen. It then communicates the game board and information to the agent, who responds with a command to issue to the game.

### 6. REINFORCEMENT LEARNING AGENT

We implemented two different agents using Q-learning: the first with a simple single-layer feed-forward neural network, and the second with a deep recurrent neural network. We used TensorFlow, an open-source library by Google, to construct our neural networks.

#### 6.1 BlueHive Server

BlueHive is a Linux server with additional GPU nodes integrated with Tensor-Flow. We used it to run NetHack and train our deep learning neural network.

Running NetHack on BlueHive:
1. Download the public NetHack

repository from `https://github.com/NetHack/NetHack`.
2. Modify the HACKDIR in `sys/unix/hints/linux` to store it where the game will be installed.
3. In `sys/unix`, run `setup.sh` with argument `hints/linux` (the file that was just modified).
4. Back in the top level directory for NetHack, enter 'make install'.
5. There should now be an executable in the directory specified. Run it!

Using TensorFlow on BlueHive:
1. TensorFlow is already downloaded in BlueHive.
2. Prefer to use TensorFlow with Python.
3. TensorFlow should be imported in the code.
4. Type '`module load python`' and '`module load TensorFlow`' and then run the Python code.

#### 6.2 BlueHive Server

We mainly used the Q-learning algorithm, which is a family of the reinforcement learning algorithm used to optimize the reward.

#### 6.2.1 Q-Value

BlueHive is a Linux server with additional GPU nodes integrated with Tensor-Flow. We used it to run NetHack and train our deep learning neural network.

Running NetHack on BlueHive:
1. Download the public NetHack

$$Q(s,a) = r + \gamma(max(Q(s',a'))$$

Q-value is the optimal state-action value. The Q-value of given state and action is calculated as the sum of the current

reward and the maximum discounted future reward expected according to our future state. This discounted value determines how important the future reward is compared to the current reward.

For a given Markov Decision Process, we can update and find the Q-value and the optimal policy, which returns the action with the highest Q-value, by iterating through every state-action pair of the agent.[1]

#### 6.2.2 Q-LEARNING ALGORITHM AND DEEP Q-LEARNING

The Q-learning algorithm is an adaptation of the Q-Value Iteration algorithm for the situation where the transition probabilities and the rewards are initially unknown. Assuming that the agent always acts optimally, the algorithm computes the sum of the average reward it receives from the current state-action pair and the reward it expects, and then takes the maximum of the Q-value estimations for the following states.[1]

However, it is hard to keep track of all Q-values given a large state-action space like that of the NetHack. As a result, we decided to use an approximate Q-learning algorithm, known as deep Q-learning, to estimate the Q-value. Since the action space is discrete, we used a multi-layer neural network, which will be discussed later, to implement the algorithm. Note that we did not use the double Deep Q-Network as DeepMind mentioned in its paper about DQN, which was published in Nature,[2] but we do think it could be a potential future improvement to our implementation.

#### 6.3 NEURAL NETWORK

We constructed two neural networks: a simple single-layer feed-forward one and a multi-layer deep one to implement

both the Q-learning and Deep Q-learning algorithms. We used TensorFlow to build our neural networks.

#### 6.3.1 TENSORFLOW

TensorFlow is an open-source library by Google used to create neural networks. The core program of TensorFlow consists of two sections: one to build a computational graph and another to run it.[3]

To build the computational graph, which is essentially the network, we can use placeholders, which are promised to later provide a value to represent the inputs, variables, and other parameters in the network, such as weights and biases. After having declared the placeholders, we can link other components of the network to the declared variables by using mathematical operations, such as matrix multiplication.

Figure 3 is part of the "building computational graph" section of our multi-layer neural network. We construct our network before initializing any variable in the network.

After building the structure of the network, in order to actually use and evaluate the neural network, we must run the graph that we just built in a session which "encapsulates the control and state of the TensorFlow runtime"[3] by calling the "session.run()" method. There are two parameters in the "session.run()" method: the list of outputs to be returned and the feed dictionary. Normally, the variables referred in session.run() are declared through the building graph process, and the feed dictionary usually maps the input variables to some actual input data.

For example, in our implementation, in order to obtain the action chosen for the next step and the vector of all Q-values for the applicable actions, the

program calls the session.run() method with the lists of "predict" and "Qout" variables, which represent the predicted action and the vector of output Q-values, respectively, and the feed dictionary of input vector x mapping to the preprocessed neighborhood game board. `a,allQ = sess.run([predict,Qout], feed_dict={x:nb})`

#### 6.3.2 SINGLE-LAYER Q-LEARNING NETWORK

Our first attempt at implementing a reinforcement learning algorithm on NetHack is to build a simple single-layer neural network with the Q-learning algorithm. We referenced the "Frozen Lake" problem and its Q-network solution[4] to construct our network.

In this network, we considered the input as the whole game board, which is a 25 by 80 matrix, with the entries of integer ASCII code and the outputs as the 14 applicable actions.

Since there is no hidden layer, the neural network is not expressive enough to handle a complicated problem like a NetHack game. Additionally, since the input space is too large in this case, the training process took over several hours to complete.

As a result, for the concern of the learning performance and running time, we decided to implement a more complex but better performing model - a deep recurrent Q-learning network.

#### 6.3.3 DEEP RECURRENT Q-NETWORK

We constructed our deep recurrent Q-learning neural network by using one (radius*2 + 1)$^2$ input layer, one Long Short Term Memory cell, two hidden layers each with 2(radius*2+ 1)$^2$ nodes, and one output layer.

For the input layer, the network feeds the 'neighborhood' of the player into the first layer. For our training, the neighborhood is a square centered around the player with a radius of 4. This means we have $(4*2 + 1)^2 = 81$ input nodes. Each input node takes one of the ASCII characters from the game board.

Then, we perform the one-hot encoding on the input layer and unstack it into a list of integers. To do so, if the ith input node is one of the following characters: -, |, ., #, >, <, +, @, $, ^, ),
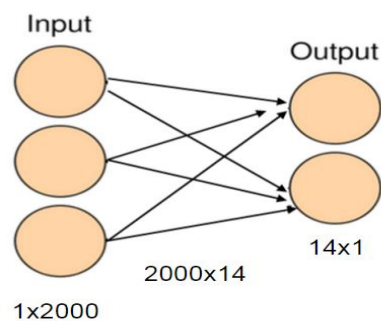
```
x = tf.placeholder(shape = [None,n_input], dtype = tf.int32)
x_one_hot = tf.one_hot(x, n_item)
rnn_input = tf.unstack(x_one_hot, axis = 1)
Wr = tf.Variable(tf.random_normal([n_rec, n_hidden_1]))
W2 = tf.Variable(tf.random_normal([n_hidden_1,n_hidden_2]))
W3 = tf.Variable(tf.random_normal([n_hidden_2,n_action]))
layer_rec = tf.contrib.rnn.BasicLSTMCell(n_rec)
rnn_output,final_state = tf.contrib.rnn.static_rnn(layer_rec, rnn_input, dtype = tf.float32)
layer_1 = tf.matmul(rnn_output[-1], Wr)
layer_1 = tf.nn.relu(layer_1)
layer_2 = tf.matmul(layer_1, W2)
layer_2 = tf.nn.relu(layer_2)
Qout = tf.matmul(layer_2, W3)
predictList = tf.nn.softmax(Qout)
predict = tf.argmax(predictList,1)
```

**Figure 3**: Our multi-layer neural network

**Figure 4**: Visualization of our single-layer-Q-learning network

[, %, {, e, x, ' ', then it is encoded as a vector with the ith entry being from 0 to 16, otherwise it is encoded with the ith entry as 17. Those 17 characters are the important items on the game map, i.e. open spaces and doors. More specifically, the characters "e" and "x" represent the only two monsters that can appear in the first six levels - the Floating Eye and the Grid Bug. Then, the 81*18 matrix was unstacked into a list of integers and used for the next layer.

Unlike DeepMind's deep Q-network, which uses a memory replay technique that keeps track of previous k steps of experience in a deque list and randomly samples a batch of experiences from the replay memory, our network uses a LSTM (Long Short Term Memory) cell instead to make the agent able to 'remember' its previous experiences. We chose LSTM because it is the game running the agent, not the agent running the game; the latter situation makes it difficult to keep track of experiences among different episodes.

The LSTM cell comes in between the input layer and the first hidden layer. We used the TensorFlow basic LSTM cell for our network. The cell takes a list/sequence as its input, for which we used the static model. In future experimentation, we can also try the dynamic model, which will possibly be more efficient, as it allows TensorFlow to create the graph dynamically at execution time.

We have two other hidden layers besides the LSTM cell. These two hidden layers each have double the nodes that the input layer has (162 nodes in our training case). All layers are fully connected to the input layer, the output layer, and to one another. We used the rectified linear

activation function for both hidden layers.

In the form of a set of 14 output nodes, each corresponds to a different action. These actions are: level prev, level next, move N, move NE, move E, move SE, move S, move SW, move W, move NW, rest, open door, search, and kick.

Each action's node holds a Q-value, and the node with the highest Q-value has its action selected. There is a small probability (about 0.01) of the algorithm ignoring the result of the network and choosing an action completely randomly. We used the Adam Optimizer, which uses the moving average of the parameters, and therefore, a larger effective step size compared to a normal gradient descent optimizer. The loss function we chose is the reduced sum of the L2 function of the difference between the theoretically maximized Q-value calculated from the next step, and the current Q-value for each node:

$$\sum_{i=1}^{m}((r_i + \gamma \times \max_{a'} Q(s'_i, a')) - Q(s_i, a_i))^2$$

where si, ai, ri, and s0i are the state, action, reward, and the next state, respectively, is the discount (which is 0.99 in our training case), and m is the number of applicable actions.

### 6.4 REWARD FUNCTIONS

Our initial reward function only accounted for current HP, player level, and whether the agent has died or not. This function was reward = `HP + (level 1)*1000*1000000000death`, where HP is the character's current HP, level is the level it is currently on, and death is a boolean that is either 0 or 1, depending on whether or not the agent died on the previous action. Implementing this function led to excessively conservative



**Figure 5**: Visualization of our deep recurrent Q-network

play and resulted in an agent who did not progress, but instead, tried to stay alive for as long as possible. Because of this, we modified our reward function to `hp + mapCharactersSeen + 10000*level*1000death`, where mapCharactersSeen is the number of non-blank characters in the game map. This value increases as the level is further explored, so the agent would learn to favor exploring a level.

### 6.5 RESULTS AND DISCUSSION

In order to track the execution and training of our agent, we output various files, such as an individual per-episode file that tracks location, a file that stores the number of steps it takes on each episode to represent its survival time, and a file that holds the sum of rewards from each episode. We trained our network on the BlueHive servers using their gpu clusters so that it could train faster than with normal hardware.

For each episode, we allowed a maximum of 900000 actions, even though during each of our trials, the character died before this number was reached. In total, we did approximately 150 episodes, in about 20 hours, to train our network.

From the graphs above, we can see that the reward graph and the step graph have very similar shapes. Although they are quite inconsistent, the peaks of the rewards and of the steps get higher over time. This means that the agent is learning and is trying to find better actions. NetHack is a complicated game, and we needed a very long time to train the machine. However, we trained it for just several hours, and therefore, it could not move for better rewards at that point.

Looking at Figure 6, we can notice

a few different features. First, we see that the agent seemed to have learned something significant on episode 60, resulting in much better performance in the following episodes. Additionally, we notice many peaks of around 1(10^6), 2(10^6) and 3(10^6) units in magnitude. These peaks suggest that they occur when the agent progresses to the 1st, 2nd, and 3rd levels, respectively.

Figure 6 looks incredibly similar to Figure 7, with most of the peaks lining up. This may suggest that the limiting factor in progression is not the agent's knowledge of how to traverse the map, but rather, is the number of steps it takes before it dies. This may not be true for higher levels, but for at least the first few, it seems that as long as the agent stays alive and continues to conduct actions, it will keep progressing through the game.

Figure 8 is essentially the same as Figure 6, but instead of plotting out the reward of each episode, we have averaged the rewards for every ten cycles. At the beginning, the graph moves up and down, but after episode 60, retains a similar shape but with much higher values. This shows that agent needs more trials to learn and improve, and therefore, we believe that we need more time to train the agent for it to have better performance. This graph also shows us that there is some sort of noticeable improvement after the major improvement at episode 60, but this improvement comes at a much slower rate. Something interesting to note is that before episode 60, our agent improves, but then loses those improvements twice before regaining knowledge of these improvements across many episodes.

### 7. HARD CODED AGENTS
#### 7.1 RANDY

Randy is our random agent. He picks his actions randomly.

In Figure 9, we can see that Randy performs some stupid and pointless actions. Therefore, the highest level reached by Randy was only 1.

#### 7.2 GRYLLS

Grylls's goal is to survive for as long as possible. Therefore, Grylls will try to avoid actions that will harm his health or points, including kicking walls and moving closer to enemies.
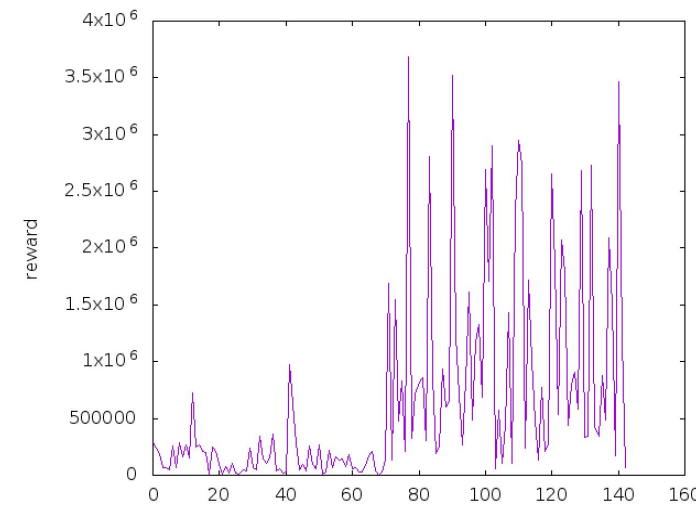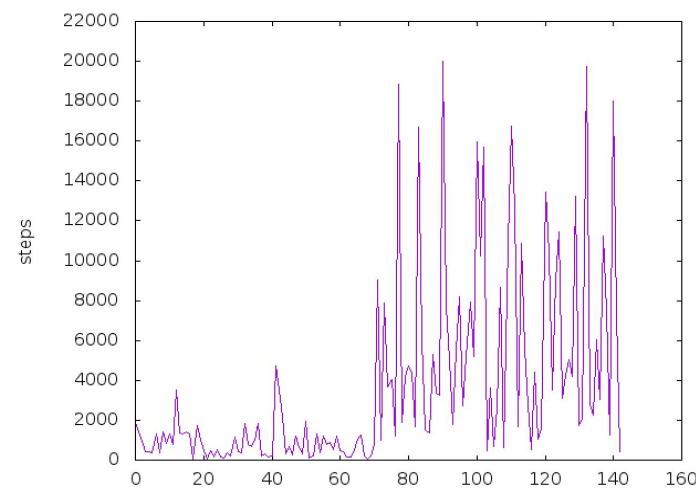


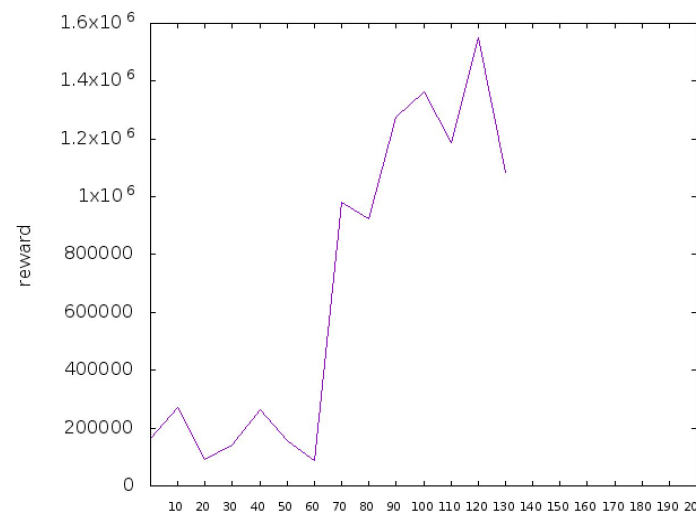**Figure 6**: Graph of rewards



**Figure 7**: Graph of steps



**Figure 8**: Graph of reward for every 10 steps
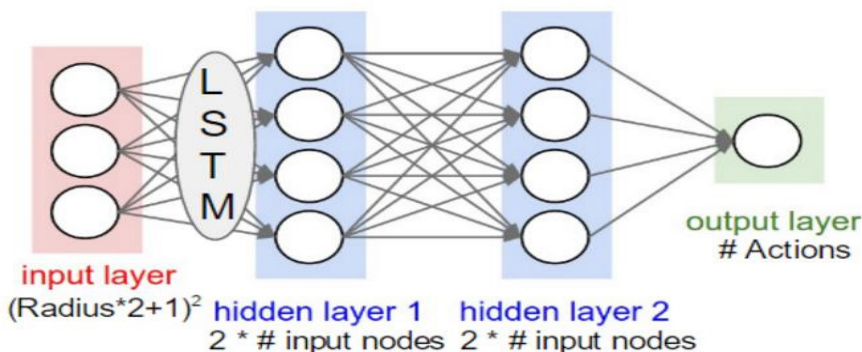
**Figure 9**: Screenshot of Randy's actions

He can also attack the Grid Bug monster if he finds that the monster is adjacent. Compared to Randy, Grylls ends up with a lower seen cell count, but a higher HP value.

The highest level reached by Grylls was also 1 (same as Randy).

However, if we used the metric `"HP + map_characters_seen + 10000 * level - 1000 * death"` to compare performance, Randy performs better on average. Grylls ends up having the same number of levels and deaths, and a slightly higher HP with fewer seen cells.

*7.3 Theseus*

Theseus always follows the left wall of the game. If Theseus is positioned in the same vertical or horizontal line as the stairs, he will move towards them. However, since Theseus cannot remember the path that he has traversed, he can easily become stuck in a loop in a particular environment and may not be able to explore fully.

The furthest level he reached was 4.

*7.4 Dora*

Dora is the best hard-coded agent we have developed so far. Dora can remember all of the places she has previously been to (on the entire map) and can pick the least visited of the 8 adjacent spots at each step. Unlike Theseus, she can try to break the loop since she remembers how many times she has been to a particular place. She is more adaptive and unpredictable than Theseus is, but can still get trapped.

The deepest level she can get to is 7!

**8. Discussion and Future Work**

*8.1 Discussion*

Comparing the performance of the agent created from 20 hours of reinforcement learning to that of agents created using hard-coded strategies, it is quite clear that the latter are superior. The former performed better than the random agent and the Grylls agent, comparably to Theseus, but worse than Dora. Although the reinforcement learning agent learned some basic self-preservation techniques, such as not kicking walls, kicking Grid Bugs, and moving around the floating eye, it still seemed to do something that caused it to die before progressing further. It is likely that the cause was starvation, meaning that the moving techniques used by Dora are much more efficient than those used by the reinforcement learning agent.

Although we trained our agent for 20 hours, it was only able to train over 150 episodes, which, for a network of our size, is not much time. It is possible, and even likely, that given more training time, the reinforcement learning agent could surpass Dora. If it could, it would run into a similar slowdown that Dora did; it would have to learn how to deal with many new enemies that only appear on the 7th floor and beyond.

*8.2 Future Work*

For a reinforcement learning agent, increasing the training time is necessary for creating a better agent. 20 hours' game playing is not even sufficient for a human player to achieve high performance in some difficult games. Our network is still being trained on BlueHive and we are looking forward to seeing future results with further training.

Another important modification

we could make on our reinforcement learning model is trying to implement double DQN, as in DeepMind's deep Q-network.[2] In their model, the actor network and the critic network are kept separate, so that these two networks might prevent the agent from being stuck in loops - a problem that is observed in both our simple and deep Q-learning networks.

The agent may be further modified by implementing the k-fold memory replay and comparing it with the LSTM cell. A dynamic model on the LSTM cell is also worth introducing.

*8.3 Future Hard-Coded Agent: Dijkstra*

Dijkstra is an agent that implements strategies of finding the shortest path to unexplored cells. Our other agent, Dora, keeps track of the cells she visited and looks at the adjacent 8 spots to select the one she visited the least. She might not be able to visit new spots because she only looks at adjacent spots at each step. Dijkstra, however, will also remember the entire map, as well as unexplored cells. He will pick the closest unexplored cells and will use the search method to figure out the shortest path route to them. We expect Dijkstra to be able to get to level 7 often.

We have made progress on some code for Dijkstra (he actually uses a form of mini-max that just maximizes at each step, rather than Dijkstra's Algorithm). However, it does not perform well and crashes fairly often, to the point that this comprises future work, rather than a working version. This is largely because the map is very difficult to model.

Humans can easily look at the map and identify where the rooms are and where their boundaries and doors are, but this is more difficult for the agent. For example, the character '|' often denotes a side wall, which cannot be walked through, but the same character in the middle of the top wall is a door. Simply using neighboring characters to classify them is very difficult because of the large number of edge cases.

**9. Github Repository**

All of our code is accessible at : `https://github.com/ShirMaimon/NetHack`

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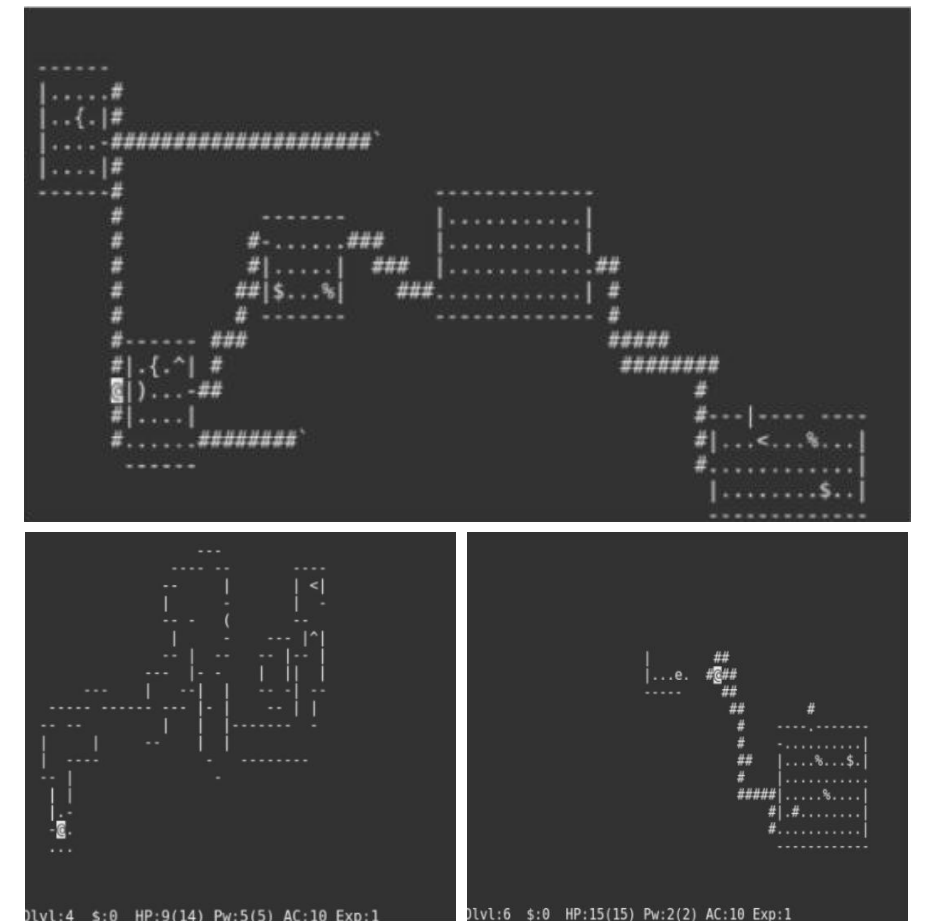
**Figure 10**: Screenshot of Theseus' actions



Figure 1: Screenshot of Dora's actions