Resilience and Resistance; Using *Physarum polycephalum* and Community Organizing to Explore Environmental Justice Work

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Abstract

My Division three thesis is about resilience to climate change and the transformation towards more equitable ways of being. Resilience is defined as “positive adaptation despite adversity” (Fleming & Ledogar. 2008, p.1). I looked at the concept of resilience from several perspectives. First I completed a review of resilience as a field of study, along with a reflection of my understandings and learnings as a facilitator for Grassroots Community Organizing under the anthropology department at UMass Amherst as part of the UMass Alliance for Community Transformation (UACT). The second section of my thesis is about sources of community resilience which includes discussion of climate action and resiliency policy, as well as discussion of a survey I created and conducted in partnership with ARISE for Social Justice Springfield, a community led organization founded to advance the rights of poor people. The third section of my thesis is a series of experiments that employ the microbe Physarum polycephalum or slime mold. These experiments document how slime mold is able or unable to model resiliency.

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Resilience and Resistance; Using *Physarum polycephalum* and Community Organizing to Explore Environmental Justice Work

**Introduction**

Unsustainable economic growth and systemic social inequalities create not only endangered environments, but also marginalized communities. We live in a country that is driven by capitalist ideals. Our capitalistic economy survives on growth and consumption but lacks a basis of sustainable use of resources as well as an equitable system of distribution of those resources. Unsustainable consumption of resources fueled by our capitalistic economy has led to a profound disruption of the environment, presenting as climate crisis and is contributing to a profound disruption to our society. Wealth has become concentrated in the hands of the “one percent” and the bulk of impacts to the environment from resource extraction are being born disparately by the less powerful. In *Readings in Ecology and Feminist Theology*, Mackinnon and McIntyre (1995) discuss the idea that “alienation from our bodies, the earth and from our fellow humans is evident. Alienation from the natural systems that sustain our bodies and the earth and opposition to a cooperative culture that allows humans to live peacefully and to thrive is obvious. Our divided society has been unable to develop resilient strategies to solve and to adapt to climate change, but has rather created a class of winners and losers that is further marginalizing less powerful communities”. (Page 195) McIntyre and Mackinnon’s (1995) reference to alienation from natural systems is borne out by such recent agricultural crisis as the effects of the use of nicotinoid based pesticides associated with the collapse of up to forty percent of the pollinator population, Chensheng Lu (2014) and a mass extinction of species. McIntyre and Mackinnon’s reference to our divided society having spawned “winners and losers’ refers to our governments inadequate response to such marginalized communities as those affected by lead tainted drinking water in Flint, Michigan in 2015, the delayed emergency response that African American and Hispanic populations experienced after hurricanes in New Orleans and most recently Puerto Rico (2005 and 2107 respectively) and the governments further marginalization of the rights of the Standing Rock Sioux tribe over the Dakota Excel Pipeline access in 2016.
It is arguable that marginalized communities are an inherent feature of our society and that unsustainable consumption of resources will be solved as our capitalistic economy rewards technological innovation. Capitalism is resilient in that it continuously survives and grows through crisis after crisis. Alternatively, capitalism is a relatively new and modern change seen as progress while indigenous values have been around longer. There is overwhelming evidence that in the rapid face of the mounting climate crisis, our capitalist economy and our patriarchal society lack the drivers needed to evolve sustainable and cooperative systems in time to divert major global social and economic upheavals. Acceptance of the need to adopt a cooperative and sustainable system to address climate change led 195 countries to adopt the first-ever universal, legally binding global climate deal at the Paris climate conference (COP21), known as the Paris Accord in December 2015. In addition to limiting greenhouse gas emissions governments agreed to strengthen societies’ ability to deal with the impacts of climate change and to provide continued international support for adaptation to developing countries. ([https://ec.europa.eu/clima/policies/international/negotiations/paris_en](https://ec.europa.eu/clima/policies/international/negotiations/paris_en), 2017) The withdrawal of the U.S. from the Paris Accord in 2017 based on the political hubris of, Let’s Make America Great Again, coupled with rolling back federal environmental protections, increasing federal subsidies for the coal industry and decreasing foreign aid etc. underscores that our capitalist economy and our patriarchal society is actively resisting adopting resilient strategies needed to solve and to adapt to climate change.

Inquiry into “resilient” policy, such as is exhibited in the Paris Accord and exhibited by many grass roots organizations focused on climate change has proven to be useful in shifting away from the resistive ideals associated with capitalist and patriarchal societies. I am interested in studying resilient economic policy and resilience in natural systems because climate change adaptation could afford us the opportunity to reimagine oppressive systems and to redirect focus to developing sustainable economies cooperatively. This work has already begun with a core understanding that adaptation policies are political. “Climate change adaptation is an opportunity for social reform, for the questioning of values that drive inequalities in development and our unsustainable relationship with the environment.” (Pelling, 2011, p.1)
The focus of my Division III is to apply concepts of resilience and resistance to social and economic reforms needed to move cooperative and sustainable policies and practices forward; to explore the potential of co-opting a natural system for patterning resilient resource allocation by studying the cooperative physiological adaptations of the single cell slime mold *Physarum polycephalum* and to personally experience working with community organizations focused on creating initiatives to address climate change. Combining these studies will give my arguments a perspective and allow me to position my ideas into the larger picture of environmental studies. I am inspired by the possibility of simultaneously creating a more resilient society and a sustainable environment by shifting away from oppressive, colonialist, and consumerist tendencies and adopting more equitable, sustainable and cooperative policies and practices. Many groups are already working to foster this shift and I hope to highlight a few of those groups, ideas, and spaces. Because the change in global and regional climate patterns has impacted our natural and built environment in increasingly extreme ways community organizers (as well as scientists) are working to understand how climate change is affecting different socioeconomic groups disproportionately. It is now more important than ever to pay attention to groups that seem to thrive and adapt under extreme or adverse conditions. Ecosystems as well as species and groups or communities can adapt and form frameworks of resilience as climatic conditions change. For these reasons, I have combined aspects of environmental studies with microbiology, ecology and community organization in this thesis. I hope to produce a usable body of knowledge in the form of a review and advisory on climate action plans and other resilient focused policy, discussion of using slime mold as a model, and finally reflections on my learnings from UACT that can move grassroots resiliency initiatives forward.

Previously my academic studies at Hampshire College have concentrated on aspects of environmental studies. I synthesized many diverse courses to gain a deeper understanding of what climate change means in a contemporary context. I arrived at college with a passion for the outdoors and an interest in helping others. Although these entry points have remained relevant in my studies, I have delved into a more intellectual, critical, and engaged approach to finding solutions for climate change. This led me to being most interested in environmental justice work. I am especially interested in environmental justice and how various groups are adapting and changing in the face of global climate shifts.
“Environmental/Climate Justice is based on the principle that all people have a right to be protected from environmental hazards and to live in and enjoy a clean and healthful environment regardless of race, color, national origin, income, or English language proficiency. Environmental justice is the equal protection and meaningful involvement of all people and communities with respect to the development, implementation, and enforcement of energy, climate change, and environmental laws, regulations, and policies, and the equitable distribution of energy and environmental benefits and burdens”. - Environmental Justice Policy of the Massachusetts, Executive Office of Energy and Environmental Affairs, 2017 (http://www.pvpc.org/sites/default/files/SHJ_REPORT_FINAL_REV_2017.pdf, 2017, paragraph 1.)

In simple terms, environmental injustices should address who is hit first and worst by pollution and natural disaster. Several fundamental questions helped drive my studies. Specifically, what strategies in adapting to climate change are taking place and imbedded in those strategies are there opportunities to create greater environmental justice? How do specific policies and actions affect not only marginalized peoples but also the precarious ecosystems they rely on? Answering these fundamental questions will help highlight how far the study of climate change has come and what some possible next steps may be.

Overview of Resilience

“I plan to work tirelessly to engage students and the entire community, to be their champion, to elevate the importance of resilience in all its dimensions so we can set an ambitious course for educating future leaders, building an inclusive community, and amplifying Hampshire’s leadership, locally and globally.”

- Newly appointed Hampshire College President Miriam E. Nelson, PhD

Resilience as a Field of Study:

I often wonder how reality, and our day to day lives, would look different if we took steps to create a social and physical world more like “worlds” or systems found in nature. Nature
has the ability to adapt, forming frameworks of resilience as climatic conditions change. One example of this is as global warming happens many flora and fauna’s traditional ranges of residence are shifting away from the equator, towards colder temperatures. Can biological principles be connected to society's ability to adapt? Are the ecological ideas of resilience and resistance relevant in creating policy and informing solutions to societal problems? In what ways are a human community’s resistance and resilience to change comparable to adaptability in nature? Concepts of resilience are often used across fields of study to refer to overcoming adversity or adapting to change. The term is common in many social justice movement as well. Bredenberg (2012) identified the term being used by social justice advocates across political, economic and social spheres to describe the volatile time we all find ourselves in. I find the term of resilience particularly relevant when discussed in relation to social justice movements. To situate my own understandings, this review paper is based on previous and current frameworks of resilience, ecological resilience, biomimicry, community organizing and the concept of emergence.

The development of the concept of resilience is quite interdisciplinary. The concept has ties to the sciences, such as ecology and psychology and more recently within disaster risk reduction and sustainability science. The term also has a connection to the humanities as well as legal and political spheres. The modern concept of resilience has an extensive history of applications and definitions. Alexander (2013), argues that resilience frameworks bridge the gap between static resistance and dynamic adaptation. A system that is resistant is hard to move or change, while a system that is adaptable is flexible and fluid. Concepts of resilience are in relationship with both extremes. Through two schematic diagrams, Alexander (2013) offers a clear historical and contemporary use of the term (figure 1). The figure to the left is a thematic diagram of the development and evolution of the word resilience, based on different schools of thought. The terms where the word was found throughout time are all separate. The link between each field is that the descriptor of resilience means dynamic or changing. Modern use of the work is most directly impacted by environmental studies. This is shown by the figure to the right, which describes the complexity of the contemporary construction of the term. I would add the diagram describes resilience in a variety of conditions for example social and physical, and on diverse scales.
Despite, or maybe due to extensive use across fields of study, the contemporary concept of resilience has fallen short, as a catch all solution for disaster reduction. “It is dangerous – or at least potentially disappointing – to read too much into the term as a model and a paradigm.” (Alexander, 2013, page 1). The term must be used with clarity and care. Like any other scientific concept, the idea has limitations and there are implications of oversimplified or conflated usage. A study completed by Ecology and Society journal identified different types of social-ecological networks. The researchers were interested in the usefulness of employing a network approach to evaluate system effectiveness. Networks have problems that impact their ability to remain resilient to disruptions. The study discussed that using resilience as a measurement was useful. “The concepts resilience, vulnerability, and adaptation are increasingly important for the study of the human dimensions of global environmental change.” (Janssen & Ostrom. 2006, p.13) Although the application of a resilience framework was useful here that is not always the case. Folke, et al. (2010) argue that the strength or capacity for resilience is contextual and depends how prepared or ready a system is for change or disturbance. Concrete transformation requires resilience thinking to understand the qualities of a current formation versus an alternative. To move towards a new direction a formation of resilience practice is important. However, at times resilience frameworks may be more appropriate for preserving systems than transforming them.
Ecological Resilience:

The field of natural science uses multiple definitions of the term resilience. According to Chapin, et al. (2002), resilience in ecological terms, is the cycling of nutrients, energy, water and carbon across macro and micro scales. Resilience is directly related to specific perturbations or disturbances, rather than being considered an absolute property of an ecosystem or for that matter an organism. In terms of the predictable nature of seasonal or diurnal patterns, ecosystems largely recover after each cycle. This is because the seasons are between a set of parameters or within a threshold. However, the loss of a rare species or influx of a pollutant may jeopardize the resilience of an ecosystem. If a pollutant alters the pH of a given area of soil it may alter the resilience of the microbial community that inhabits that soil. In Principles of Terrestrial Ecosystem Ecology, Chapin et al. (2002) discuss how ecosystems themselves can change over time. Ecological resilience is related to plasticity of a given ecosystem. If the ecosystem is plastic and has low resilience that means it may never recover to an original state and is easily altered after a perturbation. As Chaplin, et al. (2002) writes, “The important point is that systems that maintain their properties despite disturbance (i.e., are resistant to change) and that return rapidly to their original state (i.e., are resilient) exhibit more stable and predictable ecosystem properties.” (Chapin et al 2002, p. 283, while discussing the work of C.S. Holling (1986)

The study of the natural world, in particular ecology, allows us to see how ecosystems and organisms, besides ourselves, react to stress, change and influence one other. Elasticity and alternatively stability, over geological time are ideas connected to ecological resilience. There are ecological tipping points, meaning that a system is pushed in one direction past its normal reference state and is no longer stable. Levin (1998) discusses the relationship between evolution and resilience. “Does evolution increase resiliency or lead to criticality? Does it lead to the edge of chaos?” (Levin, 1998, p.435) He was interested to know if evolving towards a tipping point was advantageous to ecosystems. Levin (1998) argues that most adaptation and stimulation of growth happens when ecosystems are in critical or stressed states. Across fields of study it seems that the concepts of change, stress, and dynamic are inherently connected to resilience.
Government/Institutional Interactions with Resiliency:

The following section will discuss how resiliency frameworks influence governments. Interactions, by agencies and institutions, with resiliency frameworks at both federal and local levels have helped develop policy that encourages equitable and sustainable practices. At times, these interactions stem from arguments developed by environmental justice activists and advocates. Connection to resilience thinking has led to more governmental accountability, for example a resiliency plan from the Department of Labor aims to “ensure the training, health, and safety of workers, including minority, Native American, and low-income workers,” (https://www.dol.gov/asp/eyJ U. (2016). Environmental Justice Strategy, 2016, paragraph 2) Climate resilience plans are the most recent iteration of a series of initiatives to respond to climate change.

International agreements are a different type of government action that works to adapt to climate. The first well-known climate change policy agreement like this was the Kyoto Protocol. The historic agreement, signed in 1997, put the responsibility on single actors or countries to cut down carbon emissions. The protocol laid out strategies for how to reduce human-created pollution, but it only included developed nations that voluntarily signed up, this meant the world’s largest polluters China, India and the USA were not on board initially. A resiliency plan from the Environmental Protection Agency (EPA) has put out many statements on environmental justice and resilience. According to the EPA, their goals for all communities and persons across this nation include achieving, “The same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.” (https://www.epa.gov/environmentaljustice, 2018, paragraph 3)
Government action on resiliency policy has been created by the Conference of Parties to the United Nations Framework Convention (UNFC). The UNFC works to support nations in tackling global warming and creating safer, more resilient and prosperous countries and environments.

It is important to pay attention to how institutions and agencies create and implement climate policy. Some environmental protections do the bare minimum to care for people and
other living beings that inhabit the area the law is supposed to be protecting. Unfortunately, there continue to be barriers to creating resilience because the needs of stakeholders at different geographic, spatial, and temporal scales are not being met. However, other diverse organizations and groups are working to address this issue. There are many university and other consultant groups studying and building climate action plans and conducting resiliency research. University of Nebraska and University of Michigan’s Bierbaum et al, (2012) eloquently describe the action that needs to be taken at local and national levels to create change.

Managing U.S. water resources such as the Great Lakes to address reduced lake levels, managing the Columbia River so that it can adapt to declining snowpack, and managing the Colorado River so that it can deal with drought are examples that involve both national and international issues. Both “bottom up” community planning and “top down” national strategies will be needed to help regions deal with impacts such as increases in electrical brownouts, heat stress, floods, and wildfires. Such a mix of approaches will require Federal, state, and local operational agencies to coordinate as they incorporate climate risks and adaptation planning into their programs. - (page 1)

The next paragraph highlights two other groups that are working on addressing barriers to climate resilience. The Union of Concerned Scientists (UCS) focuses on developing resiliency policies and supporting many marginalized groups. The UCS put together fifteen principles for decision makers to use to prioritize investments in climate change adaptation, “to help ensure that their investments are scientifically sound, socially just, fiscally, and adequately ambitious.” (https://www.ucsusa.org/global-warming/science-and-impacts/impacts/climate-resilience-framework-and-principles, 2016, paragraph 1) The National Oceanic and Atmospheric Administration has also been proactive about addressing climate change and creating and sharing accessible resources with the public. NOAA put together a climate resilience toolkit, with their resources and ideas for how to shift towards resilience across scales. (https://toolkit.climate.gov/#steps, 2018). This toolkit helps identify hazards and potential vulnerabilities and risks within a community, then helps to bring together resources and to plan and act around climate preparedness.
Possible Sources of Resilience

Climate Action and Resiliency Plans:

In the following section I identify and discuss three modern sources of resilience that have the potential to lead to innovative solutions to both social and ecological crises. We are living in a climate crisis. The planet is warming and this is a threat to our survival, however, this can also mean an opportunity to innovate and respond with creativity and resilience. Part of my division three thesis inquiry, was to look at what types of practices and policies are happening on an institutional and government level to counteract climate change and global warming. How is resilience coming to fruition for many different groups of people? There have been some substantial transitions and shifts towards equitable and sustainable practices, but on a larger scale there is a history of inaction and fixes that are temporary. Moving forward policies should be socially responsible, fiscally viable, and scientifically oriented. Through my work with Arise for Social Justice Springfield, a grassroots organization focused on furthering the rights of low-income people, I learned about climate action and resiliency plans. These plans range in topic, tactic and targets, however many of them include how to adapt infrastructure to be more efficient and more ready for climate emergencies, (such as working to shift the city largely from coal to gas). Many of the broader plans are being signed into law across federal and local scales; many countries, states and even cities are implementing climate action and resiliency plans.

Federal and local governments alike grapple with how to react to climate change. Many ideas for solutions have originated from the environmental justice movement. The results of these meetings between grassroots organizing and government policy, at times, entail Climate Action and Resiliency Plans. These plans incorporate ideas, initiatives, research studies, and proposed laws to cut down carbon emissions and build up a more resilient and just society and economy. Global climate change was first addressed in United States policy around 1970 with the entrance of the Environmental Protection Agency. Frameworks of resiliency started around the same time first in the field of ecology then expanding towards anthropology and other social sciences. By the 1980’s and 90’s the concept of resilience had gain traction and incorporated
ideas of management and utilizing change to create solutions. Modern climate and resilience planning focuses on vulnerabilities, and most recently on equity and addressing the climate gap. The climate gap is an environmental justice term used to describe how low income people of color are affected by climate change disproportionately. Since then there have been a variety of policies and plans related to climate change adaptation. Many states are in working to create strong climate action plans while some states are in the process of developing plans. The most recent plans at the federal government level are interested in climate-resilient infrastructure and strategies for limiting greenhouse emissions. The Obama administration worked on creating some of the climate action initiatives we have now. “in mid-February 2014, President Obama announced his plan to propose a $1 billion “Climate Resilience Fund” (Malakoff, Sciemmag.org, paragraph1)

A specific example of the development of this type of action to adequately address climate change is Community Driven Climate Resilience Planning: A Framework, from the Planning Movement Strategy Center 2016). The group aims to learn from and to teach others, “how community driven climate resilience planning is a vital opportunity for cities to reorganize resources, foster meaningful relationships, and develop placed-based innovations that support all people to thrive despite climate disruption.” (paragraph 1). One local climate action and resiliency plan originated in a partnership between Arise for Social Justice Springfield and the Pioneer Valley Planning Commission in June of 2017 called, “Strong, Healthy & Just: Springfield Climate Action Plan & Resilience.” The plan was started after Springfield residents experienced several unprecedented natural disasters in a row. These events that threatened the city were a tornado, a snowstorm in October that took out all the city’s power, and a series of unseasonable hurricanes. Part of the climate plan is to reduce the city’s greenhouse gas emissions by 80% by 2050 and to make the city more resilient to climate change. The plan tackles many different intersectional fronts for progress in Springfield and for the whole Pioneer Valley including developing walking, biking and public transportation routes, providing solar consultants, donating seedling trees to the community and providing community garden spaces. This plan aims to create urban resilience defined as:

The capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they
experience. Chronic stresses weaken the fabric of a city on a daily or cyclical basis and examples include: poverty, segregation and the long-term consequences and effects of institutionalized racism in the country and city, unemployment, and food insecurity. (http://www.pvpc.org, 2017, paragraph 1).

The “Strong, Healthy & Just: Springfield Climate Action Plan & Resilience” serves as an example of how a community being disproportionately effected by climate change has adopted a plan to reduce their vulnerability to natural disasters that inherently provided significant improvements to the sustenance of their bodies and to their immediate environment while reducing greenhouse gas emissions. Along with providing sources of fresh vegetables through community gardens and opportunities for healthful exercise by creating safe walking and biking routes the overarching effect of these projects has been to foster a culture of cooperation. The cooperative culture now in place is expanding to allow members of this community to live more peacefully and to thrive by also tackling social issues such as introducing self-policing programs to counter police brutality. Borrowing from the ecological definition of resilience, it seems possible that when this community underwent disproportionate stresses caused by climate change such as repeated blackouts in the wake of hurricanes, they reached a tipping point or point of criticality. The community responded to the point of criticality by rapid adoption of strategies that increased the community’s health, reduced their vulnerabilities and created a culture of cooperation.

Biomimicry:

“Biomimicry is recovery rather than discovery.” (Brown, 2017, p. 128)

The current social, economic and climatic crisis calls for innovations that are equitable, profitable, and environmentally sustainable. It is not always straightforward to find solutions that are cheap and fair, however biomimicry inventions may provide options that meet all three requirements. Using patterns found in nature to create innovative designs make human enterprises more resilient and more in union with the rest of the ecosphere. “The goal is to create products, processes, and policies—new ways of living—that are well-adapted to life on earth over the long haul.” (https://biomimicry.org/what-is-biomimicry/, 2018, paragraph 1) It is
imperative that the creators of complex engineering systems as well as simple everyday products begin to think about the wellbeing of both people and the planet and create a resilient relationship that benefits both. A Vox video interview (2017) with Janine Benyus describes the idea of co-opting natural systems. Benyus describes three ways to mimic nature to create design. Recognizing a process or self-organization pattern found in nature and recreating it for human use is one concept Benyus recognizes as biomimicry. The other two are through mimicking form and structure or designing based on an ecosystem level function found in nature. Some specific examples of biomimicry are using prairie dog home design for better hotel ventilation or ant communication that then can be re-created for robotics and self-driving cars. The circular economy concept, where economic activity builds and rebuilds overall system health as well as upcycling, which uses by-products or waste materials to make products of better quality with better environmental value are examples of ecosystem crossovers. (https://www.youtube.com/watch?v=iMtXqTmfta0, 2017, Vox).

Traditionally, Biomimicry has used scientific understanding of natural science principles, specifically biological systems, to make designs and inventions for human use. “The use of biomimicry has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly, and harnessing solar energy” (Vincent et al. 2006, p.4). Biomimicry has expanded its reaches into many sectors such as physics and economics. Biomimicry has the potential to alter our social and physical reality and move us toward a more resilient future.

Emergent Strategy:

Emergent strategy discusses resilience across disciplines. In Emergent Strategy, (2017) Adrienne Maree Brown digs into what it may mean to shift towards climate resilience. Brown (2017) states that resilience deals with recovery and moving towards balance, and that resilience is grounded in nature, “mushrooms cleaning land after nuclear trauma, forest growth after fire, the way skin feels after cut (stronger than before) healing is birthright” (Page 126). A driving question in my thesis work has been, in what ways are a community’s resistance and resilience comparable to adaptability in nature? Brown explores this question with rigor and depth.
Brown (2017) tells stories, outlines ideas, and describes how to apply lessons and patterns found in nature to Anthropocene issues. The intention of these lessons aimed at growth and shifts towards new ways of living. The basis of Emergent Strategy is the concept of emergence which she defines as “the way complex systems and patterns arise out of a multiplicity of relatively simple interactions.” (Brown, 2017, p.15). Emergence are patterns and connections that lead to solutions and more livable worlds. Brown (2017) details emergence happening across scales of time and space. Brown developed a set of elements of emergence that help strengthen this concept. Table 1 represents the elements of emergence. The elements came out of critiques of social justice spaces, so the elements are ways to use mistakes to create better practices. The framework to understand these elements starts from the simple understanding to the more complex ways of thinking about applying the element to society. The elements are referring to a variety of biological principles that also have implications for community engagement practices.

<table>
<thead>
<tr>
<th>Element:</th>
<th>Nature of Element:</th>
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<tbody>
<tr>
<td>Fractal</td>
<td>relation between small and large</td>
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<tr>
<td>Adaptive</td>
<td>how we change</td>
</tr>
<tr>
<td>Interdependence and decentralization</td>
<td>who we are and how we share</td>
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<tr>
<td>Nonlinear and iterative</td>
<td>pace and pathways of change</td>
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<tr>
<td>Resilience and transformative</td>
<td>how we recover and transform</td>
</tr>
<tr>
<td>Creating possibility</td>
<td>how we move towards life</td>
</tr>
</tbody>
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Table #1 Brown, 2017 Emergent Strategy Elements from Emergent Strategy (2017), page 50.

Change needs to occur at a community level, with collaboration as a cornerstone, Brown (2017) writes “many of us have been socialized to understand that constant growth, violent competition, and critical mass are the ways to create change, but emergence shows us that adaptation and evolution depend more upon critical deep and authentic connection, as a thread that can be tugged for support and resilience.” (p.14) In order to survive and thrive we must put energy and intelligence towards collaboration and connection instead of gaining material wealth.
There are many natural examples of collaboration, including how birds travel in flocks, staying separate enough to fly but still on a shared path moving towards something together. Similarly, how ants build together and how fungi develop incredible growths throughout the earth. Species like dandelions, bamboo, vultures, and mosquitos are collaborative life forms that continue to proliferate, survive and grow. We as humans do collaborate, quite a lot, but how can we motivate our species on a global scale to enter “sustainable” collaborative relationship with our environment and co-habitants?

Throughout the chapters of *Emergent Strategy* there were descriptions and metaphors that provided language for some connections I have often tried to imagine or articulate, while at the same time some ideas that were beyond my scope of imagination. One pattern seen in nature is that no being or thing is disposable. This is a form of resiliency; by not wasting anything a system can save energy and remain strong. Mushrooms can take substances we find toxic and process them as food. Matter and energy transform and never disappear. The book highlights how to move towards growth, connection, and resilience. A key takeaway for me is that embracing change is a non-negotiable and that we must let go of the status quo to move towards a sustainable future.

**Community Resilience**

**Community Organizing as Practice of Resilience:**

“The word radical simply means grasping things at the root”

-Angela Davis

In this section I will reflect on my experience as a facilitator for Grassroots Community Organizing under the anthropology department at UMass Amherst as part of the UMass Alliance for Community Transformation (UACT). I took part in this class because community organizing is a tool used to act against injustice and to shift power towards more liberated and more resilient ways of life. Resiliency is a response to the dominant system that divides and pits people against one another. According to Collins (1990) relational culture is a transgression on the traditional narrative and builds resilience through compassion and increased understanding of our shared stakes in liberation. My facilitation training focused heavily on intentional relationship building
or relational organizing and developing critical pedagogical practices. Critical Pedagogical practices is a way of educating that decentralizes the teacher as dominant and opens space to learn from each person in a group. In critically pedagogical classrooms the recognition of power dynamics is an aim. Organizing for social change Bobo et al. (2001) takes this idea further, they describe the relationship between people and power. Their argument is that when there is a recognition of one’s own power or oppression one can fight to end it or for the latter to take it.

Under our current administration, there are many attacks on the environment and on communities, as I referenced previously, under the political hubris of “Let’s Make America Great Again”. To correct any of one of these individual problems we face we need to reach across difference and connect single issues into more broad movements for positive change. The idea of broad transformative connections, reminds me of many synonyms or metaphors for resilience. I argue that using resilience frameworks in organizing strategy is possible and would be productive. One group already exemplifying this idea is the newly revived Poor People’s Campaign which is working to fight poverty, “systemic racism, poverty, the war economy, ecological devastation and the nation’s distorted morality.”(https://www.poorpeoplescampaign.org/index.php/fundamental-principles/2017, paragraph 1), What will hopefully make this movement sustainable and resilient against challengers are the connections made across lines of difference like race, gender, class, and sexual orientation. Another way the movement will build strength and power against hate is by making connections through religion and raising the voices of the people most affected by oppression. Once again, borrowing from the ecological definition of resilience, it seems possible that when the communities most affected by oppression reach a tipping point or point of criticality they responded by adopting strategies that increase the community’s health, reduce their vulnerabilities and create a culture of cooperation, thus maximizing their community’s resilience.

Reflection of Facilitator Training

The UMass Alliance for Community Transformation (UACT) develops the knowledge and capacity for transformative learning and action across lines of difference. As a participatory organization of the UMass Department of Anthropology, UACT builds the capacity for diverse, solidarity, deeply relational, community-based social justice work. -http://www.uactumass.org/about, 2017 paragraph 1
In this section I will reflect on my experience training to become a facilitator for Grassroots Community Organizing:

When I reflect on the Critical Pedagogy class, as well as the facilitator training space, I can identify the learning, the challenges, and the continued transformation that has been part of my time in UACT. One theme I kept circling back to when I think about my learning last semester, has to do with accountability. For me accountability feels very tied to vulnerability. In The Long Haul, (1990) Myles Horton brings up many examples of being accountable to the Highlander school, or to the union, or movement he was a part of at that time. In each example the actions he took were different, but most of the time he was not a charismatic leader but instead empowered others to create change or become leaders. During one class, we spent maybe an hour discussing how to be accountable to the training space and each other, we talked about accountability after the race caucus and again towards the end of the semester. I appreciated hearing other thoughts on this since they were sometimes very different or very like my own. I thought a lot about ways to be there for myself and others, working to go past just “responsibility”. Vulnerability, in a way, is putting yourself out there or opening your own process for others to witness. It also means pushing oneself to hold space and recognize others truths, however uncomfortable you may feel. I thought I knew what this meant after I took grassroots community organizing (GCO), however the fall semester opened me up in a whole new way. I was unfamiliar with being intentionally open and honest with a group. I felt challenged and little like my way of being in the world was sort of lacking wholeness and realness, as I witnessed others be transparent and took some stabs at it myself. It was a different way of being.

In the GCO classroom I envision that if and when folks feel comfortable and trust the space enough to share themselves, then a group can move and get somewhere. There are many levels and variations to this, and it is not a rule or recipe. I will work to foster a sense of commitment and accountability in my classroom by being open about my own process and working to recognize when others are doing the same. The outcome of this hard work will be a
cooperative and trusting group going through spring break and into the final project of the semester. Importantly, there is a lot of growth and the strengthening that can happen in spaces where folks can become accountable and feel vulnerable.

A second theme that continues to cross my mind, while reflecting on the fall semester, is how to deeply listen and how to hear someone. Listening to someone can mean seeing or holding a person in their complexity. In *Pedagogy of the Oppressed* (1968) Paulo Freire wrote about dialogue. This is different than active listening, but for me both are working towards the same goal. The aim being humanization and liberation. I thought I had become comfortable with this idea during my time in GCO, however as a facilitator one must work to reach a whole new ability to listen and be present. I learned to slow my brain down and just sit with what was being said or what I was reading. There are times to dig in to certain aspects of what is happening, or to ask clarifying questions that may be helpful for you or the other person, or times to just listen and engage or soak up other’s knowledge and experience. This type of deep listening can be found when the tools of resonance, dialogue and one to ones are used correctly. This skill is about being in the moment and will help students begin to understand each other, our community partners and organization, and hopefully the readings that we employ in the class as well.

An additional key learning that I touched on above is the practice of recognition without judgements or attachments. When someone recognizes my experience or when I can be there for them an extremely valuable space can be created. A tool for creating this space is to ask generous questions, and to talk through mistakes and learn what is valuable even when things go wrong. To confront yourself and others when a gut feeling or messed up thing is said can feel difficult; but it is imperative to building trust, and for me personally working to focus on internalized oppressive tendencies. I learned how challenging communication and honest legitimate dialogue is. In *Building a Teaching Community*, (2003) Hooks says, “dialogue is one of the simplest ways to cross boundaries between people.” (p. 8) Hooks describes the importance of dialogue, but for me it was easier said than done. As a facilitator, you need to be present for what is being said and happening but also molding what learning you want to push towards. For GCO students this semester I aspire to push towards dialogues that foster learning and reflection and growth, instead of reiterating or regurgitating information and ideas. I hope for myself and my class to be aware of the difference between friendliness and courteousness versus solidarity and real commitment. This means going beyond superficial and automatic responses, actions, and
towards true relationship building. Finally, I came upon the idea that research or inquiry and action are inherently connected. Divorcing the two seem degenerative to me. I have constantly felt stuck, suffocated or held back in my academic work; however, CP class and learning about PAR helped me push myself and think in different ways. Chambers (2008) describes the idea that “PAR is not monolithic but is a pluralistic orientation to knowledge making and social change.” This is refreshing, although difficult, but feels transformative moving from static traditional consumption of knowledge to a more generative whole way of production. I hope I can continue to pay attention to these practices and ideas and expose the GCO students to them as well.

After reflecting on a series of conversations and dialogues our facilitator group was a part of including coaching team conversations, some themes I can recall have to do with how to fulfill our roles as facilitators in the ways we see fit this spring. This includes supporting students and stepping up in confrontation and uncomfortable moments. Another theme was how to navigate self-care and mental health in a way that is transparent and accountable. A challenge for me was to move through how to confront my internalized white supremacy and oppressive thoughts in a transparent fashion and learn to recognize and hold myself accountable to the community I was working to create with the other facilitators and trainers. How to confront one another in generative ways is still something that I am challenged by, it will be necessary for my class and our tot community. I am feeling more and more that this practice or skill is critical and attainable and worth it to strengthen our group even further. Some of my fears at the beginning of the semester had to do with “teaching or Facilitating” on a topic and making sure I was knowledgeable about that topic. I also was worried about getting to know the other tots on a deeper level. Some of my hopes at the beginning were focused on adding an environmental justice section or organization to UACT. Over the year my anxieties and aspirations have transformed or moved. I developed such skills as, learning to share my own experiences and ways to bring others into that space. I learned to sit with silence and how to efficiently lesson plan and pull out imperative parts of a text. I feel confident in my abilities to find resources and plans that will help my class this spring. I still feel challenged by having the skill of two-eyeing folks or knowing the direction and big picture for my students, and especially how to support each one individually. Over the semester, I felt solid and weak in different areas. Change was a
constant, as there was a steep learning curve during our facilitator training. Towards the end of the semester and now, I am much more aware and concerned about UACT as a project and the goals and aspirations for my class and myself, instead of being worried about the skills needed or small pieces or assignments that need to be checked off.

I hope to create an intentional space next semester. I have a few goals that work toward this intentional, mindful, and committed classroom. Specifically, I hope my class can approach our own differences, challenges, even faults with curiosity and a commitment to learning. I am especially thinking about how some far-right folks are reacting to the same current economic and political climate that we are, but they are reacting with hate and bigoted reactions. I think that if our class can have a focus on dialogue and being purposeful in thinking about how our personal lives are connected to systematic and societal isms and issues, that will be important and can create room for change making. A focus on how oppressions are internalized and how one may be complicit in a system will provide evidence for this focus. I am interested in how our class can be committed to liberator behavior and not a continued cycle of symbolism, while also making connections with folks considered “far right” or different than us in other ways (thinking of the folks we will spend spring break with)? As a facilitator and white person, I know this is safer for some of my students, so a goal or aspiration I have for myself is to be aware of who I am thinking of and being generous to in my actions, words, lesson plans, etc. I plan to be aware of my co-facilitator Mica and use tools and strategies to help in communication and hopefully unity with her. I have reviewed the questions we answered when we first found out who our co-facilitators were and I am excited to dig into actively working through them. I have been inspired by the Poor People’s Campaign and the intersectionality I see there. I aim to work on my own process and decolonizing myself through a focus on mentorship and talking with lots of different people each with complex perspectives. I strive to be a whole facilitator and person, so that the students in my class can feel they also can be themselves and that we together confront any issue that may come up to learn a language and skills to critically understand the tensions and contradictions of our experience. Some aspirations I have for my students and our GCO class going into the spring have to do with seeking true cooperation and collaboration past the “assignments” of the class. I hope that the students feel pushed to true self-reflection, growth, and learning however that may come to fruition.
Grassroots Community Organizing Facilitation Reflection May 2018:

In this section I will reflect on the experience I had as a facilitator for one section of the community organizing class that was named New York City Grassroots Community Organizing 2018:

It has been a whirlwind roller coaster of growth! The role of a GCO facilitator is complex. I worked to be a space creator, a guide for accountability measures, a gentle conspirator and part educator-part organizer. My role as a facilitator included lesson planning for about five hours a week, for a three-hour class, I had to read half of my student’s 1-2 page reflections and give feedback each week. I also had to lead a week-long spring break trip and help plan a retreat part of the way through the semester. As a facilitator, it is important to become skilled at opening, and at times closing space for students. I could foster the skill of opening space through practice, and then lots of reflection around what worked or needed to change each Thursday class and during spring break. I found that asking questions that are grounded in key learnings and ideas from the authors and articles we were reading was a way to create dialogue. Other times asking questions that got the students to think about themselves, and then to become curious and fluid with their own process. I felt this added an elasticity and resilience to the relationships of the students. Opening space can look like pointing out my gut feeling or the irony in a situation to move through a tension that has come up. At the same time as I ask a question I learned to try to recognize and to be aware of what had been said and by who it was said, to move the students in the direction a goal or learning.

During training, I learned the skill of being reflective about how I am approaching discomfort as well as how to hold others accountable. This was a theme for me as a facilitator. I am still challenged by this skill of leaning in and being curious about tension, and bringing others with me in that process. As a facilitator, there were many opportunities that required me to push the students to wonder about how they were reacting to a given situation. To be specific, I am thinking about, over spring break, how the students did or did not engage with our community partners at WEACT. At moments, the students became extremely focused on certain aspects of the experience or issues at hand. Before we left for spring break there was a
particularly difficult class where the students were being critical of WEACT and wondering how “anti-capitalist” they were. During that time, it was important to agitate the students, by asking what they themselves were doing about the issue and how they were grappling with environmental justice initiatives. I felt Mica (my co-facilitator) and I could scaffold and build layers of wonder onto the student’s initial analysis of the community organization.

I know I still have much to learn and grow towards in terms of facilitating through conflict, being able to confront difficulty and tension and calling in offensive statements and actions. A main takeaway for me right now is that I now have skills to shift and change situations that happen around me. In a reflection from the end of last semester I discussed the idea of reaching across difference and having conversations with far-right “close minded” people. Now I feel like I could facilitate a group of people with vastly different experiences and get somewhere generative, and push people if they are not being aware of the assumptions or damage they are causing. This feels like a microcosm for a larger change of awareness I have had around the importance of action and of moving towards the hard, tricky, messy, complicated stuff! This is where real change and tangible relationship building can happen. This is where learning happens and where a group can begin to move towards more just, liberated ways of being. Pushing my students to reflect more and to gain depth in already difficult moments around identity, privilege, and stake in a struggle (for example) was a challenge for me this semester, and that being a challenge means that I have more work to do around how I am holding myself accountable to reflecting on these things.

Resiliency Survey

Arise for Social Justice Springfield

Community resilience is about the individual resident’s behavior and opinions on policy strength of local government and the quality of practice of community organizations. The following section will discuss a survey I created and conducted in collaboration with Arise for Justice in Springfield Massachusetts. Part of my division three thesis work included partnering with a local community organization. I volunteered with ARISE for Social Justice in Springfield. I spent
most Wednesday afternoons from mid-October to mid-March volunteering there. My contributions included a glossary for their newsletter, a fundraising event pamphlet, notes to be used as a review of the City of Springfield Cold Weather Policy with comparisons to improved policy in other municipalities, and a zine for their Earth Day event (Documentation Appendix Section #1). Arise for Social Justice Springfield, in collaboration with the Pioneer Valley Planning Commission, was instrumental in developing and implementing a new climate action plan. The Strong, Healthy & Just: Springfield Climate Action & Resilience Plan, was completed in June 2017. For my thesis, I created and conducted a survey about resilience in Springfield to follow up on the concepts and themes in the new climate action plan. Finally, I worked closely with Arise to help inform my PVTA investigation using Physarum polycephalum. Members of Arise have direct local knowledge of the current public transit service and members of Arise were involved in organizing to save some important transit routes and services this past summer.

Introduction

The purpose of this survey was multipronged. The survey was related to what factors are considered useful in measuring climate change preparedness. The survey was intended to find out information about Springfield residents, who are affiliated with Arise. It is important to gather perspectives from Springfield residents about the city’s ability to form resilience to climate disturbances. The survey topics included questions about housing, health, safety and emergency preparedness, public transit, and finally a section for opinions and feedback regarding community preparedness for climate change. The survey was created using themes, concepts and understandings found in in the Strong, Healthy & Just: Springfield Climate Action & Resilience Plan. A secondary purpose of this research was to engage with what different individuals are doing to shift their everyday behaviors to counteract climate change and to become more resilient to climate emergencies. This could include individual sustainability behaviors. The survey was also conducted to find out if any constituents are knowledgeable about sustainability and resiliency and could offer insight into viable solutions. Many surveys focus solely on secondary interventions or reactions to counteract climate change, this survey’s intentions are to define prevention and resilience and gain awareness into both. “Prevention is any attempt to stop
climate change from happening while the focus of resilience is surviving and living within the current conditions or through inevitable changes brought on by climate change” (Pioneer Valley Planning Commission, 2017, p8).

Method

*Participants:*

There were sixteen participants who took the survey during spring 2018. The majority were Springfield residents. I recruited the volunteers, organizers, and interns at Arise to take the survey as well. Participants were recruited in-person, by making an ask to them when they visited the Arise office, or through Arise email member lists. My participants were all over the age of eighteen (adults). Participants information was kept confidential and anonymous by using Google forms.

*Materials:*

I collected my data via a Google forms application online. I also provided printed paper copies of the survey for those participants that did not have access to a computer. All participants received a consent form and had the ability to see the interview questions ahead of time.

*Procedure:*

I collected quantitative data in the form of a survey. The survey was open for responses from mid-February to mid-April. I developed the survey by creating thematic questions based on different sections of the climate action plan. The questions range in topic from health, safety and emergency preparedness, to public transit and housing, to advisories on how to become resilient and feelings about local government and community action on this topic. I then worked with a few staff members to edit the questions and make them relevant to the Springfield community. I wrote a description for the survey participants in which I stated; This survey is based off the newly implemented city plan “Strong, Healthy & Just: Springfield Climate Action & Resilience Plan.” I introduced myself and the survey by saying, “Hello my name is Gusty Catherin-Sauer and I am a senior at Hampshire College, I am also a volunteer at ARISE. I am wondering if you have at least ten minutes to participate in a survey about climate change and sustainability. This
will be an online survey and your responses will be confidential.” I received a site authorization from Arise for Social Justice Springfield. I explained the study to participants either in person or as an introduction to the online form. The participants were instructed to take about ten minutes to fill out the survey to their own understanding. The online survey form, complete with all the interview questions and materials, as well as a full Institutional Review Board report is available in the documentation appendix (section #2).

Results

_Housing:_

A section of the survey was about the home infrastructure and housing demographics of the participants (Fig 2).

*Figure #2 Housing.* This figure represents the number of participants who are renters and homeowners. From Google forms, Resiliency Survey by author.

I found that one participant was experiencing homelessness. A similar number of participants were homeowners or renters, specifically 56.3% of the participants were renters. About 90% of the participants felt secure in their place of residence. Another question was about housing services, 60% of the participants report having satisfactory heating, cooling, electricity, septic and plumbing, waste services in their place of residence. When asked about appliances, 75% of
the participants said they had energy efficient appliances in their homes such as LED light bulbs, ENERGY STAR certified appliances, drying racks or clotheslines, and shower-heads.

*Health, Safety, and Emergency Preparedness:*
A section of the resiliency survey was about the health and sustainability habits of participants. Participants were asked about their behaviors and feedback around the sustainability principles of reduce, reuse, recycle, and composting. The participants were asked about safety in Springfield. Questions such as satisfaction with health care and emergency services as well as local government preparedness for natural disasters and participants own planning for emergency preparedness were a part of the survey.

![Pie chart](image)

*Figure # 3 Health Care.* This figure represents the amount of participants who feel they have satisfactory health care services. From Google forms, Resiliency Survey by author.
Figure #4 Effect from Extreme Weather Events. This figure represents how many participants have been affected by an extreme weather event. From Google forms, Resiliency Survey by author.

All the participants felt fairly familiar or very familiar with the terms climate change, sustainability, energy efficiency, and community education. Most (93.8%) of the participants recycle. 68.8% of the participants eat meat and 56.3% compost. A majority (87.5%) of participants feel they have access to green spaces like parks and forested areas. Most (75%) of the participants either have asthma or have a family member who does. Health care services are satisfactory, 62.5% of participants feel they have satisfactory health care services (Fig #3). This question allowed participants to decide what satisfactory health care service meant. Half of the participants do not have access to a grocery store with “good affordable” food nearby (less than 1 square mile from home). A majority (75%) of participants do not feel that their city government provides appropriate services to support their sustainability attempts. Only 12.5% of participants felt that local government/community is prepared for an extreme climate event or natural disaster. Many families or individuals in Springfield have been affected by a natural disaster, specifically 72.7% of participants (Fig #4). Importantly, 75% of participants feel they can rely on emergency services.

Public Transit:
There was a section of the survey that was about transportation in Springfield. 25% of the participants take the bus more than three times a week. 87.3% of the participants have a bus stop less than a 15-minute walk from their home. 56.3 % of the participants think that there are not safe or useable bike paths and the same amount believe that there is access to good bikes and bike repair.

**What is most important to you in terms of bus service?**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>More frequent service to fewer destinations</td>
<td>36.5%</td>
</tr>
<tr>
<td>Less frequent service to more destinations</td>
<td>46.2%</td>
</tr>
<tr>
<td>More affordable service</td>
<td>15.4%</td>
</tr>
</tbody>
</table>

*Figure #5* Public Transit. Represents what is most important to participants in terms of public transit service, given three options. From Google forms, Resiliency Survey by author.

There were various answers when participants were asked, in a free-text style question, about ways that the Pioneer Valley Transit Authority could offer better service. Less frequent service to more destinations was the most important feature to a majority (46.2%) of the participants (Fig. # 5). Some participants wanted “income based bus routes” and “increased stops, destinations and routes.” Participants wanted more service to places like “Chicopee, Ludlow and downtown Springfield” as well as more service that “links Springfield to adjacent cities and towns”

**Issues of Concern:**
Part of the survey was about community participation. This section asked for feedback and opinions sometimes in the form of short answers.
The current issue that a majority (37.5%) of participants were most concerned about was housing (fig. # 6). When asked how to engage citizens in community resilience planning, participants discussed the need for “intersectional local social justice organizations” that also were in communication with the city government. The organizations should do outreach and go “door to door and make education or literature shared relevant to the communities being engaged.” The participants identified a need to make education accessible and to provide opportunities for youth to be involved. Some energy and money saving tips that the participants shared had to do with working with volunteer groups to do conservation work together and advise about conserving money, energy, water, food, materials. When asked about ways to solve city wide problems participants offered ideas like having more “bike paths and access to fresh food, more solar panel infrastructure, more staff in city council who care about the environment and finally revolution.” Some questions the participants have for local stakeholders, such as community organizations, city government or local officials, included how to “connect resources, how to ensure investment in public transit, public education and living wages, how to work together to have a sustainable plan for homeless people facing weather extremes, and how to ban the use of single use plastic bags, and how to deal with water shortages.”
Comparison to Census Data

I contextualized my own data further by comparing my findings to a census profile from 2017 for Springfield, Massachusetts. This census profile recorded those who took public transit to work, as well as the number of residents who rent or own a housing unit (Fig. # 7).

Figure #7 Census profile: Springfield, MA. This figure represents the mean travel time to work and the ownership of housing units in Springfield. From the Census profile: Springfield, MA. (2017). Retrieved April 2018, from https://censusreporter.org/profiles/16000US2567000-springfield-ma/

Discussion
I found that the participants provided some feedback about ways that Springfield can work towards further resilience. The result of the resiliency survey were some statistical representations of Springfield residents and Arise Staff’s opinions and demographics. I found that the participants have somewhat satisfactory housing, healthcare, public transit and emergencies preparedness infrastructure. My findings were like the 2017 Census profile (Fig #7). According to the census site 53% of housing units are renter occupied and I found that 56.3% percent of my participants were renters. Similarly, I found that only 18.2 % of my participants ride the bus more than three times a week and the census profile reported that 5% of citizens use public transit to get to work. Unfortunately, I did not find census data about emergency preparedness or behaviors and opinions about sustainability practice. Therefore, the data I found about emergency preparedness is an asset since, to my knowledge, there are few measurements or datasets on this information. This feedback emphasizes and contextualizes what individuals are facing in terms of the effects of climate change and/or what city level barriers are to be able to become sustainable.

A challenge I came across in my study was gaining appropriate participation. There was a relatively low number of participants, given the networks that Arise for Social Justice has. I had hoped for twenty to thirty participants and there were sixteen, approximately eight of which were Arise staff, although some of these staff members also reside in Springfield. I did not add the question, “Do you work for Arise or are you a community member” until part of the way through the survey period. Because of this, I had issues keeping track of the number of participants who were residents or who worked for Arise. Potentially I could take the first 8 responses, since most of those responses are from staff, however I set up the survey using Google forms which keeps the identity of the participants anonymous meaning that although I can see the participant’s responses I am not sure what person said what. This mean I am unable to categorize between staff and residents with complete confidence after the survey has already been completed. The bias of the questions was a problem too. For example, I did not add an option to describe the “other” column for the “most important issue” question. Another flaw was not defining my terms, an example was about access to “affordable” food, as it was up to the participants to decide what “affordable” meant.
Moving forward, the survey and the preliminary results can be used in the future by Arise to develop strategies to make their community more resilient. The survey even has the potential to be useful in holding the city government accountable to implementing the climate action plan. It is important to Arise, hopefully as well as the Springfield City government, to know which parts of the plan matter most to residents, as well as what other ways residents are working to become resilient in the face of climate change. There could be potential for publication of the survey in an Arise newsletter of the survey by Arise. ARISE could put some results from the survey in their newsletter. I shared the response to the interview questions with ARISE and so they could archive the information. This information is valuable because it is coming from residents and individuals that Arise works with. The feedback about opinions on climate change and the climate action plan inform the direction that Arise could take its strategy to support the community in being resilient to climate change.

Pioneer Valley Transit Authority Background

This section will discuss the recent public transit funding cuts. Community resilience includes having an efficient transit service. For part of my thesis I created experiments related to transit efficiency. Public Transit services are a critical resource for local economies and for individual transportation dependent citizens. Buses are necessary to get people to work, to the grocery store or to the doctor’s office. Any alteration to funding for transit service will most likely create service reductions on a system of fixed public transit routes. These reductions will put a strain on employers, businesses and residents that depend on reliable transit options being available. The Pioneer Valley Transit Authority’s (PVTA) services are an asset to Western Massachusetts. “This transportation service oversees and coordinates public transportation and offers fixed-route bus service as well as paratransit service for the elderly and disabled.” (http://pvta.com, 2015, about section) According to pvta.com (2015) the PVTA was founded in 1974, has about one hundred eighty-six buses in service and serves twenty-four communities. In 2012, their annual ridership was eleven and one half million individuals, and in 2017 that number has increased to thirteen million riders. Unfortunately, in the last fiscal year there was a major cut in state funding. The decision to make these cuts was at the state level, headed by
Governor Baker. There was a $1.38 million gap due to the lack of funding from the state budget. The PVTA Advisory board voted Wednesday July 19th, 2017 to eliminate or cut bus service on a proposed twenty routes, saving “$838,000 in the coming year on the way toward closing the $1.38 million gap in its total budget of $48.21 million. The rest of the budget gap, about $500,000 would be made up by taking $100,000 from the reserve fund the PVTA maintains to pay insurance claims, and $400,000 from its restricted reserve account.”


Due to this budget cut the PVTA was forced to discontinue certain service it had previously provided. The routes cut connected Springfield to Agawam and Longmeadow, Enfield, Holyoke mall, as well as 5 college service. There was also an idea to have a fare increase even though, according to the PVTA “performance and efficiencies” section, the PVTA only gets about 7% of revenue from the fare box. Further evidence and representations of public transit need and use can be found in the documentation appendix (section # 3). Thankfully after a large amount of hard work and community organizing many routes were saved and there were only four to get cut. Table #2 represents the most recent local route cuts and changes that have been proposed to go in to effect in May. In April of 2018 the decision was made by PVTA advisory board members to vote a fare increase and there have been another round of route cuts or service reductions, in addition to what happened in the summer of 2017. Now is the time to test the bus system's efficiency.
Community resilience involves innovative or outside of the box solutions. For part of my thesis I designed an experiment to model a PVTA route. My inquiry focused on testing efficiency. I used the microbe slime mold (*Physarum polycephalum*), which is extremely efficient at finding the shortest path between food sources. The research team Reid, et al. (2012) claims to “show that the brainless slime mold *Physarum polycephalum* constructs a form of

Table #2 Original Proposal vs Mitigation. A table of some of the proposed PVTA service changes and Mitigation Modification after public comments in April 2017. From [http://www.pvta.com/media/pdfs/Service%20Changes%20with%20Mitigation%204-6-18.pdf](http://www.pvta.com/media/pdfs/Service%20Changes%20with%20Mitigation%204-6-18.pdf), 2018, page 1)
space memory by avoiding areas it has previously explored.” (page 1). Slime mold is an excellent biological network system and has been used to recreate the Tokyo railway system and the U.S road system among other transportation routes. According to Tero et al.2010), “Capturing the essence of this system in simple rules might be useful in guiding the development of decentralized networks in other domains.” (p.439) I employed slime mold as a biological network system to model possible public transit routes in Springfield, MA. Specifically, I modeled the PVTA B7. I chose this route because it had the highest ridership according to the PVTA’s analysis (see Documentation Appendix Section # 3, http://pvta.com, 2015), as well as, Arise for Social Justice Springfield staff advised me to model the B7. I also designed a new connector route between the town of Holyoke and the G2 bus route. According to employer data I found in collaboration with Arise. The bus would serve a large population of commuting workers that use public transportation regularly. The novel route would connect two large employers (Ethos Energy and the Hampden County House of Corrections) in Hampden county. To create this route, I used mapping data where the commuter “highest population areas without transportation availability” was identified. (http://censusviewer.com,2017). I have identified top employers on an Springfield employer list and also areas that have limited transit service. (http://lmi2.detma.org/lmi/Top_employer_list.asp?gstfips=25&areatype=04&gCountyCode=000013, 2017). I hypothesize that slime mold will follow the bus routes that are in place some of the time, while finding more efficient routes where possible. Slime mold can map out efficient pathways in mere hours. This is something that would take computer software programmers days to write, or engineers years to design.

**Slime Mold as Model of Resilience**

**Introduction:**

In this section I will discuss my experience of using slime mold as a resilience model. I will introduce the ideas for the Pioneer Valley Transit Authority Experiment and the Temperature Stress Experiment. The section also provides some background information, characteristics, and abilities of slime mold.

One direction my investigation into resilience has taken me is working in the lab with slime mold or *Physarum polycephalum*, which is one of many species grouped under one common nomenclature. The purpose of this inquiry is to study the ability of *P. polycephalum* to
display resilient behavior in its decision making. This was done in two parts: My first experiment was on the subject of *P. polycephalum* navigating a public transit route to find the most efficient path, and the second wondering about the effects of temperature on the rate at which *P. polycephalum* is able to solve a simple maze. The problem was developed based on the need to understand route efficiency: as well as, asking how different organisms, and more broadly groups, adapt their decision making and become resilient under stress. This is related to the broader study of environmental issues, such as the impact of global warming on microorganisms.

*Physarum polycephalum* Background and Characteristics

Slime mold has been used in laboratories, for art in gallery spaces, and as a topic for *think* pieces for several years. *P. polycephalum* has intriguing growth patterns that can be seen without the use of a microscope. Slime mold has been used in kindergarten classrooms and in graduate molecular biology labs, it is extremely useful and easy to grow. Slime mold experiments have included testing the microbe’s decision making; specifically, route finding (Adamatzky, 2015), computation and solving mazes (Tero, 2007) given its perceived “problem solving” abilities. The organism has been difficult for humans to name and categorize. This is because it has a complex evolutionary history. Over time it has shifted taxonomic identifiers and has strange behavior patterns that are not like other fungi or microbes. Regardless slime mold has been extremely interesting and thought evoking when used experimentally and as a model.

*P. polycephalum* is a model in many senses of the word. Models, commonly defined as three-dimensional representations, typically on a smaller more simplified scale than the original, serve a range of purposes. Models help us understand ideas, objects or systems. The word model may also refer to a role one can play such as (role model) a leader, or influencer. My use of slime mold as a model meant translating the human problem of route efficiency and temperature change into slime mold terms. I created habitable or attractive pathways for slime mold to inhabit. I limited its movement by placing repellants or inhospitable barriers in my experiments. My own experimentation resulted in an understanding of slime mold’s capabilities and limitations as a model for creating efficient routes and for answering questions about resilience to temperature.
The term **slime mold** is an informal name given to several kinds of unrelated eukaryotic organisms that can live freely as single cells. Although not directly related to one another, different species are currently placed in the paraphyletic group referred to as kingdom Protista. Plasmodia, which is the result of flagellated cells fusing to form one sack of cytoplasm with thousands of diploid nuclei, can be found in the soil, on lawns, and most commonly on fallen or dead trees in forests. Slime mold is known to fill the niche of a decomposer in many terrestrial ecosystems and is ubiquitous in the environment. Slime mold contributes to the decomposition of dead vegetation, and feed on bacteria, yeasts, and fungi. Interestingly, it is even considered a delicacy that is eaten in Mexico like scrambled eggs, however there is also one species of slime mold called dog vomit that takes over whole logs and lawns in North America.

The microbe can range in size and thickness, sometimes the size of a penny while other species can grow as large as several square meters and masses of up to thirty grams, there are accounts of growing slime mold to fill a five-gallon bucket. “Plasmodia slime mold are usually 3-4 cm (1/2-1”) in diameter and 3-5 thick.” (Ivins, 1997 p.2). Slime mold can travel as fast as one centimeter per hour. In laboratory settings, the medium the plasmodium receives nutrients from is also what it can travel across. The exact types of nutrients required for the slime mold to survive are not known, but the 2% agar medium I used allow the slime mold to grow efficiently.

The life cycle and reproduction of *P. polycephalum* is a complex one. Plasmodial slime molds (*Physarum*) are gigantic single cells with thousands of nuclei. There are hundreds of species of slime mold grouped into three types; Plasmodial slime molds, like *P. polycephalum*, cellular slime mold like *Diachea* and *Labyrinthulomycota* or slime nets. Slime mold is between 600 million and 1 billion years old and has been found on every continent. “Slime mold can be microscopic myxamoebae as haploids or macroscopic plasmodia as diploids” (Ravi, 2014, p.1). Myxamoebae are uninucleate protoplast that lack both cilia and flagella, a characteristic stage in the life cycle of slime molds. If nutrients are not found, the slime mold can move in search of nutrients, producing haploid fruiting bodies, or enter its dormant phase, called sclerotium. Under unfavorable conditions, such as the spring or fall, plasmodial slime molds reproduce by forming a reproductive stalk containing spores that turn into sex cells then are released into the environment (see figure #8 below). Similarly, cellular slime molds complete a similar cycle just with a differing number of nuclei.
Figure #8. The life cycle of both cellular and plasmodial slime mold. Both cellular and plasmodial slime mold develop reproductive stocks. From Cummings, 2006, Pearson Education Inc. [http://bioweb.uwlax.edu/bio203/2010/renner_brad/reproduction.htm](http://bioweb.uwlax.edu/bio203/2010/renner_brad/reproduction.htm).

Plasmodial slime mold species begin life as amoeba-like haploid cells. These amoebae can mate if they encounter a damp favorable environment and identify the correct mating type. For many slime mold species there are two sexes, however *P. polycephalum* has over five hundred sexes. There are three mating loci. Therefore, there are many combinations or sexes that slime mold can develop into. Finally, a slime mold will form zygotes that then grow into plasmodia. According to Judson, Olivia. (2002)

Slime molds make sex cells that are only one size (isogamous); when size is the same, other features determine cell sex. In slime molds, it's three genes, matA, matB, and matC (all of which contain variants) that are responsible for determining sex. A mature individual has two copies of every gene and is capable of producing 8 types of sex cells. When one counts all the different combinations of variants of matA1-13, matB1-13 and matC1-3 available, you get more than 500 potential different sexes!

Abilities of *Physarum polycephalum*

*P. polycephalum* has caught the attention of scientists and researchers for having a unique form of spatial or environmental intelligence, simply put the ability to avoid areas previously
explored (Tero et al, 2010). This is along with its many other extraordinary behaviors, genetic significance and ability to survive extreme conditions. In past semesters, I was a part of a research group interested in slime mold’s capabilities and behaviors, as well as how to use it as a model to solve human problems. Importantly, “plasmodia slime molds are renowned for their ability to network, to learn, to survive adversity, and to navigate complex systems in an efficient and equitable way” (Keats, 2018, p.2). The research group I was a part of used an electronic organizational platform called Trello Board as a place to collect interesting findings, articles, and information on slime mold. Slime mold has many fascinating characteristics and abilities. Slime mold is proficient at distributed sensing and information processing (Mayne, 2016), decentralized decision-making and collective action, and transferring learned behavior to fused cells (Boisseau et al. 2016). Part of my work in past semesters was to use P. polycephalum to model the human issue of affluence, whether a world with fewer materials and less pollution is preferable to a world with more affluence as well as more toxicity, (Documentation Appendix Section #4)

Other accomplishments of P. Polycephalum include growing on water, escaping containers, growing vertically, learning given previous experience, predicting and adapting, detection and avoidance of repellants, and taking risks! Another set of experiments suggested that slime mold navigates time as well as space, “using a rudimentary internal clock to anticipate and prepare for future changes in the environment” (https://www.nature.com/news/how-brainless-slime-molds-redefine-intelligence-1.11811,2012, paragraph 5, originally published by Saigusa 2008 ). Apparently slime mold can be irrational like humans, Latty et al, 2015 discussed slime mold violating the rational choice of picking a nutrient option due to an absolute value of the nutrient choice given. Instead the slime mold sample seemingly compared the values of the nutrient options and exposure to light as slime mold is photophobic. The slime mold sample’s preference when a third inferior nutrient source was added changed from when there were only two choices. This preference could be described as irrational behavior. However, the preference could also be slime mold using a more “thought based” approach to reasoning by using comparative value reasoning as seen in other animals including humans. This previously investigated literature provides findings and reasoning for P. polycephalum as a good candidate to model decision making and resiliency behavior.
Although there is always more to know, *P. polycephalum* has been thoroughly studied and documented. Starting in the 1940’s, or possibly earlier, scientists were interested in both the extensive diversity in phylogeny as well as the mechanisms allowing for the behavior and decision making abilities of slime mold. Slime molds are also useful for studying the movement of the cell contents (cytoplasmic streaming) because it is easy to see under low magnification. The aim for my series of experiments is to look at how does a microbial body experiencing stress react to a challenge versus facing more optimal conditions. What does the condition of temperature produce? The information and description of slime mold chemotaxis has been an exciting recent achievement. “Chemotaxis is a response of motile cells or organisms in which the direction of movement is affected by the gradient of a diffusible substance” (Delacucostello et al, 2013, p. 5) This mechanism is like peristalsis or involuntary constriction of a muscle tissue. To explain further, slime mold travels through the environment through moving oscillators and through a type of hydrostatic pressure. By recognizing chemical substances, a threshold is passed that allows for the mobile mechanism to set the direction and rate at which the oscillators move. The larger study of, or understanding around, this ability refers to the focus for models of self-organization and the grouping behavior of slime mold cells.

**Experimental Design Goals**

The rationale for my study was based on slime mold’s ability to find efficient routes that recreate - in mere days - networks such as the Tokyo subway and US highway systems (Tero, 2010): systems that took human engineers much more time to design. The first experiment is based on the placement of nutrition at key stops and junctures along a bus route. Slime mold is a good choice for this endeavor given its ability to shift its mass by adapting the assembly and structure of its body. Adamantsky (2011) claims that the inoculation site of slime mold is less important because the active growth (alive surface area) moves over time as slime mold forages for food. I wanted to know if *P. polycephalum* could find the most efficient and effective routes connecting areas of high ridership and need. Transport quandaries are amongst the most widespread scenarios for which *Physarum polycephalum* expertise have been considered. I hypothesize that slime mold will pick the previous transit route most the time.
I was interested in using the ecological ideas resilience and resistance to inform my design. “Resilience is the rate at which a system returns to its reference state after a perturbation. Resistance is the tendency of a system to remain in its reference state in the face of a perturbation.” (Chapin et al. 2002, p282) I investigated how a microbe’s decision making and resiliency behavior changed in optimal versus stressful temperature conditions. I was interested in slime mold’s ability to, “maintain its properties despite disturbance” (Chaplin, 2002, p. 282) The second experiment was based on previous research done by Ravi (2014) who showed that *P. polycephalum* has maximum growth at thirty degrees Celsius, with less growth at higher temperatures. The question here is, how does stress affect decision making, how does it respond (become resilient) to being exposed to stress and when brought back to a comfortable livable temperature, what happens? Based on Ravi and others’ work I am confident that the slime mold prefers and grows best between 22 and 27 degrees Celsius and that the slime mold can recover from stress or cold when returned to warmer temperatures. The hypothesis is that slime mold would solve the maze at an increased growth rate and with more precision at preferable temperatures. Based on previous research these temperatures are between 20 and 30 degrees Celsius. The methods I adapted originated from Ravi’s experiments on the Study of the Migration of *Physarum polycephalum*.

**Method**

**Subjects:**

The subject of my study was *Physarum polycephalum* in its plasmodium phase. I grew a plasmodium phase slime mold from a *Carolina* brand stock sclerotium sample. For each model PVTA route I used a plasmodium sample weighing approximately one gram per storage bin replicate. For the Temperature Stress experiment I place a plasmodium sample at the “start” of each maze in 24 petri dishes. Each sample weighed approximately one gram.

**Materials/Apparatus and Equipment:**

- Incubators (Constant Temperature) at 37 and 30 degrees Celsius (2)
- Autoclave (1)
- Black cloth/felt 1X1 ft (3)
• Balance (1)
• Weight paper (1 box)
• Tape (1 roll)
• Sharpie (1)
• Chem-wipes (1 box)
• Paper towels (1 roll)
• Bunsen burner (1)
• Camera digital (1)
• Computer with Image J software (1)
• Spatula (1)
• Tweezers (1)
• Wooden cotton tipped Q-Tips (1 package)
• Razor blade/scalpel (1)
• Quaker oatmeal flakes (1 package)
• Ethanol applicator (1 Spray bottle)
• Gloves (1 box)
• Parafilm (1 box)
• Drawer kept at room temperature at 20± 2 degrees celsius (1)
• Refrigerator kept at 15±2 degrees celsius (1)
• Laminated mazes (24)
• Laminated bus route maps (2)
• Supply of ddh2o
• sterile plastic storage bin (9” × 12”) (4)
• Petri dishes (size tbd) (24)
• Two percent agar medium
  • Enough for 24 petri dishes with about 20 ml in each dish, so approximately 500 ml

Procedure and Technique:

Procedure
For every experiment, I used appropriate safety practices and equipment, aseptic techniques such as latex gloves, sterile instruments and work area, and lighting a Bunsen burner. Proof of concept experimentation was used to test the validity of my experimental design before I ran it. I tracked a healthy plasmodium sample’s movement to calculate a growth rate (figure #9). I grew a slime mold sample on few different materials (documentation appendix section #4) including plastic wrap, felt, and different sizes of petri dishes with a variety of percentages of agar nutrient. This was important to test for the samples ability to utilize less nutritious agar while still being able to see the image of the map below the agar, as well as to have the sample successfully navigate different material landscapes. Next I had the slime mold solve two different mazes at room temperature to replicate what had been done in previous literature (documentation appendix section #4).

My proof of concept experimentation included growing a stock plate of slime mold (figure #9). This was performed by making agar following the Dobro Protocol (documentation Appendix section #5), pouring agar into petri plates and letting it dry, placing microwaved oats in the dish then placing a slime mold sample on one of the oats, using a sterile cotton Q-tip. Once a stock plate is growing I was able to take samples from it in order to inoculate my other experiments. For each experiment, I began by inoculating a slime mold sample into a petri dish filled with solid two percent agar and then placed oatmeal (nutrient) at specific locations within the petri dish or storage bin.
Figure #9. Stock Slime Mold Sample. This figure represents the growth of one sample stock plate. The numbers were marked every three hours. Stock plates were used to inoculate all experimental replicates in my study. Photo by author, (January 2018).

The PVTA Experiment #1 was set up to model the PVTA B7 public transit route in Springfield, Massachusetts (http://www.pvta.com/B7x.php). I set up, ran, and documented slime mold’s path given three possible routes. I repeated the experiment four times. The three agar “routes” and nutrient “stops” were chosen by looking at google maps recommendations and the B7 route map. First I prepared approximately 1000 ml one percent agar, then I poured agar over shape of particular region (8X11” map of specified route) and placed in sterile plastic storage bin (9” × 12”). After the agar was solid I outline the desired routes with a scalpel tool and removed excess agar. I placed a sample plasmodium at the “Springfield Union Station Bus Hub.” Next I placed oat flakes (at a constant weight) along predetermined stops (determined using http://www.pvta.com/busStopConsolidation.php most popular stops along their routes), at similar
scale, each about two inches apart, along proposed routes. Figure # 10 is a schematic diagram of the experiment set up.

![Diagram of experiment set up](image)

**Figure #10.** Experiment Set Up for PVTA Experiment 1. The diagram represents the routes and stops possible. The start is where the first red stop is. Diagram by author (November 2017).

The bins were kept in darkness, at constant climatic conditions, except for observation and image recording (Documentation Appendix Section # 4). Periodically (usually at 12 hour intervals) the dishes were photographed I let the experiment run for seventy-two hours.

The procedure for the PVTA experiment 2 (Novel Route Design) was the same as the procedure used for the PVTA experiment one. However, I repeated the PVTA Experiment 2 (Novel Route Design) twice instead of four times. I first poured agar over the whole plate then outlined the route and finally I removed excess agar from the bin. A need, highlighted by the most recent PVTA survey as well certain staff at ARISE I spoke with, had to do with the populations who are dependent on transit services, who need stops within reasonable walking distance, or appropriate service times i.e. late at night or on the weekends, and who need bus service to their place of employment. I did research and designed the novel route for the slime mold to solve (refer to the PVTA background, page 38. This area links the Holyoke Housing
Authority (Franklin and High street Holyoke, MA) to Ethos-energy, (Memorial and Pendleton street) to the Big Y store in Chicopee. Next the route heads north east, via Burnett Road and Randall road through the Ludlow Area specifically with service to the House of Corrections where 1000-1500 individuals are employed (figure #11). It is possible to take the B6 from Springfield City Library, to the Hampden County House of Corrections, however it takes over two hours with walking and does not run the same on weekends, also serves another large Employer in Hampden County. After designing this novel route between the Holyoke Housing Authority and the Hampden County House of Corrections I used Google maps to find two alternative routes to link all the important stops. Then I designed a map with nutrient stops for slime mold to run.
Figure #11. PVTA Experiment 2, Novel route design. This figure represents the route the plasmodial sample could occupy, i.e. Where there was agar top) and a schematic diagram with the major nutrient stops (bottom). From the author and Google Maps [https://www.google.com/maps/d/u/0/edit?mid=1DrJsgCxsJCNsOli0GUFbDFDcOqsmJtw9&ll=42.137903207851906%2C-72.64949546630862&z=12](November 2017)

Procedure for Maze Solving Given Temperature Experiment

An understanding of slime mold intelligence and decision making, aided or controlled by its chemotaxis mechanism, is the ability to navigate its environment and make “a decision” given the conditions. This is known as a spatial intelligence or as a biological networking system. “Spatial memory enhances an organism’s navigational ability” (Reid et al, 2012, page 1). The brainless slime mold *P. polycephalum* constructs a form of spatial memory by avoiding areas it has previously explored, by recognizing the extracellular slime path it leaves behind. This led me conceptualize and create an experimental design asking how slime mold could navigate a maze given a series of less or more comfortable temperatures.

First I made enough 2% agar medium for 24 petri dishes. I used a dish size of (145X20mm) and for replicate #1 a maze size of (40X880mm). For replicate 1 I put the maze in the dish then poured the agar, for the other replicates I poured approximately 20 ml of 2% agar medium directly into the petri dish and let it solidify overnight, (store in fridge upside down). I outlined the maze using a scalpel tool and removed excess agar. I labeled the dishes with my name, date, and degree sample will be kept at (6 dishes at each temperature, except replicate #1 where there were five dishes at each temperature). Each plate was set up the same for replicates 2 &3 (figure #13). Next I placed one oat flake weighing approximately the same each time at the “start” of each petri dish as well as several oats weighing the same (1 gram, usually 3 oats) at the “finish” of the maze in all petri dishes. Next I used a cotton swab and a healthy Physarum culture to transfer the Physarum to each petri dish from stock plate. For iteration #3 cover the petri dish and sealed the dish, to prevent moisture from leaving the dish. I cover the set of petri dishes (6 at each temperature) with black cloth, so no light will affect the *P. polycephalum* sample. Finally, I placed the petri dish in its designated temperature chamber (16C±2 degrees, 25C± 4 degrees, 30C± 1 degree or 37C ± 1 degree). I photographed and recorded observations of the *P.*
*Physarum polycephalum* sample every twelve hours for 72 hours. Figure #12 represents a sample plate from each experimental replicate.

![Maze Solving Given Temperature Experiment](image)

*Figure #12.* Representation of Maze Solving Given Temperature Set up. The arrow represents the short side or most efficient way to solve the maze. The slime mold sample was placed at the start in each replicate. Photo by author, April 2018.

**Techniques:**

Both quantitative and qualitative experimental techniques were used to fully observe the behavior of *Physarum polycephalum*. For the PVTA experiments 1 and 2 I replicated my experiments and compared results to find the slime mold sample’s most common decision or choice. For PVTA experiment 1 I replicated the experiment four times and for the PVTA experiment two I replicated the experiment twice. For the Maze Solving Given Temperature Experiment I took notes and used a camera to take pictures of all the samples in each replicate every twelve hours for seventy-two hours. To retrieve quantitative data from the images collected, the length or distance of a sample’s trail (bright yellow healthy plasmodium) was measured. I used the measurement tool in ImageJ (software) to take measurements of the slime mold sample’s growth at each time interval. Finally, I used Google excel/sheets to analyze the data and find an average growth rate over time. I used the equation “= AVE” in Google sheets which calculates by dividing the sum of values in a set by their number. To find the Average growth rate over time I used “growth rate = (present - past / past) x 100. “Present” being the final
record length, taken at 72 hours in this case, minus the “past” referring to the length measurement taken at an earlier time, for this experiment (36 hours). This is a common equation used to measure growth rates in biological experimentation.

* Protocols for each experiment can be found in the Documentation Appendix (Section #6).

Results

Proof of Concept: Many of these proof of concept experiments took multiple attempts but were successful given time. The longer maze was not completed in one iteration due to moisture problems with the agar drying up. The slime mold sample solved the shorter maze in 72 hours (Documentation Appendix Section # 4)
Figure #13. Maze Solving Given Temperature Representative Petri Dishes for each Temperature (16, 25, 30, 37 Degrees Celsius). Photos from author (April 2018)

Observations & Results for PVTA Experiment 1 (Route B7):

After recording notes and photographing for seventy-two hours the slime mold reached the end of the B7 route and generally over 4 replicates always chose route #2, which is the route that is
currently in place. My results are not conclusive. This is because for replicate 1 and 2 between hour zero and forty-eight the *P. polycephalum* sample displayed an exploratory phase, going off the routes and some “trails” sclerotized. For the replicate that maintained the B7 route #1, at hour 12 the slime mold had covered approximately a third of the map, but had veered in several directions. After hour 48 (figure #14) the slime mold was half way and had solidified the original B7 route and had abandoned the “#2 and #3” routes. After 72 hours, the slime mold sample had completed the route and was occupying the final oat pile at the East Longmeadow Mall, and had a sustained trail between “nutrient stops.”

**PVTA Experiment 1 (Route B7):**

![Figure #14 PVTA Experiment 1 (Route B7). Route options 1 and 2(Left), 3(right). Nutrient/Oats at all “highest ridership stops.” Agar removed where no viable roadway available. Hour 48. Photo from author (November 2017)](image)

Observations & Results for PVTA Experiment 2 (Novel Route Design):

After recording notes and photographing for 72 hours the slime mold reached the end of the novel route over 2 replicates. After day one the slime mold had covered approximately a third of the map, but had veered in several directions. After day two (Fig. #15) the slime mold was half way and had solidified the “route” and had abandoned the exploration. After 72 hours, the slime mold sample had completed the route and was occupying the final oat pile at the Hampden County Jail, and had a sustained trail between “nutrient stops”.

Observations & Results for Maze Experiment (Decision Making Given Temperature):

After recording notes and photographing for 72 hours and completing four replicates, I found that slime mold has the “best” growth rate at room temperature and can recover after being exposed to stressful temperature conditions, in some cases. The first, second and third replicates ended with slime mold contamination on both the 30 and 37 degree samples, in the second attempt the agar was thinner and was began to be too dry in the 37 degree dishes. The sample in the room temperature dishes solved the maze “correctly” about half the time. For the temperature stress experiment the “fridge” dishes, four samples total solved the maze correctly and in the resilience study (fourth iteration) the slime mold when the “wrong” way in four dishes but was able to solve the maze in all cases. For the 30 degree samples, one dish in the third replicate grew towards the finish but was unable to solve the maze in seventy-two hours. There were no “successful” dishes in the 37 degree samples. Figure # 13 is a synthesis figure of representative petri dishes at each temperature. Table #3 represents the outcomes of the first three replicates of the temperature stress experiment. Table #4 represents the 4th iteration of the experiment, the resilience survey, where all the plates were brought back to room temperature. Figure #16 provides the average growth rate of replicate 1-3 after 72 hours. Figure #17 is a graph of the average growth rate for the fourth iteration’s growth rate.
Possible Outcomes Given Temperature

<table>
<thead>
<tr>
<th>Temperature (Celsius)</th>
<th>14-17 (Fridge)</th>
<th>19-22 (Room Temperature)</th>
<th>29-31</th>
<th>35-38</th>
</tr>
</thead>
<tbody>
<tr>
<td># petri dishes Solved Maze &quot;short&quot; way</td>
<td>4</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td># petri dishes Solved Maze &quot;Long&quot; way</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td># petri dishes Sclerotized</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td># petri dishes Contaminated</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td># petri dishes Did not solve the maze, but neither Contaminated or Sclerotized</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Table #3. Possible Outcomes Given Temperature. This table represents the results of three experimental replicates (18 dishes per replicate or 72 plates total) taken at the end of each experiment (72 hours). From Author

Average Growth Rate (Inches) over Time (Hours)

![Average Growth Rate Graph](image)

Figure #16. Average Growth Rate (Inches) Over Time (Hours). This figure represents the average growth rate at each temperature (Celsius). The rate found is for all four experimental replicates (measurements taken every 12 hours for 72 hours). From Author
<table>
<thead>
<tr>
<th>Temperature (Celsius)</th>
<th>14-17(Fridge)</th>
<th>19-22(Room Temperature)</th>
<th>29-31</th>
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</tr>
</thead>
<tbody>
<tr>
<td># petri dishes Solved Maze &quot;short&quot; way</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td># petri dishes Solved Maze &quot;Long&quot; way</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td># petri dishes Sclerotized</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td># petri dishes Contaminated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td># petri dishes Did not solve the maze, but neither Contaminated or Sclerotized</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Table #4. This table represents the success rate of slime mold samples that were all grown at room temperature after being grown at a colder temperature (14-17), the same temperature (19-22), or warmer temperatures (30 or 37) degrees Celsius.

Figure #17 Resiliency Experiment. This graph represents the growth rate of slime mold samples that were all grown at room temperature after being grown at a colder temperature (14-17), the
same temperature (19-22), or warmer temperatures (30 or 37) degrees Celsius. Figure from author.

**Discussion:**

In this inquiry, I looked at *P. polycephalum* (slime mold) as model system of resilience and resistance. I was interested in slime mold’s ability to maintain observed properties documented in past literature despite disturbance or stress. I used slime mold to model a public transit route. The second experiment was interested in looking at what metabolic threshold slime mold may have for optimal and suboptimal temperatures, while solving a maze and recording *P. polycephalum* reaction to a variety of less or more comfortable temperatures.

According to both Tero and Adamatzky *P. polycephalum* can efficiently and effectively create transit routes. Both researcher’s experimental designs were based off a subway system (Tero, 2010) and the US highway system (Adamatzky, 2015). Using slime mold as a biological networking system or bio-computer is exciting, however there are a lot of problems replicating studies previously conducted. “Much has been published in recent years regarding the use of bio-computers to solve minimal path problems such as route optimization and labyrinth navigation, but their outputs are typically difficult to reproduce and somewhat abstract in nature, suggesting that both experimental design and analysis in the field require standardizing.” (Mayne, 2017, page 1) In my experimentation I found that most bus systems are based on street/city maps and are therefore grids that become difficult for the slime mold. This is because subway systems and many highway systems follow geographical barriers so follow curved pathways versus public transit that is based on a grid system. Both subways and highway models merely describe what an actual system may look like instead of being modeled to scale as with a bus system. In other words, if a transit system can use the most direct both straight and curving paths, then using *P. polycephalum* as a biological network model is advised. If the transit system must follow a predetermined grid like system, that complicates slime molds ability to seek out the most efficient route, given it must take time to explore all the possible options before finding the “most efficient” and maintaining a trail or path between start and finish. This is further
complicated by the size of your system. Although not on purpose I found that the slime mold sample preferred the agar-rich, nutrient-poor sections instead of the opposite. This means that the slime mold sample spends more time exploring the periphery or edges of its container instead of strictly sticking to a single path between each oat. The maze experimentation was about what decision making changes occur based on a temperature gradient. I found that stress from both too hot or cold temperature as well as from contamination impeded the *P. polycephalum* sample’s ability to successfully solve the maze.

Given the average growth rate of all the samples I found that the “room temperature samples” had the most optimal growth rate but that the fridge sample were considered the most resilient. The fridge samples were described as the most resilient because when brought back to room temperature, they had the highest growth rate out of the three “less comfortable” temperatures. The success of maze solving (whether they made it to the finish) could be correlated to the rate of growth of each sample. I found that the samples had the most optimal growth at room temperature which was between 20 and 25 degrees Celsius. I had to change my procedure in order to troubleshoot some issues I had during the process of running these experiments. For the second, third and fourth replicate I simplified the maze and for the third replicate I sealed the dishes. I simplified the maze to increase the solvability of the maze. The simplification of the maze was to encourage an increased rate of success for the slime mold sample making it to the “finish” of the maze. This included having to use a different maze because the slime mold samples began to escape from the first model. I also tried to slow the amount of contamination that was happening in the two higher temperature samples by using para-film, which is a type of seal or plastic cover to keep moisture and contaminants out.

**Conclusion**

When compared to other literature using slime mold as a biological model my study met some of the same conclusions as in the articles, while not reaching other points of measurement. For example, I was able to complete the proof of concept, but not to the same consistency or viability as Adamatzky (2012). I also was able to have the slime mold sample re-create the B7 route but it was less able to create a novel route or system that a bus could efficiently and
effectively use. Based on the research studied, the hypothesis was that *Physarum polycephalum* would have the most success at room temperature. This hypothesis is gathered from research done previously (Ravi, 2014), where it was found that higher and lower temperatures will show a decrease in growth rate. The hypothesis was correct. During replicates 2 and 3, the 30 and 37 degrees’ sample did not exhibit good growth because mold contamination occurred which suffocated all nutrients from the Physarum.

In the fourth iteration of the temperature experiment I was studying resilience. I was interested if the chemotaxis mechanism was affected by different temperatures, and what would happen when all the samples were moved from stressful conditions to more a comfortable environment. I found my hypothesis was correct iteration 4 that *Physarum polycephalum* can recover from stressful conditions when introduced to a more optimal temperature of 20-30°C from hot (37-38°C) and cold (15°C) environments. The maze experiment was difficult to quantify given a variety of variables, including measuring its movement to small and exacting preciseness as well as combating contamination along with wondering how to analyze the sample’s decision making when the maze was not solved “correctly”. However it is clear that slime mold is versatile and can return from extreme temperatures and do even better in a more livable setting.

**Implications, Next Steps, and Future Experimentation:**

Future experiments can be done to see if *P. polycephalum* can be modified or “mutated” to adapt to a certain temperature condition. As with any living thing the slime mold samples did not always choose the same path every time, so in the future it would be important to generalize my experimental results. This could be done using a graph with weighted edges like in Tero’s et al. (2010) article. Tero et al, 2010 developed a mathematical model to communicate the results of their study on route finding and slime mold resilience. By using principles in graphing that allowed for an average or mean behavior the researchers could generalize the results further. “Unlike anthropogenic infrastructure systems, these biological networks have been subjected to successive rounds of evolutionary selection and are likely to have reached a point at which cost, efficiency, and resilience are appropriately balanced” (Tero et al, 2010 page 439) If I had more time for the resilience experiment I would differentiate between the growth rate and the decision making given temperature. To explain further one experiment would measure growth rate from
one point to another at different temperatures, while an alternative experiment would be interested in decision making, so how a slime mold sample solves a maze at different temperatures, without measuring growth rate.

These experiments can relate to global warming as the Earth’s global temperature is increasing microorganisms will be a key to understanding what changes in the larger ecosystem may look like, and possibly how one organism is adapting and surviving. The experiments completed modeled a type of route solving and creation, as well as how \textit{P. polycephalum} would react to the rising temperatures, and if they could recover from such temperatures. Some next steps could include humidity change, water content (flood or drought), in lieu of pollution; contamination (fungus) or toxin (salt), even food scarcity. As far as the PVTA transit route, I think replicating my experiment given more street options would be important. Another experiment could be providing slime mold decisions about the importance of particular stops along the route, this could be done using protein: carbohydrate ratios similar to the food scarcity project by Abby Moore that was part of the \textit{Physarum polycephalum} symposium (Hampshire college, March second 2018). I would also be interested in using a biological network (slime mold) to model how energy in the form of crude oil or coal or solar energy gets from the primary source (like an oil field) to our home or to the consumer. Specifically, how efficient are our systems of energy gathering and transport?

\textbf{Discussion}

Outcomes, Implications and Next Steps:

My thesis included research, synthesis and meaning making of resiliency. I discussed how the term is defined and used in both fields of social and natural science. I reflected on the practices that create more resilient communities. I designed and conducted a survey with Springfield residents and the staff at Arise as participants. The survey was about factors that lead to furthering community resilience. Finally I created and conducted experiments using the microbe \textit{Physarum polycephalum} to model resilient behavior. My thesis is broad and worked to tie together ideas from different sectors of study. The outcome was a review of previous literature and application of pedagogical practices, that arguably are resilient or lead to community resilience. An outcome of this vast inquiry, that can be drawn on in the future, are results from the resiliency survey. The feedback section, included many responses that recommended making
education about sustainable practices more accessible and creating infrastructure that makes it easier for residents to make just and sustainable choices. A suggestion I have, after this project, is for more communities to implement and uphold climate action and resilience plans that are written by people affected directly by climate change.

A possible next step would be to share my findings with others. I hope to discuss my findings with community stakeholders, climate scientists and those working on designing climate adaptation policy. If I had more time for this research I would have used a Community-Based Participatory Research (CBPR) approach. This methodology allows for a community’s needs and desires to be considered during the design of the project. This allows for community capacity building versus the traditional type of research that is much more individualistic with less input form participants or community members.

Conclusion:

The focus of my Division three thesis grappled with how to adapt to climate change. I identified resilience planning and frameworks as being key to survival and adaptation in our current climate crisis. After reviewing the historic and current understandings of the concept of resilience, I claim that resilience frameworks are not only viable to help adapt to climate change, but also to shift towards a more just and equitable world. I discuss possible sources of resilience. These sources being the concept and design principle biomimicry, climate action and resilience plans which are new policies that many governments are implementing, and the book Emergent Strategy. I outlined and explained my work with two organizations working in communities to solve current issues and create strong and resilient communities. All this inquiry into the foundations, structure and application of resilience gave my own argument a perspective, and allowed me to gain a position on ways to counteract climate change while simultaneously creating practices and understandings about what justice looks like.

A valuable tool I learned during the process of working on this thesis was to use the tenancies of resiliency as a guide. Conflict or stress may end with change or with a tipping point of criticality. However, when a system, group or an individual can meet this shift by searching to adopt strategies that increase trust and connection a stronger and more powerful system, group or individual will emerge. Resilient practices and orientations can lead groups to thrive.
References


*Census* profile: Springfield, MA. This figure represents the mean travel time to work and the ownership of housing units in Springfield. From the *Census* profile: Springfield, MA. (2017). Retrieved April 2018, from [https://censusreporter.org/profiles/16000US2567000-springfield-ma/](https://censusreporter.org/profiles/16000US2567000-springfield-ma/)


Collins, (2006), Pearson Education Inc.


**Engagement Documentation Appendix**

**Section#1) Arise for Justice Springfield Work:**

Environmental Justice Glossary
<table>
<thead>
<tr>
<th>Letter</th>
<th>Term</th>
<th>Definition</th>
<th>More Information</th>
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<tbody>
<tr>
<td>A</td>
<td>Arise for Social Justice, Springfield</td>
<td>is a member-led community organization dedicated to defending and advancing the rights of poor people. Arise has worked on issues such as housing, homelessness, criminal justice, environmental justice, and public health.</td>
<td><a href="http://www.arisespringfield.org/">www.arisespringfield.org</a></td>
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<tr>
<td></td>
<td>Asthma</td>
<td>a respiratory condition marked by spasms in the bronchi of the lungs, causing difficulty in breathing. It usually results from an allergic reaction or other forms of hypersensitivity.</td>
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<td>C</td>
<td>Climate Justice</td>
<td>is a term used for framing global</td>
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<tr>
<td>Coalition</td>
<td>an alliance for combined action</td>
<td>Since 2014 the Springfield Climate Justice Coalition has brought together organizations across the City of Springfield to take on the issues of Climate Change and Environmental Justice at the local level, out of a deep concern for the future of our environment and public health</td>
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<tr>
<td>Coordinator</td>
<td>a person whose job is to organize events or activities and to negotiate with others in order to ensure they work together effectively</td>
<td>The new PVPC plan hopes to put an environmental justice coordinator in our local government</td>
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<td>D</td>
<td>Debris Ban</td>
<td>city-wide ban on burning Construction and Demolition Debris as there are harmful chemicals involved when many materials are burned</td>
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<tr>
<td>E</td>
<td>Environmental Justice</td>
<td>is the fair treatment and meaningful</td>
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<td><strong>Environmental Justice Policy</strong></td>
<td>A Massachusetts statewide Policy, requires agencies to move towards treatment and mitigation of pollution and hazards in EJ communities</td>
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<td><strong>Environmental Justice Community</strong></td>
<td>A community that is frontline to climate change effects, it is an area that has done the least to cause these effects and areas with significant numbers of low-income individuals and historically marginalized populations</td>
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<tr>
<td><strong>Equality</strong></td>
<td>the state of being equal, especially in status, rights, and opportunities</td>
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<tr>
<td><strong>Equity</strong></td>
<td>the quality of being fair and impartial</td>
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<td>G</td>
<td>Global Warming</td>
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<td></td>
<td>a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, chlorofluorocarbons, and other pollutants.</td>
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<td>H</td>
<td>H.E.E.T</td>
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<td></td>
<td>Home energy efficiency team</td>
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<td>heetma.org</td>
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<td>J</td>
<td>Jobs With Justice (Mass)</td>
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<td></td>
<td>Mission is to improve working people's standard of living, fight for job security, and protect workers' right to organize. There are around 80 groups and projects</td>
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<td><a href="http://wmjwj.org/about-us">http://wmjwj.org/about-us</a></td>
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<tr>
<td>M</td>
<td>Mass Power Forward</td>
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<td></td>
<td>A group of environmental leaders, community development organizations, clean energy businesses, faith groups, neighborhood health and safety</td>
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<td></td>
<td>Coalition</td>
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advocates and Massachusetts families fighting for our future. We believe our state and region can power forward with clean, affordable, reliable energy and a thriving economy. We have no other choice.

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<tr>
<td>P</td>
<td>Plastic Bag Ban</td>
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<tr>
<td>R</td>
<td>R.G.G.I</td>
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the United States to reduce greenhouse gas emissions. RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont to cap and reduce CO₂ emissions from the power sector.¹

RGGI compliance obligations apply to fossil-fueled power plants 25MW and larger within the nine-state region.

<table>
<thead>
<tr>
<th>S</th>
<th>Sustainability</th>
<th>the ability to be maintained at a certain rate or level.</th>
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<tr>
<td>T</td>
<td>Toxic Action Center</td>
<td>mission is to work side-by-side with communities, providing you with the skills and resources needed to prevent or clean up pollution at the local level.</td>
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¹
Local Resources and how to get involved:
- Energy save, weatherization services;
- Senior Long Term/Springfield
- Mass save (housing);
- How to save gas and have less emissions;
- Prog custom route finder;
- Lead free housing initiative;
- Energy Efficient Appliances:
Links to above resources can be found at:
https://solar.energyboard.org/2059506a9c-2
To get involved visit https://www.areaspringfield.org

There is NO planet B!

P.S. If you liked this Zine check out all those other REALLY cool Zines about
stuff! Go to: https://medium.com/animals/blog/the-green-zine-reads-4few
https://www.howareyouare.net/2019/07/31/,
https://www.sustainableliving.sub/
And for other AWESOME resources go to:
http://www.alternativeearth.ca/sustainable-living-zine-scene or
https://scienceforthepeople.org
Gusty Catherin  
December 2017  
Notes on Current Extreme Weather Policy  
(Volunteer at ARISE)  

The Department of Health and Human Services located in Western Massachusetts discusses education as being important to implementing the extreme weather policy. For example, “all staff will be educated about hypothermia, and then will in turn educate residents”, specifically trying to outreach to the homeless, and target/find family and friends to support homeless in extreme weather Conditions.

- The official dates of “cold weather are November 1st-March 31st, with “extreme cold” temperatures being ten degrees or below, as well as a core body temperature of around ninety five degrees, this refers to Hypothermia
- Staff are supposed to find “high risk” residents
- Staff should “assess for vulnerability”
- The policy highlights homes having an emergency preparedness kit
- In cases of extreme weather a “prevention” team will respond to individuals in need of transportation to shelter services and/or emergency medical services
- Weather policy  

The Mass.dot (Department of Transportation) has advisories about how to be safe while driving in the snow and icy conditions, they have links to an emergency car kit, “winter highway maintenance research,” as well as a page for the priority snow removal for the larger Boston area.

http://www.massdot.state.ma.us/highway/Departments/SnowIce/WinterRoadTreatmentSnowRemoval.aspx

Other agencies such as the department of public works have alert systems to tell about school closing, media and severe weather services.

index.php (dept of public works: snow and ice)
http://wrhsac.org (info about first responders and emergency preparedness)

My Research/Questions/Notes:

Research:
- According to westernmassnews.com more than half of state's homeless are families
- Current policy discusses that ten degrees or below is “cold weather” however does that include humidity or not?
  - For example, if the air temperature is 75 degrees Fahrenheit (24 degrees Celsius) and the relative humidity is zero percent, the air temperature feels like 69 degrees Fahrenheit (21 C) to our bodies. If the air temperature is 75 degrees Fahrenheit (24 C) and the relative humidity is 100 percent, we feel like it's 80 degrees (27 C) out.
(https://science.howstuffworks.com/nature/climate-weather/atmospheric/question651.htm)

- Other city policies that have different or better frameworks? 
  http://www.mass.gov/eohhs/gov/newsroom/press-releases/eohhs/comprehensive-winter-efforts-to-address-cold-weather.html (this seems to sum up what is available statewide but extremely pointed towards Boston but maybe helpful)

- Writing about how businesses should react and support to inclement weather (Winter-weather-policy.aspx)

Questions:

What about hot weather parameters and policy (supporting residents during extreme heat)
What could be changed/added in this policy?
Is it good or bad that they have that they have a specific temperature (10 degrees) when they deploy their team?
How can we move from “highest risk residents idea to highest support during cold weather? (taking blame/responsibility away from those affected)
- What is accountability for staff “educating residents,” do they have check-ins with peers or Supervisors?
- What are the places of shelter besides Friends of the Hampshire County Homeless?
- Who will do educating (of the staff) about cold weather preparedness?
- What does “assess for vulnerability look like?” Are they referring to elderly, children, those living alone, pets? Or some other population or parameter?
- What support is there for the winter home emergency kit and heating equipment?
- Have alarm systems ever been used in the cases of natural disaster preparedness what else could be included in it?

Notes:
- There is a need for a more consistent and dependable warming shelter framework (there are only a few shelters the policy discusses, predominantly the Friends of the Homeless
-The whole of the policy is very much reactionary and at times preventative instead of focusing on support and resiliency since extreme weather events are likely to become more frequent in the near future.
- The responsibility is put on agencies and Springfield public to prepare and help individuals during extreme weather.
- Prevention team responds to folks already in need of transportation to shelter services.
- Alternate power system for city in extreme weather (such as back up generators).

Ideas for better communication about policy and during extreme weather events:
- “Bus shelter billboard for emergency services - lisa “
- Does the city have brochures/information about weather emergency/natural disaster preparedness, radio's (even walkie-talkie), local news services broadcast updates, but what about when power goes out? (maybe wind up radios, flashlights, or sources of heat and solar power).


Section #2)
Resiliency Survey:
https://docs.google.com/forms/d/1AekPVW11h4TL7LeVg6RbT5eHOYuChCf8TmBpnKhyAAE/edit

Survey Institutional Review Board Report:
Title of research project: Resiliency Survey
Resilience and Resistance; Using Physarum Polycephalum and Critical Pedagogy to explore Environmental Justice work

Faculty Supervisor (if applicable): Sarah Partan
Date submitted: 11-14-17

Description: The purpose of this research is to engage with what different individuals are doing to shift everyday behavior to counteract climate change and to become more resilient communities. I am a volunteer with ARISE for Social Justice in Springfield, who recently helped implement the Strong, Healthy & Just: Springfield Climate Action & Resilience Plan, completed by the Pioneer Valley Planning Commission. Part of the plan is to reduce the city’s greenhouse
gas emissions by 80% by 2050 and to make the city more resilient. The purpose of my survey is to gain a understanding of Springfield residents attitudes and reactions to climate change and initiatives to fight it. I hope to create a product that would emphasize and contextualize what folks are facing in terms of effects of climate change and/or barriers to becoming sustainable. I plan to gather feedback about the Springfield Climate plan. It is important to know which parts of the plan matter most as well as what other ways residents are working to become resilient in the face of climate change. “I am interested in learning about what you and the people close to you feel and/or are doing about climate change.”

Participants: I hope to have 15-20 participants, however given the networks that Arise for Social Justice has, there may be many more. My participants will be recruited by making an ask to them if and when they visit the ARISE office. I am seeking anyone who is a resident of Springfield; However, my participants will be only be those over the age of eighteen (adults). Participants can decide whether they want to be anonymous.

Procedures: After participants are recruited, I will ask them to sit with me to be interviewed. I will give them consent forms (this includes Informed consent and oral consent) and interview questions ahead of time. Participants will decide if they prefer one-on-one interviews if they would like group interviews, if that is possible at that time. Interviews will be audio recorded, and I will take handwritten notes, if consent is granted. Participants will decide if they would like anonymity or if they would like to use their true identities. Interviews will be kept to under an hour and I will make sure all participants know this. Interviews will take place at the location of the participants’ choosing. Also, I will also be getting a site authorization from ARISE for Social Justice Springfield. I will remind any groups that are interviewed that it is not possible to maintain confidentiality in that setting. I will keep confidential all data collected in individual interviews and I will not share information that emerges from group discussions. However, in groups, I cannot force group participants to keep anything they hear or see confidential.
Risk assessment: There are minimal risks to participating in this study. I am aware that people will have a variation of viewpoints and opinions on this topic, and that asking people to share their thoughts may be recalling events where a person needed to be rescued can bring up negative emotions, and will be extra careful during interviews to continually check in with participants to make sure they are OK. I will have cards with information about local mental health facilities should participants need assistance. I will remind all participants that they can stop at any time, can refuse to answer any question, and may withdraw from the study at any time for any reason.

Informed consent: All participants will be given their respective Consent Forms: Oral Consent Forms, Informed Consent Forms, Parent Consent Forms, Assent Forms. I will ask participants before interviewing if they agree to audio, notes, and written work being used. If they do not, I will make a note on an oral consent form that this anonymous interviewee only agrees to be interviewed. I will inform all participants that all data will be confidential and will be secured at all times.

Debriefing of participants: I will explain to all participants that the result of this research is one part of my Division III Project and some content may appear in the my thesis product or in ARISE’s publications and that it will be a public piece that will be available to the public indefinitely. They will be able to read the entire story before publication and may strike any direct quotations, they wish, before publication.

Privacy ensured: All data will be kept confidential. All data will be stored on a password-protected computer. All files will be deleted upon completion of story. All notes will be shredded by publication of the story, not to exceed one year. Only information used in the Division III project will be available to the public indefinitely through the Hampshire College library ARISE for social justice where it will be archived.

Other: Site Authorization Was obtained from Arise
Section #3) Pioneer Valley Transit Authority Background Research:

Evidence:

According to their last passenger satisfaction survey, PVTA found that 61 to 65% of those surveyed want improvement to the service going where they need to go (location accuracy), the frequency of service was also important. Finally only 47%-61% were satisfied with total travel time as well as on-time performance of the PVTA.

http://www.pvta.com/media/pdfs/PVTA%202015%20Southern%20System%20Survey%202014-2016%20FINAL.pdf

This figure shows the projected ridership between the fiscal years 2014-2017. Provided by the PVTA and PVPC. http://www.pvta.com/

Maps:
This figure is a PVTA full service system map.

http://www.pvta.com/systemMap.php (access the link for a more thorough diagram of the full route Map)

B7:

This figure highlights the performance efficiency parameters and analysis produced overtime by the PVTA and the Pioneer Valley Planning Commission (PVPC). http://www.pvta.com/
Section #4) Slime Mold Affluence Experiment:
Timelapse Video attached can be found at the following Link:
https://drive.google.com/drive/folders/1k_vICInKtoqWDyf0Z9E7-ZRF0DxmAUj

Section #4) Evidence of Slime Mold Growth and Maze Solving:
Section #5) Agar Making Protocol:
Protocol for making slime mold plates (2% agar plates)
Time Needed: At least 2 hours

Get a 500mL bottle from the cabinet near the classroom and add 500mL dH₂O. Ideally you’d use a graduated cylinder to measure exactly 500mL and transfer it to the bottle. Get the powdered agar (may be in the basement lab) and measure out 10g. Add the powder to the bottle of water, tighten the cap, and gently mix the powder by tilting the bottle upside down a few times.

Bring the bottle downstairs to the autoclave. Put the bottle in a metal tray filled with about 1 inch of water. Loosen the cap and add autoclave tape. Autoclave on liquid setting according to chart taped to front (cycle #4, liquid #2). You will have about an hour to wait. In the meantime, you can take out one sleeve of petri dishes, lay the plates out on an empty bench and label them all “slime mold group.” Keep the sleeve for storing the plates later.

After the autoclave is done, be careful not to have your face near the door as you open it to avoid the hot steam. With autoclave gloves, remove the tray. Tighten the cap on the bottle and dump the water from the tray into the sink. Carefully bring the bottle upstairs (using elevator if you can’t open doors with gloved hands).

Rest the bottle on the bench to cool. If the agar is too hot, it will melt the plates. If it’s too cool, the agar will start solidifying and you won’t be able to pour it. You should be able to touch the bottle with bare hands for longer than 1 second without burning yourself, but it should still feel hot.

With an autoclave glove on your hand, pour the agar into each plate, covering the entire bottom with liquid (about 20mLs per plate). Just tilt the cover of the plate like a clamshell to pour the liquid inside, and return the cover onto the plate after each pour. Never leave the plates uncovered for very long.

After about 30 minutes, the agar should be solid. Test this by gently tilting one to the side. If the agar seems solid, put the plates back into the sleeve they came in and label the sleeve with tape that says, “slime mold group.” Put this sleeve in the fridge so that the agar is upside down in the plate.

-Megan Dobro Hampshire College September 2017
**Section #6) Slime Mold PVTA and Maze Experiment Protocol:**

**PVTA Experiment 1 Protocol:**
- Use aseptic techniques such as latex gloves, sterile instruments, sterilizing your work area, and lighting a bunsen burner. Be sure to be wearing close toes shoes and if you have long hair pull it up out of your face.
- Use 1% agar gel, pour over shape of particular region (8X11” Map of B7) and placed in sterile plastic storage bin (9” × 12”)
- At the beginning of each iteration a piece of plasmodium, always already attached to an oat flake, is placed at the Springfield Union station bus hub.
- For each iteration the most popular/used (according to PVTA stats) public transit stops were used as sites for nutrients (oat flakes * weighted and a constant each time)
- In some iterations oat flakes were placed at similar scale (to original route) between 1-2 inches along alternate routes (roadways) a bus could likely take (*these routes were found using google map advisories)
- The bins with plasmodium were kept in darkness, at constant temperature and climatic conditions, except for observation and image recording (appendix Fig. ?).
- Periodically (usually at 12 hour then 24 hour intervals) the dishes were photographed
- Experiment ran for seventy two hours

**PVTA Experiment #2 Protocol:**
- Use aseptic techniques such as latex gloves, sterile instruments, sterilizing your work area, and lighting a bunsen burner. Be sure to be wearing close toes shoes and if you have long hair pull it up out of your face.
- Use 1% agar gel, pour over shape of particular region (8X11” map of Novel specified route) and placed in sterile plastic storage bin (9” × 12”)
- At the beginning of experiment a piece of plasmodium, always already attached to an oat flake, is placed at the Holyoke Housing Authority.
- For each iteration oat flakes (at a constant weight) were placed at similar scale between 1-2 inches along proposed routes (roadways) a bus could likely take
- The bins with plasmodium were kept in darkness, at constant climatic conditions, except for observation and image recording
Periodically (usually at 12 hour and 24 hour intervals) the dishes were photographed.

- Experiment ran for seventy-two hours

Maze Solving Given Temperature Experiment Protocol:

- Use aseptic techniques such as latex gloves, sterile instruments, sterilizing your work area, and lighting a Bunsen burner. Be sure to be wearing close toes shoes and if you have long hair pull it up out of your face.
- **Using Professor Dobro’s protocol make 2% agar medium**
- Use 24 petri dishes that are completely sterilized.
- Label with name, date, and degree sample will be kept at (6 dishes at each temperature, except iteration #1 where there was five dishes at each temperature)
- For iteration #1 place laminated mazes in base of dishes, careful to place in same location each time
  - Dish size is (145X20mm) maze size (40X880mm) maze should be located as close to the middle as possible
- Pour approximately 20 ml of 2% agar medium into the petri dish and let it solidify over night, store in fridge upside down.
- Take out the scalpel and dip it into alcohol and dry it over the Bunsen burner to remove any bacteria or mold.
- Cut out the maze pattern in a millimeter wide cut, use the tweezers to remove excess agar.
- Place one oat flake weighing approximately the same each time at the “start/in” of each petri dish (24)
- Place several oats weighing the same (1 gram, usually 3 oats) at the “finish/out” of the maze in all petri dishes (24)
- Use a cotton swab and a healthy Physarum culture to transfer the Physarum to each petri dish from stock plate.
- For iteration #3 cover the petri dish and wrap with parafilm, to prevent moisture from leaving the dish.
- Cover the set of petri dishes (6 at each temperature) with black cloth, so no light will affect the *Physarum polycephalum* sample.
• Place the petri dish in its designated temperature chamber (16°C±2 degrees, 25°C±4 degrees, 30°C±1 degree or 37°C±1 degree).

• Photograph and take observations of the physarum 2X daily for 72 hours.

• Record results.