As a sophomore in college, I took on the task of convincing one hundred over-scheduled undergraduates to complete four weekly hours of work in our dining cooperative. I loved the intellectual challenge of coordinating scheduling conflicts and creating rules to incentivize cooperation. Moreover, nothing is as satisfying to me as the impact that my skills can have on my community and the world at large. In my pursuit of a PhD, I research topics in Algorithmic Game Theory (AGT) for which a provable solution suggests mechanisms for use in the real world. Since my days in the co-op, I cultivated a strong background in math and theoretical computer science through coursework and an array of research experiences. In addition, in my first year of graduate work at the University of Washington (UW), I developed a research vision and acquired the analytical tools to see it through.

Theoretical computer science aims to characterize the tradeoff in algorithms between optimality, run time, and storage space. In the age of the Internet, an additional concern is the honesty of our input, which is collected from diverse self-interested users. AGT studies this extra tradeoff by considering an algorithm's performance in the presence of individuals who treat the process as a game, strategizing how to play it. The additional set of constraints necessary to make an algorithm robust to selfish individuals makes finding a solution to the problem particularly challenging. This challenge—combined with the space of real-world problems that AGT is suited to solve and understand—is what makes the field so interesting to me.

I plan to use AGT to realistically model and understand real-world problems with strategic input. I am interested in approaching this from two directions. First, I am interested in problems "in the wild," such as those arising in Bitcoin, distributed systems, and computer security. Second, much of known auction theory makes unrealistic modeling assumptions in order to develop elegant mathematical solutions, but I feel this loses sight of the point of AGT. For example, we typically exclude the possibility that a left and right shoe could be more valuable sold as a pair than separately. Similarly, we generally assume the auctioneer has precise knowledge about the specific bidders in advance and can tailor the auction to them. I aim to extend auction theory beyond these overly restrictive assumptions. I want to emphasize that this agenda is a large undertaking; I plan to pursue it over the course of my career.

Undergraduate Background and Research: I developed my strong foundation in math and computer science at Oberlin College. In a community where the professors are so heavily invested in undergraduates, I developed close relationships with my professors, leading to my independent study in advanced algorithm design with Professor Alexa Sharp. On the research front, after performing original research for my optimization course project (on constraint programming in puzzles), the class professor Bob Bosch invited me to join one of his research projects, resulting in a semester of forming and solving optimization problems to make art. Oberlin's intimacy taught me to fully pursue the questions that pique my curiosity, and provided me with the confidence to seek out guidance from and collaborations with even the top researchers in AGT, a skill that is serving me well in my graduate career.

After exhausting Oberlin's math curriculum, I studied abroad at the Budapest Semesters in Mathematics program, learning from Hungarian combinatorics experts. To broaden my research experiences, I spent two summers at NSF Research Experience for Undergraduates (REU) programs intensively working on research projects in game theory and automata theory.

At Ohio Wesleyan's REU, Professor Sean McCulloch and I examined a connection cost-sharing game, a formal model of individuals who want to minimize their commute time from home to work and have the option of carpooling. The initial problem was: what heuristics give a stable solution (Pure Nash Equilibrium) that approximately minimizes total congestion? My curiosity led me to pose other interesting questions as well: how can we maximize fairness, reducing the worst travel time of any individual? How can we find a solution robust even to collusion amongst individuals? **I developed heuristics that answered all of these questions, resulting in a publication** [3] and two presentations at regional undergraduate conferences.

At the UNC Greenboro's REU, my partner and I discovered that compressing a deterministic finite automaton into a new model called a ^-DFA is NP-Hard, but we gave a 3/2-approximation algorithm for this problem. Hence, **we can exponentially reduce the number of states but still use deterministic computation**. We published at CIAA[1] [1], a top automata theory conference; I traveled to Germany to present our work to top researchers in the field.

Graduate Research Progress: At UW, I am working with Professor Anna Karlin to address questions pertaining to incentives in Bitcoin. In this distributed electronic market, individuals called "miners" compete to record a set of transactions in a "block," extending an existing chain of blocks that forms a discretized transactional history. An incentive-compatible distributed agreement protocol is essential for the security of Bitcoin itself—otherwise, there will not be universal agreement on the transaction history and thus on who owns which Bitcoins. Unfortunately, miners can benefit by ignoring this protocol, with respect to extending the block-chain [2] and, **as we have discovered in our work, by dishonestly extorting fees from Bitcoin users by selectively including transactions**. We are working with computer systems expert Professor John Zahorjan to better understand the behavior incentivized by the current protocol and to come up with modifications to incentivize rule-following. Beyond Bitcoin, this protocol could be widely useful both for distributed systems and security protocols for multi-party communication. What makes this problem so interesting and challenging is that we can only verify if a miner is following the rules for some parts of the protocol, and the extent to which the rules even exist depends on the agreement between the majority of the miners. I have presented our partial results in posters at CRA-W Grad Cohort and a local undergraduate recruiting event.

In a different project, I am collaborating with a Cornell student to design single-item auctions that maximize the seller's revenue when the buyers' valuations are correlated. The bulk of the literature on revenue-optimal auction design assumes that each bidder's value for an item is unrelated to the others. We are working to extend the single-item revenue maximization theory for the following setting: n online shoppers live in a ZIP code that indicates to advertisers a higher likelihood of purchase, but they have individual shopping tendencies, and advertisers cannot precisely separate these components. **We have already found the optimal auction**, but it requires the computationally expensive calculations of conditional distributions. We are now looking at simple auctions that give good approximations in this setting.

Finally, I am making progress on designing mechanisms that are not dependent on precise knowledge of the bidders in an auction. I describe this setting in detail, my plans for my project, and my preliminary results in my Graduate Research Plan.

In addition to these research projects, my graduate study thus far has helped me develop a strong understanding of existing analytical tools that will be useful in solving these problems. An intense combination of coursework, seminars, and reading groups has taught me cutting-edge algorithmic techniques in randomization, spectral theory, machine learning, and linear and semi-definite programming. I am eager to apply these techniques from the more mature field of algorithm design to the newer field of AGT.

Taking Initiative: This semester, I am an invited visitor at the Economics and Computation program at the Simons Institute for Theory of Computation located at UC Berkeley. Here, I have found collaborators among the other visiting graduate students, post-docs, and faculty, including

[1]Conference on Implementation and Application of Automata 2014

some authors of the work I plan to extend: Amos Fiat and Elias Koutsoupias. I am now well positioned in the research community where I aim to contribute my work.

I spent my free time in my first year teaching myself two graduate courses on AGT from Stanford, working through textbooks, closely reading myriad papers in the field and presenting these concepts to my peers to solidify my understanding. I also received travel awards, allowing me to attend STOC, CCC, and EC[1] to learn about the state-of-the-art and make connections with other theory researchers for future collaborations. I intend to continue working with a diverse set of collaborators to have the proper balance of experience and perspective to solve open problems. I hope to use my newfound connections to the top researchers in this community and the NSF Graduate Research Fellowship to visit and work with them through the remainder of my PhD. **These experiences demonstrate that I seek out and make the most of the opportunities available to me, and as such, I am well poised to make use of the funding that the NSF Graduate Research Fellowship would provide me.**

Supporting Diversity: As a woman in STEM, I have had my share of experiences in which I have been underrepresented, and even actively discouraged. It was the support and encouragement of highly skilled and dedicated educators and research advisors that inspired me to overcome these situations and pursue my goals. As a result of my own experiences, I am committed to fostering a more diverse STEM workforce through mentorship and education.

I founded and co-chaired Oberlin's Women in Math and Computer Science group, and I am the current co-chair of UW CSE's Graduate Women's organization. At Oberlin and UW, I have **facilitated discussions** about diversity and efforts for inclusion: regular meetings in women's groups, department-wide conversations about improving the community and classroom dynamics, and an email list for sharing resources. I have focused on **education**, serving often both at Oberlin and UW as a Teaching Assistant, which allowed me to reach students interested in pursuing careers in computer science. I interned at an inner city Chicago public school where I transformed standardized math test preparation into an engaging game. I also taught puzzles and card games to encourage students to improve their problem-solving skills in their free time. I am also invested in **mentorship**: arranging panels to help women at Oberlin apply to both research and industry opportunities, assigning graduate women mentors for undergraduate women, soliciting feedback to improve the effectiveness of the first-year graduate student mentoring program. Last summer, I mentored an undergraduate from Smith College, helping her to pose relevant but tractable questions for a summer-long project.

Future Goals: I am pursuing a career in academia, where I will have the privilege to continue producing theoretical solutions for real problems, where I can communicate both my research and the foundations of theoretical computer science to a wide audience, and where I can mentor and encourage the next generation to join the ranks of the STEM workforce.

Conclusion: My strong background in mathematics and theoretical computer science combines with my prior successes in theoretically solving real problems to make me an ideal candidate to contribute to the Algorithmic Game Theory research community. I aim to relax the unrealistic constraints that existing auction theory requires to broaden its applications and better our understanding of a wider array of instances. I have the passion and skill to find solutions to the incentive problems facing software design, the internet, and computation in general.

References:

[1] F. Blanchet-Sadri, **K. Goldner**, A. Shackleton. "Minimal Partial Languages and Automata." *CIAA*, 2014.
[2] I. Eyal and E. G. Sirer. "Majority is not enough: Bitcoin mining is vulnerable." *Financial Cryptography*, 2014.
[3] **Kira Goldner** and Sean McCulloch. "Different Optimal Solutions in Shared Path Graphs." *MCURCSM*, 2012.

[1]ACM Symposium on Theory of Computation, Conference on Computational Complexity, and ACM Conference on Economics and Computation – 2015