Designing an Updated System for Time Lapse Microscopy to Study *Toxoplasma gondii* Invasion in Intestinal Epithelial Cells

(Technical Paper)

The Grocery Gap in America:
How segregation policies of the past live on through the inequality of food accessibility

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

While the majority of households in the United States are food secure, there is still a minority of roughly 10.5% of households that are food insecure (*USDA ERS - Food Security and Nutrition Assistance*, 2020). The United States Department of Agriculture (USDA) defines food insecurity as "a household-level economic and social condition of limited or uncertain access to adequate food" (*USDA ERS - Definitions of Food Security*, 2020). Most Americans who are food insecure, and thus lack access to healthy foods, also fall below the poverty line (Murthy, 2016). Related to food insecurity is food safety, including prevalence of foodborne illnesses. One of the leading causes of death in the U.S. attributed to foodborne illness is toxoplasmosis, a disease caused by the infectious parasite *Toxoplasma gondii* (*CDC - Toxoplasmosis*, 2019). Even though it is estimated that roughly one third of the world's population is infected with *T. gondii* and does not show symptoms, the parasite can cause serious complications in pregnant women, as well as immunocompromised individuals, including those with inflammatory bowel disease (IBD). The technical project involves collaboratively designing an environmental chamber that will allow for live cell imaging with a microscope during experimentation with *T. gondii*. This imaging will provide data for understanding the relationship between the parasite *T. gondii* and epithelial cells representing the intestinal wall.

Issues of food insecurity are related to social determinants of health, conditions that people endure throughout life and are affected by social, political and economic factors (Islam, 2019). Food insecurity is also associated with the grocery gap, which describes the disparity of access to healthy foods between communities across America, specifically due to a lack of supermarkets and grocery stores in lower income neighborhoods (*The Food Trust | The Grocery*

Gap, n.d.). The proposed research paper will look into the history of housing segregation and districting policies, such as redlining, that provide evidence of why this grocery gap exists, especially for racial and ethnic minorities, and why households below the poverty line are food insecure. In this era of a global pandemic, racial and ethnic minority groups have been hit hard in all aspects, food security included (Webb Hooper et al., 2020). Therefore, it is especially important now to understand the historical policies behind why food insecurity exists where it does and how these policies currently affect people.

Technical Topic

Inflammatory bowel disease (IBD) is an umbrella term used to describe Crohn's disease and ulcerative colitis, both of which can cause extreme discomfort and debilitation. This disease affects roughly 6.8 million people worldwide, with the United States having ones of the highest prevalence rates in the world (Alatab et al., 2020; Kaplan, 2015). This disease impacts muscular contractions of the intestine, commonly referred to as peristalsis. (Alatab et al., 2020; Fakhoury et al., 2014). Studies have shown relationships between gastrointestinal motor disorders and infectious parasites, such as *Toxoplasma gondii* (Halliez & Buret, 2015). It is estimated that roughly 30% of the world's population is infected with *T. gondii*, yet the majority of people are asymptomatic (Kato, 2018). However, *T. gondii* infection still poses a high risk to immunocompromised people, those with IBD, and pregnant women.

The current standard of care for these patients includes antimalarial drugs and antibiotics; however, for those with compromised immune systems, this treatment plan is not effective. In fact, these immunocompromised patients have a 40-80% chance of relapsing after treatment and about 50% of patients experience severe adverse side effects (Fung & Kirschenbaum, 1996).

Thus, while treatments exist for this potentially life-threatening illness, more research must be done to develop safe and effective treatment options. Along with this motivation for improving care for patients, a better relationship between *T. gondii* invasion and the health of epithelial cells (such as those that line the intestine) must be understood. While it is known that diseased cells have a distinct cobblestone-like appearance that is unlike the normal columnal phenotype of gut epithelial cells, it is unknown how this cell structure contributes to the increased susceptibility of *T. gondii* invasion in IBD patients (Booth, 1970). A mechanobiology-focused approach is required to determine whether *T. gondii* invasion is a consequence of the non-stretch adapted epithelial cells associated with the disease state, or whether *T. gondii* invasion produces the diseased cell state.

Experimentation by the research team will involve stretching epithelial cells using a stretch device that mimics the contractile movements of the intestine and infecting the cells with *T. gondii*. Currently available stretch devices, such as the Cytostretcher from CuriBio and the StageFlexer from FLEXCell, are insufficient for the goals of this project due to the high cost, poor microscope resolution, and suboptimal microscope protection. In order to study the interactions between living parasites and host cells in real time using live-cell microscopy, the cells must remain in an environmental chamber that mimics physiological conditions. *T. gondii* invasion rates, epithelial cell responses and structural dynamics can all be analyzed with this imaging technique and the presence of an environmental chamber.

Therefore, the primary goal of this technical project is to design an environmental chamber in which the relationship between *T. gondii* invasion and the health of epithelial cells will be observed. The team will design a 3D printed enclosed chamber using AutoCAD that will

serve as a mountable microscope incubator. Specifications such as maintaining incubator conditions and protecting the microscope will be incorporated into the design and will allow the team to conduct accurate experiments in an efficient manner that produce consistent data. Dr. Brian P. Helmke in the University of Virginia Department of Biomedical Engineering will serve as the team's technical advisor, who will provide guidance and support throughout the design process. Once an environmental chamber is produced, cells can be plated, infected with *T. gondii* and stretched based on mimicking diseased or healthy cells. Invasion mechanisms will be observed, and effective research will be done to understand the relationship between *T. gondii* and intestinal diseases like IBD. A final technical report will be written by the research team that will compile findings based on the success of the chamber and results of the *T. gondii* experiments and thus evaluate the role of this parasite in host cell invasion. Due to the COVID-19 pandemic, the team has not been able to observe the lab equipment or perform any in-lab experiments. It is highly likely that this will remain the case in the spring semester, in which case the team will focus primarily on the research and design sections of the project, rather than testing. Dr. Helmke, as the lab head, will be able to test the team's environmental chamber design and report back with findings that the team will analyze.

STS Topic

In the United States, it is estimated that roughly 2.3 million people are living in what is called a food desert, meaning that this population does not have a supermarket within one mile of their home if they live in an urban area, or within ten miles if they live in a rural area ("The Grocery Gap," 2018). This lack of food access typically means these people have a much harder time buying fresh foods because they must travel longer distances to reach that type of food. If a

household lives in one of these food deserts, it is also very likely that they are food insecure and fall below the U.S. poverty line. Food insecurity means that a household does not have consistent access to enough food for an active, healthy lifestyle due to a lack of financial resources to acquire this food (*What Is Food Insecurity in America?*, n.d.). In 2019, roughly 35.2 million Americans, including 5.3 million children were food insecure (*USDA ERS - Key Statistics & Graphics*, 2020). Additionally, 40% of Americans with incomes below the national poverty level are also food insecure (Murthy, 2016).

The issues of food deserts, food insecurity and poverty levels all play into the term "grocery gap." This term refers to a lack of supermarkets, selling healthy and fresh foods, in low-income areas compared to higher income areas. Convenience stores and fast-food restaurants are much more common in these areas than supermarkets. Reasons such as high insurance rates for supermarkets in high crime areas, and trouble dealing with business fluctuations due to the food stamp program (SNAP) schedule are potential contributors to this gap. The grocery gap disproportionately affects neighborhoods of color; African Americans are 2.5 times more likely and Latinos are 1.38 times more likely to live in an area without full-service supermarkets, and thus more likely to suffer effects from this grocery gap, than Whites are (*The Food Trust | The Grocery Gap*, n.d.). One possible cause of the grocery gap that affects Americans of color is the historical policies related to segregation and redlining that were developed in the 20th century and continue to affect people's access to healthy and fresh food.

According to Richard Rothstein, author of *The Color of Law,* federal, local and state housing policies aimed at segregating African Americans and other groups of color started after the Great Depression (Rothestein, 2017). These policies allowed for the refusal of mortgages and

loans to African Americans in an effort to provide white Americans with houses in the suburbs and keep people of color in urban areas. Redlining is a common term used to describe this housing segregation and denial of certain services by federal and local governments by raising prices or denying loans in certain communities (Gross, 2017). While the Fair Housing Act in 1968 made redlining illegal on paper, there is plenty of evidence that these policies still have a lasting effect, particularly on people of color (Rothstein, 2017). This research paper will look at the relationship between housing policies of the 20th century and how their legacy lives on through the grocery gap experienced by low income households, namely African Americans and people of color, in addition to offering a policy-oriented approach to solving this issue.

Just as political policy has negatively shaped our communities and negatively affected people of color to this day, policy creation can serve as a tool to help reverse these inequalities and socioeconomic disparities where they relate to food insecurity and the grocery gap specifically. The federal, state and local governments should look to the past to analyze how policies many may think no longer exist still play a role today. While what is written in fine ink in the Fair Housing Act in 1968 might suggest housing discrimination does not exist anymore, the actions taken by politicians and realities of our communities show the opposite (Fullwood III, 2015). Housing segregation and redlining policies implemented by governments across the U.S. were, and continue to be, used as political technologies (Winner, 1980). United States policy regarding housing segregation is used to segregate Americans into certain communities, creating effects that relate to education, poverty and living conditions, health and food accessibility. While critics, such as German sociology professor Benward Joerges, argue that the political technologies theory is actually counterfactual, and the story of Robert Moses's low bridges is

simply a “highly successful parable”, the evidence against these critiques is strong (Joerges, 1999). Analyzing how policies in the past were used, and how those policies and other systemic factors continue to be used, as political technologies that affect people’s ability to obtain healthy and fresh foods will be an important step to reversing the damage done and creating new policies that will specifically tackle this grocery gap.

Methodologies

Research Question: How have historical segregation policies, including “redlining,” in America contributed to the current issue of grocery gaps between communities, where lower income neighborhoods have significantly fewer supermarkets than their wealthier and even middle-class counterparts?

Policy Analysis, Historical Case Studies and Literature Review methodologies will be used to answer this question. First, current statistics and facts about the grocery gap in America will be presented. Setting up the current situation relating to this disparity and who it is affecting most (African Americans and people of color) will provide informative background information for the research. Then, the Policy Analysis methodology will be used to study past and present policy documents, such as the New Deal that introduced redlining in the 1930s and the Fair Housing Act in 1968 (Gross, 2017). This method will use quantitative and qualitative methods to analyze policy issues at the federal, state and local levels that have played a role in the current grocery gap (Patton et al., 2012). Then these policies will be analyzed to explain how they have had a lasting impact on communities of color today, specifically through the disparity of supermarkets (*The Food Trust | The Grocery Gap*, n.d.). Additionally, the Historical Case Studies methodology will be used to emphasize the importance of seemingly irrelevant and

outdated policies, events and ideals in the grocery gap. The differences between the obvious, outright segregation of the time and the hidden, implicit segregation today will be carefully evaluated. The gathered sources will be organized in a way that brings to light just how broad and deep these effects are today.

The Literature Review methodology will also be used to study secondary sources to determine what is already known about the grocery gap (Snyder, 2019). It will be important to establish a base of knowledge relating to poverty levels, food insecurity, food deserts and who these three things affect in America. Performing this literature review will help support the idea that people of color are disproportionately affected by poverty and food insecurity and therefore do not have the same access to proper nutrition. Literature explicitly about the effects of segregation and redlining will also be analyzed. Finally, this literature review and policy analysis will be combined to explain how policies of the past have caused the current grocery gap in America.

Conclusion

This proposal discusses the need to design an environmental chamber for studying the invasion of intestinal epithelial cells by *Toxoplasma gondii*, as well as the grocery gap in America due to 20th century policies regarding segregation and housing. The technical research team will design a 3D printed environmental chamber that will allow the study of the relationship between *T. gondii* invasion and host cells that mimic the intestinal walls, while cells are being stretched. The creation and use of a functioning chamber will further understanding of the parasite-cell interactions. Additionally, the team hopes the method of studying this parasite and its relationship with human cells will lead to downstream development of new therapeutics

for diseases like IBD.

Relating to foodborne illnesses, one of which *T. gondii* causes (toxoplasmosis), the proposed research paper covers the socioeconomic and health effects of American policies of housing segregation and how they contributed to the grocery gap experienced by lower income households, especially people of color. Limited access to fresh and healthy foods because of a lack of supermarkets in certain neighborhoods affects people's health, well-being and even opportunities they have access to. It is important to acknowledge the disparities these "policies of the past" have caused for many Americans and how their effects are still felt today through access to something as essential as food. This research will dive into exactly how former American policy lives on today and what the local and federal governments can do to provide more equal access to food and proper nutrition across the country.

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