THE PLASMODIUM CONSORTIUM

POLICY CIRCULAR NO. 1
HAMPSHIRE COLLEGE
2018

INTRODUCTION

The plasmodial slime mold *Physarum polycephalum* has foraged on forest floors for over half a billion years, successfully inhabiting every continent except Antarctica. In the Spring of 2017, a population of *P. polycephalum* was invited to Hampshire College, appointed to the faculty position of visiting non-human scholar, and enlisted to analyze some of the world's most vexing problems. Aided by a team of student research assistants, the Plasmodium Consortium has already attained significant results. The purpose of this circular is to make the findings public in the interest of informing governmental policy and facilitating needed improvements to society.

The species *Physarum polycephalum* is singularly qualified to provide policy analysis for myriad reasons. Most obviously, slime molds are objective: On matters of human politics, they are impartial and nonpartisan. Slime molds are also known for their ability to solve complex problems. In order to survive over half a billion years, often in adverse conditions, *P. polycephalum* has evolved an aptitude for assessing opportunities and risks to achieve optimal results. Moreover, because plasmodia are super-organisms – containing many genetically distinct nuclei in a single amoeboid body – the decisions represent a collective optimum for the whole population, reached by consensus.

Humankind is likewise a super-organism. Through the agency of technology, people around the world are now densely networked, and technology amplifies the impact of human activity: The decisions of one individual can have repercussions for everybody. However, since these technological enhancements are relatively recent, humans have not yet evolved the aptitude to live as a super-organism. Human policy is therefore often deficient, and may even imperil future survival. The collective optimum sought by slime molds can inform administrators, politicians and citizens of all nations, who may confidently act on the plasmodial advice because *P. polycephalum* is free of human biases.

This circular summarizes investigations of five issues that humans have not been able to resolve on their own. The Plasmodium Consortium has studied the implications of regulating borders, drugs and the environment, and has explored new approaches to eradicating food deserts and improving public transportation. Although none of the results are definitive, preliminary policy recommendations are provided in the form of letters dispatched to government officials.

The efforts of the Plasmodium Consortium are ongoing. Future circulars will disseminate new analyses and insights. In addition, the public is encouraged to participate by providing suggestions for investigations, and independently collaborating with slime molds as a prelude to internalizing the ability to act as a super-organism.

- JONATHON KEATS, SECRETARY

BORDER POLICY

Neither natural nor immutable, national borders can be based on geographical, cultural, or political boundaries. Borders typically involve some measure of control over the flow of people and goods: since slime mold can be understood as both a population and a system for transporting resources (nutrients), it presents a compelling model for observing the effects of diverse border conditions.

According to one hypothesis, all populations will benefit most by having free flow of citizens and resources across completely open borders. A contrary hypothesis holds that border restrictions provide beneficial protections by preventing populations from unfairly taking advantage of one another.

For this investigation, two countries are represented in a single petri dish, as equal populations on opposite sides. One side has exclusively protein as a nutrient, while the other has exclusively carbohydrate. Optimally, slime mold would have access to both. Light acts as a deterrent or risk factor, disincentivizing movement and representing modes of border control.

Border conditions are modeled in the following ways: in the first scenario, the populations are completely separated by the unpassable border of a sealed plexiglass wall; in the second, a brightly illuminated central strip operates as a controlled border; in the third, the illumination is intermittent, simulating erratic border control; and in the final scenario, there is no barrier at all. After 72 hours, the populations are measured in terms of surface area covered, indicating which conditions are most beneficial for the world as a whole. Further steps to be taken might include modeling asymmetric border controls and the dynamics of multiple international trade agreements.

Investigation undertaken by Rick Noble (F17, Div II)

International borders are expressed in varying degrees of severity: border markers, custom and immigration controls for passports and visas, fences, walls, border guards, and even national military troops. Border types can be classified into soft and hard borders. Soft borders include entirely open as well as regulated and controlled frontiers. Hard (also known as fortified) borders include wire-fenced, walled, and militarized borders.

Soft Borders

Open

- USA - Mexico
- USA - Canada
- European Union
- Historically most borders

Regulated

- USA - Mexico
- USA - Canada

Hard Borders

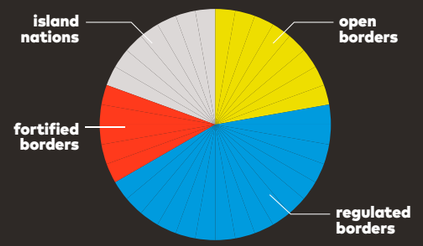
Fenced

- USA - Mexico
- Most fortified borders

Walled

- USA - Mexico
- Israeli-Palestine
- Maginot Line
- Hardin's Wall
- China Wall

Total countries in the world divided by border type



Given a total of 195 sovereign countries in the world (with some dispute as to that total), 50 are island countries. The border type of the other 145 land-based nation-states can be categorized as follows:

15-28 have open borders

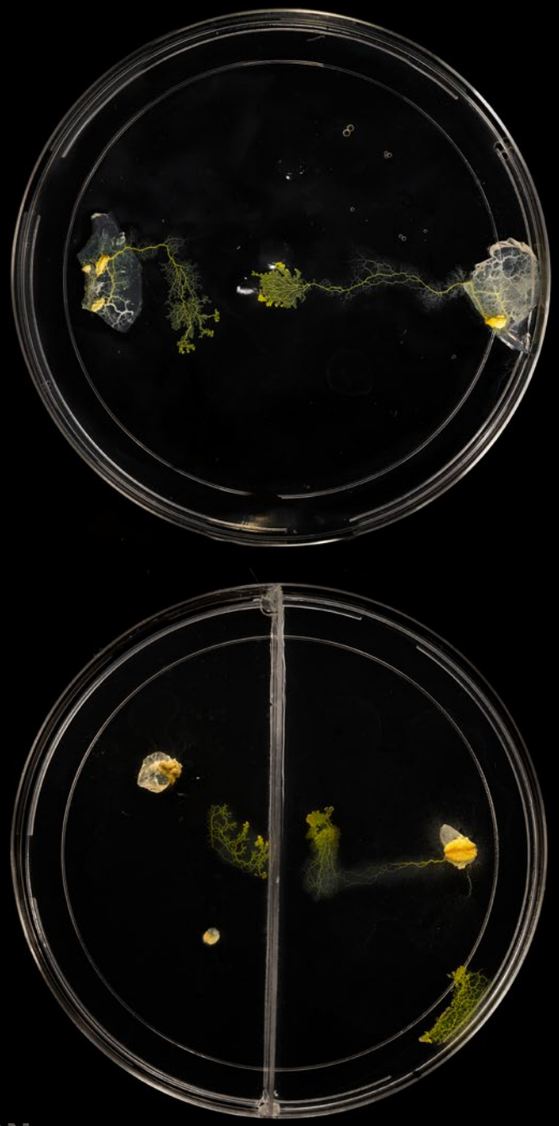
75-88 have regulated borders

42 have fortified borders

U.S. Borders

Borders Compared	Length	Federal Agents	Bordering U.S. States
U.S.-Canada	4,000 mi. (6,440 km)	Less than 1000	10
U.S.-Mexico	1,970 mi. (3,140 km)	12,000	4

SOURCES: Vogeler, Ingolf. (n.d.). Types of International Borders along the U.S.-Mexico Border. http://www.siue.edu/GEOGRAPHY/ONLINE/Vogeler/TypesBorders.htm



The Honorable Kirstjen Nielsen
Secretary of Homeland Security
U.S. Department of Homeland Security
245 Murray Lane SW
Washington, DC 20528-0075

February 7, 2018

Dear Ms. Secretary:
I am writing on behalf of the Plasmodium Consortium, an independent policy institute based at Hampshire College in the United States. One of our research groups studies how national border walls effect society. A primary objective of this research is to determine whether barriers improve or impair the livelihood of citizens on both sides of the divide. Every territory offers some opportunities, but not all that may be wanted by the resident population. A major dilemma for policy-makers is whether to secure exclusive access to internal resources by restricting movement of people and goods, or to allow free circulation in the interest of sharing.

Our researchers are uniquely qualified to provide policy advice because of their objectivity: As members of the species *Physarum polycephalum* – a type of plasmodial slime mold – they have none of the prejudices common to human researchers, administrators, and politicians. At Hampshire College, where they hold a collective faculty appointment as visiting non-human scholars, they are able to immerse themselves in human problems without human preconceptions. Moreover, slime molds are superorganisms. Populations are capable of fusion and cooperative behavior that can reveal how humans could cooperate to their mutual benefit without the burden of nationalism.

Preliminary results from the plasmodial research group suggest that the United States government should not build a border wall, and should replace current national barriers with parklands. These suggestions are based on the observation of slime mold populations grown in petri dishes with different nutrient types on each side, simulating the different opportunities available in different countries. One dish was prepared with an impenetrable plastic barrier down the middle. Another was free of obstructions. After a period of several days, the unconstrained slime molds were found to join together and thrive in the open border zone, suggesting that borders may be especially vital regions if allowed to develop without government interference.

Additional research will provide further details on this important topic. The Plasmodium Consortium will continue to brief interested parties with periodic circulars. We also invite dialogue with the Department of Homeland Security, the United States government, and the American public. Please do not hesitate to contact us with any questions.

Sincerely,

Jonathon Keats
Secretary

cc: President of the United States, President of Mexico, Prime Minister of Canada, Secretary General of the United Nations

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ADDICTION

Valerian root (commonly used as a sleep aid) is a chemoattractant for Physarum polycephalum: the organism's preference for valerian interrupts healthy foraging behavior in a manner that can potentially be modeled in terms of addiction.

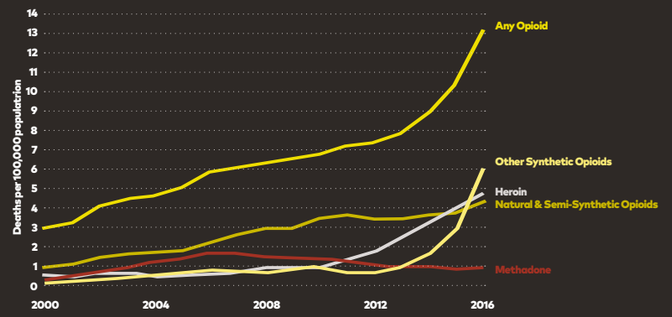
In the midst of the opioid crisis, one widespread hypothesis in drug policy circles is that people can be weaned from hard drugs with access to less harmful ones, while others claim that milder drugs act as gateways to more serious addictions. To model these ideas, this investigation subdivides petri dishes into concentric rings: pure valerian root is placed at the center and pure nutrient in the outermost ring. Intermediate rings have progressively less valerian root and more nutrient from center to rim.

Slime mold is placed at the center as a means of investigating the effectiveness of weaning through the availability of less concentrated drugs, and observed as to whether the bulk of its biomass will migrate outwards over time. Conversely, slime mold is placed at the rim of a similar dish to observe the perils of having "gateway" drugs widely available, effectively "pulling" the slime mold towards the most concentrated valerian and away from balanced nutritional sources.

Further steps to be taken include modeling different approaches to making the movement outward more pronounced than the movement inward, incentivizing the slime mold to make healthier choices, as well as observing how slime mold "habituated" to more addictive environments behave when sampled and placed in new decision-making scenarios.

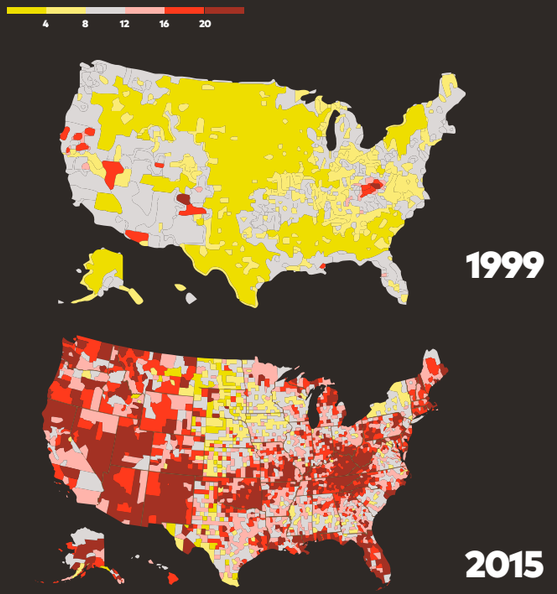
Investigation undertaken by Matt Hinderhofer (F17, Div I), Rick Noble (F17, Div II), and Hannah Davidson (F16, Div II), with initial workshopping alongside Daniel Altschuler (Linguistics, CSI) and Pamela Stone (Anthropology, CSI)

Overdose Deaths Involving Opioids, by Type of Opioid, US



Each year since 2013, the rate of deadly overdoses from synthetic opioids other than methadone has increased by an average of 88 percent. Heroin, an illegal opioid, claimed more than 15,000 lives in 2016, compared to nearly 13,000 in 2015. By comparison, opioids killed more people in 2016 than car crashes (about 37,400), guns (about 38,000) or breast cancer (about 40,000).

Overdose deaths in 2015 per 100,000



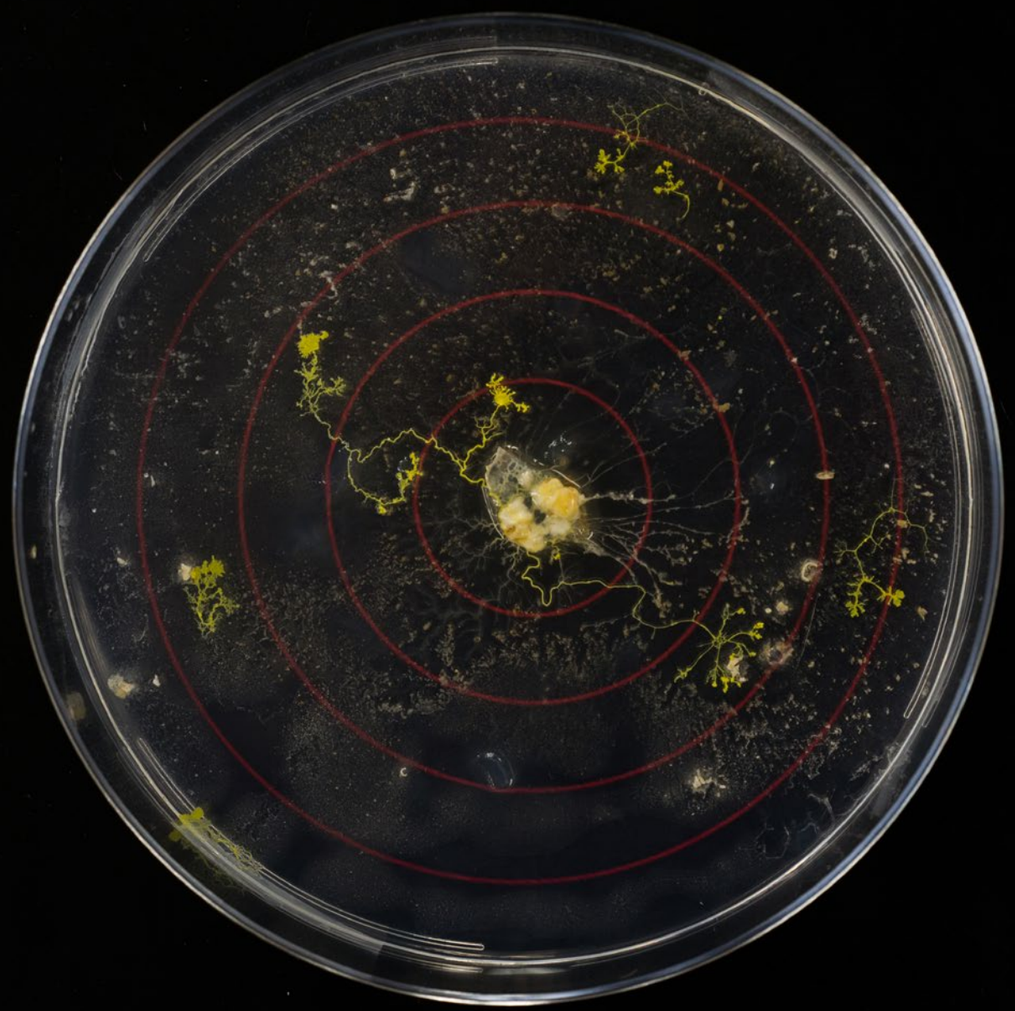
The Epidemic

For the second year in a row, U.S. life expectancy has dropped, a trend largely attributed to the surge in fatal opioid overdoses.

More than 63,000 Americans died of drug overdoses in 2016 — and 42,249 of those deaths involved opioids, according to a new analysis from the Atlanta-based Centers for Disease Control and Prevention.

Between 2015 and 2016, the U.S. saw a 28 percent increase of fatal opioid overdoses. In 2015, more than 52,400 deaths were attributed to drug overdoses, and 33,000 of them involved opioids.

SOURCES: Overdose Deaths Involving Opioids, United States. 2000-2015. [Digital image]. (n.d.). The New York Times, https://www.nytimes.com/2017/10/26/us/opioid-crisis-public-health-emergency.html



The Honorable Jeff Sessions
Attorney General of the United States
U.S. Department of Justice
950 Pennsylvania Avenue, NW
Washington, DC 20530-0001

February 7, 2018

Dear Mr. Attorney General:
I am writing on behalf of the Plasmodium Consortium, an independent policy institute based at Hampshire College in the United States. One of our research groups studies the social dynamics of drug use, specifically investigating how availability of soft drugs such as marijuana may impact dependency on hard drugs such as cocaine and heroin. A primary objective of this research is to determine whether legalizing cannabis and its chemical derivatives will increase or decrease hard drug use by the American public. Marijuana is often referred to as a gateway drug. The conundrum faced by responsible policy-makers is whether it's a gateway to dangerous chemical addiction or a gateway from addiction to well-being.

Our researchers are uniquely qualified to undertake this investigation because of their objectivity: As members of the species *Physarum polycephalum* – a type of plasmodial slime mold – they have none of the prejudices common to human researchers, administrators, and politicians. At Hampshire College, where they hold a collective faculty appointment as visiting non-human scholars, they are able to immerse themselves in human problems without human preconceptions. This is especially important when confronting an issue as polarizing as drug policy. Moreover, because *P. polycephalum* populations are superorganisms, their collective activity can effectively model large-scale behavior in a highly-connected society such as our own. They can anticipate how the American population may collectively respond to policy changes before changes have been made.

Preliminary results from the plasmodial research group suggest that cannabis and its chemical derivatives should be legalized by the United States government. Confronted with a binary choice between a highly-addictive chemical and a nutritionally-balanced meal, slime mold populations will consistently choose the former, with consequences that can be fatal. However when presented with a chemical gradient between the addictive substance and nutrients – equivalent to availability of gateway drugs in a human environment – slime molds show a distinct tendency to migrate from the former toward the latter, but not from the latter to the former, a choice that improves their chance of survival. This asymmetrical movement is important evidence that psychopharmacological gateways are thresholds to well-being for individuals and society as a whole.

Additional research will provide further details on this important topic. The Plasmodium Consortium will continue to brief interested parties with periodic circulars. We also invite dialogue with the Department of Justice, the United States government, and the American public. Please do not hesitate to contact us with any questions.

Sincerely,

Jonathon Keats
Secretary

cc: President of the United States; Director General of the World Health Organization; Commissioners of the Global Commission on Drug Policy

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MATERIALISM

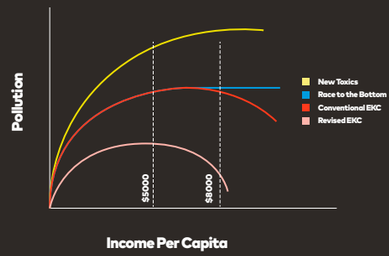
This investigation models a world in which material affluence and environmental hardship are positively correlated, such that humanity equally experiences both the gains (such as car ownership) and losses (such as toxic smog). While this is a simplification – omitting the fact that the poor are disproportionately impacted by toxic waste – the model broadly explores the ideal balance between affluence and hardship in terms of wellbeing. Are we better off in a society with more of everything, or better off making do with less?

Given slime mold's nutritional resource needs, as well as its aversion to salt, we can model scenarios of varying material abundance and toxicity. Two paste dilutions are made to combine salt (pollution) and powdered oats (affluence) at different nutrient to salt ratios: one mixture has a low concentration of both substances, while the other has a high concentration of both. These represent scenarios that follow the initial upward trend of the Environmental Kuznets Curve, in which, in the early stages of industrialization, environmental pollution rises rapidly alongside affluence.

Petri dishes are prepared with a nutrient-free agar and subdivided into two equal semicircular zones, each covered with one of the mixtures. Slime mold is placed in the center of each dish, and observed for which zone attracts the majority of the plasmodium, signalling slime mold preferences. In a second scenario, dishes of the same preparation are exposed to environmental volatility (a symptom of climate change) in the form of intermittent light, and observed as to whether slime mold preferences or strategies shift. Further steps to be taken include modelling environments in which sub-populations of slime mold are disproportionately impacted by toxicity.

Investigations undertaken by Sophie Spillmann (F14, Div III), Gusty Catherin (F14, Div III), and Yasmina Mattison (F17, Div II)

Environmental Kuznets Curve: Different Models

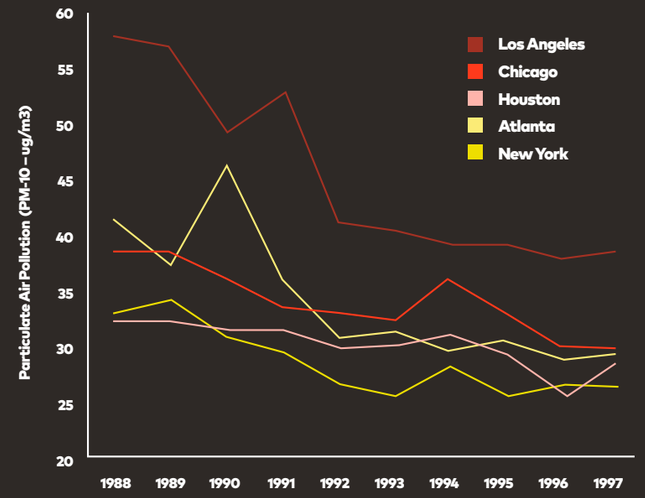


Air Pollution Regulation and Income Per Capita in 31 Countries

How do societies make decisions about the levels of wealth they wish to enjoy while realizing the costs of emissions and its toxicity in their lives? Historical evidence suggests societies get wealthier and emit more, but then decide to decrease emissions once they've reached a certain level of wealth (as shown in the Environmental Kuznets Curve model).

Might societies rather have less wealth and lower levels of pollution, or is pollution a cost we must endure to gain wealth and flourishing?

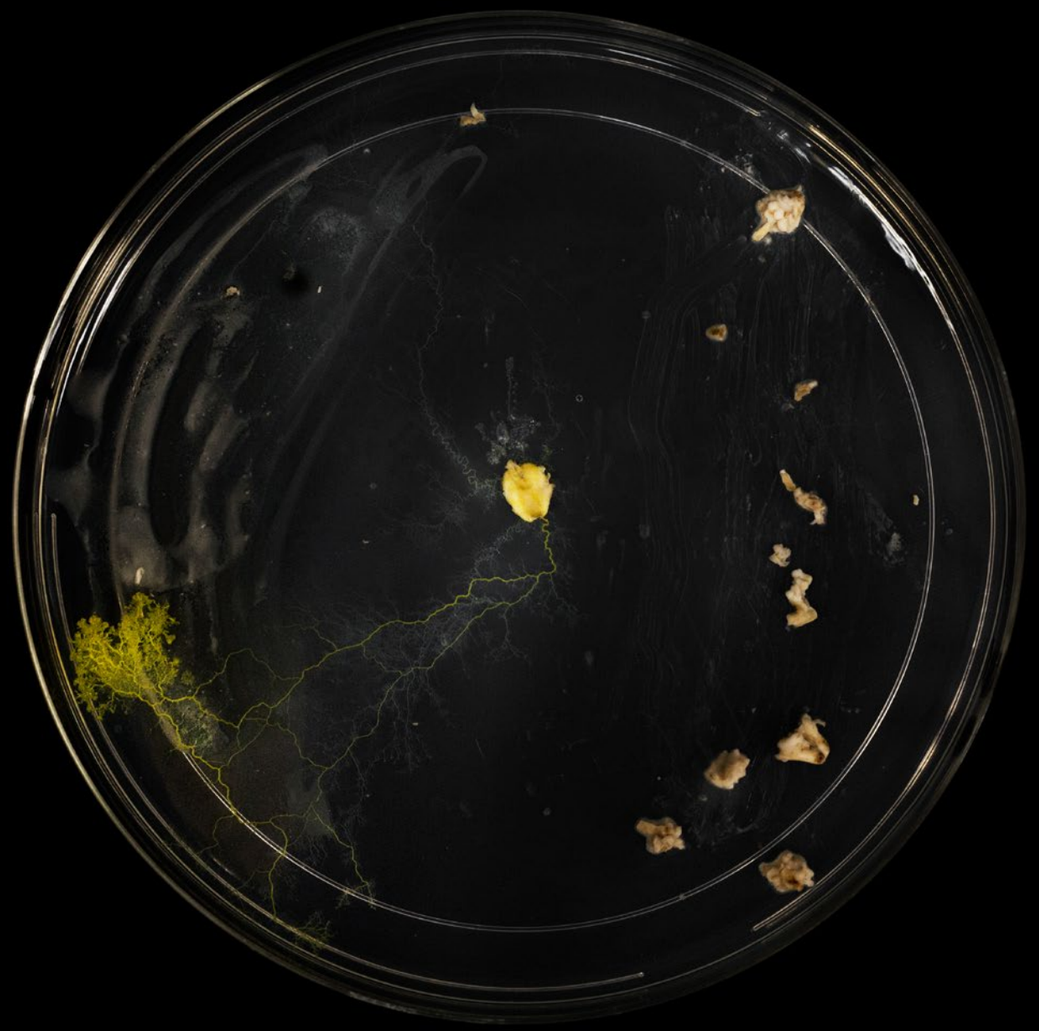
Air Pollution in US Metropolitan Areas, 1988-1997



The Role of Environmental Regulation

Observed changes in pollution as per capita income rises could come from several different sources: whether firms can emit less as they get bigger or as they produce more diverse products, whether a firm can adopt technologies in production that result in lower emissions, or whether a government's choice of regulation can get firms to decrease overall emissions. But isolating these different causes can be hard for researchers without good quality data from firms across time and space to test what firms actually do.

SOURCES: Journal of Economic Perspectives—' Volume 16, Number 1—Winter 2002—Pages 147–168 Confronting the Environmental Kuznets Curve Susmita Dasgupta, Benoit Laplante, Hua Wang and David Wheeler



The Honorable Scott Pruitt
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

February 7, 2018

Dear Mr. Administrator:
I am writing on behalf of the Plasmodium Consortium, an independent policy institute based at Hampshire College in the United States. One of our research groups studies the relationship between economic development and the environment. A primary objective of this research is to determine whether, from the standpoint of societal well-being, environmental degradation is a price worth paying for material wealth. The extraction of resources and production of goods are polluting activities, and environmental toxicity may detract from the enjoyment of the resulting commodities. In myriad policy decisions, governments must prioritize either productivity or regulation. The challenge for responsible administrators is to determine which is in the best interest of the public.

Our researchers are uniquely qualified to provide policy advice because of their objectivity: As members of the species *Physarum polycephalum* – a type of plasmodial slime mold – they have none of the prejudices common to human researchers, administrators, and politicians. At Hampshire College, where they hold a collective faculty appointment as visiting non-human scholars, they are able to immerse themselves in human problems without human preconceptions. Moreover, as superorganisms they are able assess problems rationally, finding universal optima using sophisticated computational mechanisms such as quorum sensing. This is especially important when confronting an issue as contentious as environmental regulation.

Preliminary results from the plasmodial research group suggest that the United States government should protect the environment even to the detriment of short-term economic growth. For instance, offshore oil drilling should be banned, and greenhouse gas emissions should be a primary consideration in environmental reviews of factories. These suggestions are based on the observation of slime mold populations given a choice between environments with high concentrations of nutrient and repellant, and environments with low concentrations of both. Slime molds consistently migrate toward the latter and thrive as a result. Given slime molds' ability to collectively reach optimal decisions, their behavior can be seen simultaneously as an indication of preference and best interest. Regulation is better for society, and citizens are likely to favor it in terms of how they vote.

Additional research will provide further details on this important topic. The Plasmodium Consortium will continue to brief interested parties with periodic circulars. We also invite dialogue with the Environmental Protection Agency, the United States government, and the American public. Please do not hesitate to contact us with any questions.

Sincerely,

Jonathon Keats
Secretary

cc: President of the United States, Director General of the World Trade Organization, Executive Director of the United Nations Environment Programme

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FOOD DESERTS

Given slime molds' ability to balance their own diet and distinguish among foods of varying quality, how might they navigate or adapt to a "food desert?" Four criteria are generally used to determine neighborhood food environments: access, availability, quality and affordability. This model maps two components - access and quality - across a small region of Hampden County, Massachusetts, which includes a variety of food sources, as well as areas identified by the Pioneer Valley Planning Commission as having high and low food access.

Food sources with varying ratios of digestible carbohydrate to protein are composed to correlate with the quality of food accessible at various outlets - supermarkets, grocery stores, outdoor markets, and convenience stores - consistent with slime mold's preference for a balanced diet of 2 (protein) to 1 (carbohydrate). Plasmodia are positioned at equal intervals on a 1% agar covered, laminated map representing a 1.5 square mile section of the Brighton and Metro Center areas of Springfield. Food banks were removed from consideration in this first iteration.

By observing how slime molds distribute themselves to get a balanced meal, suggestions can be made as to where outdoor markets could be located to at least partially alleviate the time and other costly trade-offs associated with accessing balanced nutrition. Further steps to be taken include expanding the area under study, adding additional food environment criteria (such as affordability), and comparing or expanding analysis through the use of agent-based modeling software emulating slime mold behavior.

Investigation undertaken by Abigail Moore (F16, Div II) with initial workshopping alongside Thom Long (Architecture and Design, HACU), Ben Solis (community member), and Lee Spector (Computer Science, CS)

1.8% of U.S. Households
or 2.1 million households

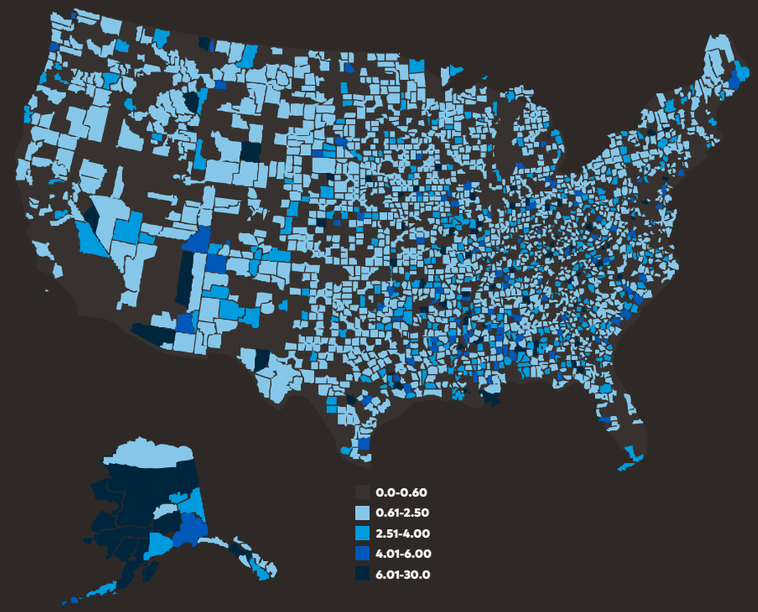
= + **> 1 mile from supermarket**

9.7% of U.S. Population
or 29.7 million people

= **LOW INCOME** + **> 1 mile from supermarket**

A food desert is a low-income census tract where either a substantial number or share of residents has low access to a supermarket or large grocery store.

U.S. Population > 1 mile from food and no vehicle access (%)



The majority of the evidence continues to support—or strengthen—three primary findings:

- Accessing healthy food is still a challenge for many families, particularly those living in low-income neighborhoods, communities of color, and rural areas.
- Living closer to healthy food retail is among the factors associated with better eating habits and decreased risk for obesity and diet-related diseases.
- Healthy food retail stimulates economic activity.

SOURCES: Ver Ploeg ET AL, Access to Affordable and Nutritious Food. Updated Estimates of Distance to Supermarkets Using 2010 Data. ERR-143 US Department of Agriculture. Economic Research Service, November 2012; US Department of Agriculture. Created by Brianna Davis, 11/7/2016. University of Illinois Urbana-Champaign; PolicyLink/The Food Trust, Access to Healthy Food and Why It Matters: A Review of Research.

The Honorable Ben Carson
Secretary of Housing and Urban Development
U.S. Department of Housing and Urban Development
451 7th Street, SW
Washington, DC 20410

February 7, 2018

Dear Mr. Secretary:
I am writing on behalf of the Plasmodium Consortium, an independent policy institute based at Hampshire College in the United States. One of our research groups studies food deserts, districts where underprivileged communities struggle to access healthful ingredients because grocery stores and supermarkets are far away. A primary objective of this research is to determine how populations cope with these desert conditions, and how they might benefit from additional grocery sources. At present, most zoning laws are extremely broad, making few distinctions between categories of commercial property. While this is understandable in circumstances where administrators cannot make informed decisions about the impact of specific types of business, the Plasmodium Consortium is developing methods that will allow planning agencies to provide for community needs through more nuanced zoning designations.

Our researchers are uniquely qualified to provide planning advice because of their objectivity: As members of the species *Physarum polycephalum* – a type of plasmodial slime mold – they have none of the prejudices common to human researchers, administrators, and politicians. At Hampshire College, where they hold a collective faculty appointment as visiting non-human scholars, they are able to immerse themselves in human problems without human preconceptions. Moreover, the foraging techniques of slime molds have been refined over billions of years. Plasmodia rapidly form highly efficient networks between food sources, dynamically balancing their diet.

Preliminary results from the plasmodial research group shows significant food deserts in Western Massachusetts, and further study is revealing where grocery stores and supermarkets can best be positioned to serve the community as a whole. On the basis of these initial insights – which will be relayed to local officials in a timely manner – we recommend that zoning laws be amended to account for local nutritional needs and that future zoning decisions be reviewed by our non-human scholars. The Plasmodium Consortium is available for consultation at Hampshire College. In addition, mobile units can be dispatched to government offices and agencies in Washington DC and elsewhere.

Additional research will further refine this important new planning methodology. The Plasmodium Consortium will continue to brief interested parties with periodic circulars. We also invite dialogue with the Department of Housing and Urban Development, the United States government, and the American public. Please do not hesitate to contact us with any questions.

Sincerely,

Jonathon Keats
Secretary

cc: President of the United States, Governor of Massachusetts, Director General of the United Nations Food And Agriculture Organization

THE PLASMODIUM CONSORTIUM | HAMPSHIRE COLLEGE | 893 WEST STREET, AMHERST MA 01002

PUBLIC TRANSPORT

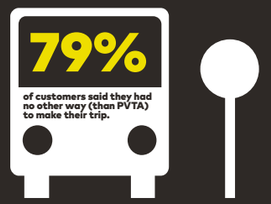
Based on the placement of nutrition at key stops and junctures, slime mold has famously charted efficient routes that recreate - in mere days - networks such as the Tokyo subway and US highway systems: infrastructure that took human engineers and planners many years to design. Indeed, transport quandaries are amongst the most widespread scenarios on which Physarum polycephalum's optimization skills have been tested.

In western Massachusetts, the Pioneer Valley Transit Authority oversees the local public bus system. When a 1.38 billion dollar funding gap emerged in the PVTA budget last year due to a cut in state funding, several bus routes and stops were eliminated, and services changed. Local tensions continue to run high over which routes and stops to eliminate or amend, as further budget cuts seem imminent: could Physarum polycephalum find the most efficient and effective routes connecting areas of high ridership and need?

As part of her Division III thesis project, Gusty Catherin (F14) is exploring local public transportation from the perspective of multiple stakeholders, including community members and organizers (such as ARISE for Social Justice) and the Pioneer Valley Planning Commission (a consultant to the PVTA). Related investigations she is pursuing include the design of a novel connector route among non- or under-serviced locations identified, for example, as major employers by census data; recommendations on frequency of service to stops on existing routes; and potential route modifications for efficiency.

Investigation undertake by Gusty Catherin (F14, Div III)

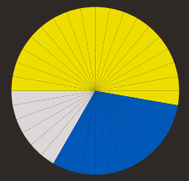
The PVTA Rider



71% of riders reported annual incomes of $20,000 or less

55% of riders reported incomes at or below the federal poverty level of $11,770 per year.

The majority of PVTA riders are transit dependent. Based on ridership, fare payment data, and customer trip frequencies reported on rider surveys, there are an estimated 15,000 to 20,000 people in the region who use PVTA on a regular basis (at least once a week).



51% of customers ride the bus everyday

33% ride the bus at least twice per week

The proportion of transit customers in the PVTA service region who are people of color is approximately four times greater than the proportion of persons of color in the region as a whole.

Transit Dependency is Defined as:

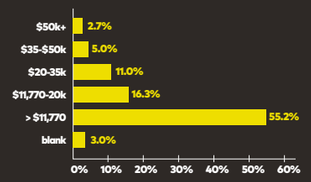
- people without private transportation or
- private car
- elderly age 65 and older
- youths under age 18
- persons below poverty level or median income

The PVTA Reports:

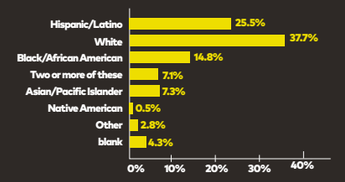
- 52% of PVTA customers do not own or have access to a private auto.
- 3.7 % are age 65 or older.
- Approximately one-fifth are 18 or younger.
- More than half (55.2%) of PVTA riders have incomes at or below the federal poverty level.

SOURCES: PVTA Equity Analysis report; Equity Analysis for Service Changes Effective Fall 2017, Prepared by the Pioneer Valley Planning Commission for the Pioneer Valley Transit Authority

PVTA Rider Income Levels

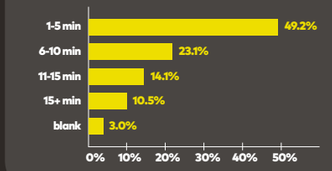


PVTA Rider Racial Characteristics

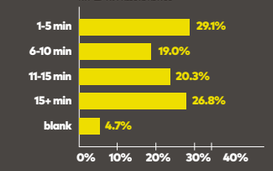


The PVTA Rider Experience

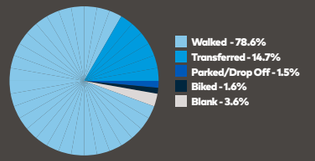
Time to Bus Stop

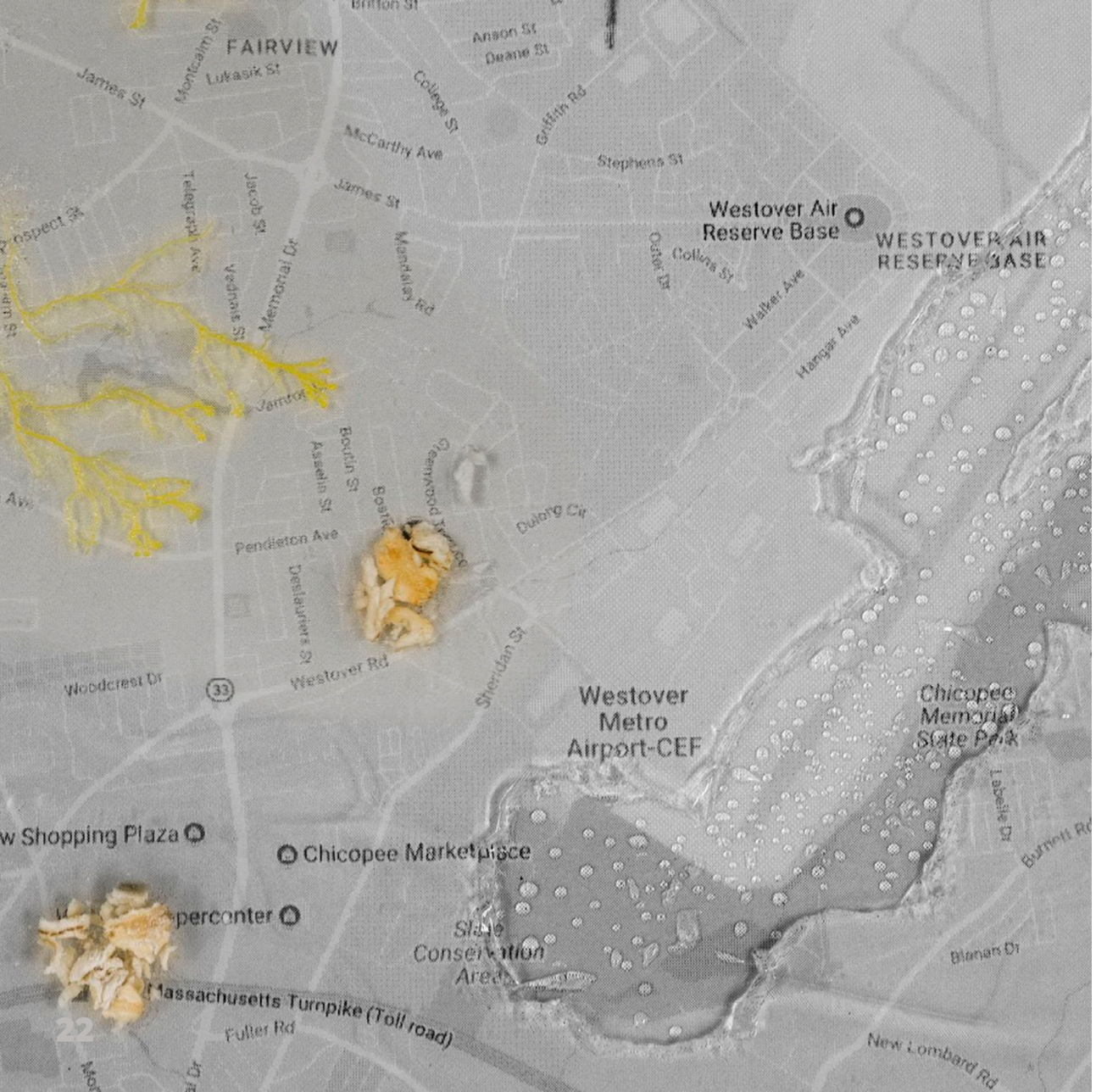


Time from Bus Stop to Destination



Method of Travel to Bus Stop





The Honorable Elaine Chao
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Ave, SE
Washington, DC 20590

February 7, 2018

Dear Ms. Secretary:
I am writing on behalf of the Plasmodium Consortium, an independent policy institute based at Hampshire College in the United States. One of our research groups studies public transportation. A primary objective of this research is to determine how public transit routes can most equitably serve economically disadvantaged populations. Governmental efforts to make routes geographically efficient often overlook important considerations such as access to community services for those in public housing.

Our researchers are uniquely qualified to provide planning advice because of their objectivity: As members of the species *Physarum polycephalum* – a type of plasmodial slime mold – they have none of the prejudices common to human researchers, administrators, and politicians. At Hampshire College, where they hold a collective faculty appointment as visiting non-human scholars, they are able to immerse themselves in human problems without human preconceptions. Moreover, the optimization techniques of slime molds has been refined over billions of years. Slime mold plasmodia form networks as they forage, and those networks are optimized to account for multiple desiderata.

Preliminary results from the plasmodial research group shows significant public transit oversights in the Pioneer Valley of Western Massachusetts, and further study is revealing how routes can better serve the community as a whole. On the basis of these initial insights – which will be relayed to local officials in a timely manner – we recommend that all infrastructure improvements planned by the Department of Transportation be reviewed by our non-human scholars. The Plasmodium Consortium is available for consultation at Hampshire College. In addition, mobile units can be dispatched to government offices in Washington DC and elsewhere.

Additional research will further refine this important new planning methodology. The Plasmodium Consortium will continue to brief interested parties with periodic circulars. We also invite dialogue with the Department of Transportation, the United States government, and the American public. Please do not hesitate to contact us with any questions.

Sincerely,

Jonathon Keats
Secretary

cc: President of the United States, U.S. Secretary of Housing and Urban Development, Governor of Massachusetts

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NOTES ON *PHYSARUM POLYCEPHALUM* AS ORGANISM, COLLABORATOR AND MODELING AGENT

The plasmodial slime mold *Physarum polycephalum* is a single-celled organism of the supergroup Ameobozoa. They decompose organic matter in the damp, shady areas of temperate forests, and can exist in multiple biological states. The single unit is an amoeba-like cell that engulfs bacteria and other microbes to survive. When food is scarce, two cells of different mating types can fuse their cell membranes and nuclei in a form of sexual reproduction toward genetic variability. Other cells can continue fusing while the nuclei divide simultaneously to grow the mass of slime mold, or the plasmodium, well over 12 inches across. This super-organism can now grow in many directions at once, sending out protoplasmic tubes to maintain links between nutrients and communicating through chemical signals rapidly transported throughout the connected network.

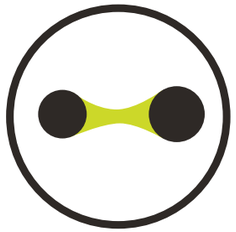
Slime mold are ideal collaborators and modeling agents due to several valuable abilities. Sophisticated programmers and mathematicians, they can quickly create the most efficient networks between food sources, navigate obstacles, and assess risk versus reward for the overall survival of the organism. Historically, slime mold networks have been used to map human transportation systems[1], solve mazes with complicated obstacles[2], create electronic devices such as transistors and sensors[2], and make circuits,[3] amongst myriad other applications. Significantly, their progress and preferences can be tracked and measured with the naked eye, as well as by multiple metrics on a microscopic scale, making them adaptable to investigations broad in type, scale, and scope. They are also very easy and safe to work with, have been known to get along well with collaborators of all ages, and can thrive in wide-ranging environments.

Our investigations in the *Plasmodium Consortium* present several human problems modeled with a non-human agent, in collaboration with students, staff and faculty from a variety of disciplines. An important note should be made about the purpose and limitations of models: models can never perfectly replicate the real world, nor can they account for all variables. In reducing the complexity of problems, focusing on certain aspects and variables through a process of simplification and abstraction, we are often able to gain greater clarity and perspective, allowing us to see the problems in new ways.

- MEGAN DOBRO, SCIENTIFIC ATTACHÉ

References:
Andrew Adamatzky and Andrew Ilachinski. Slime Mold Imitates the United States Interstate System. Complex Systems 21 (2012) 1-20.
Andrew Adamatzky. Physarum Machines: Computers from Slime Mould. World Scientific Series on Nonlinear Science (2010). ISBN 978-981-58-9.
Andrew Adamatzky. Advances in Physarum Machines: Sensing and Computing with Slime Mould. Springer (2016). ISBN 978-3-319-26661-9.

Laboratory research on the plasmodial slime mold *Physarum polycephalum* reveals problem-solving capabilities including the following:



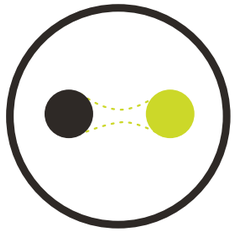
the ability of individual cells to swarm and fuse into a single organism

the ability to sense nutrients and other chemicals at a distance and to locate them in two-dimensional space

the ability to explore an environment and rationally decide when to stop exploring in order to exploit a resource

the ability to optimally balance light avoidance and food acquisition

the ability to habituate, learn new foraging behaviors based on past experience, and to forget what has been learned over time

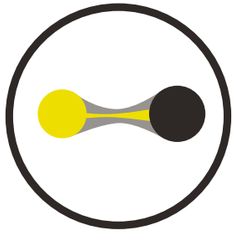


the ability to break apart into multiple organisms and to spore

the ability to form a network across a two-dimensional surface in order to feed on multiple isolated nutrient sources

the ability to avoid light by movement away from sources of illumination

the ability to optimally balance overall diet by detecting nutritional proportions in foods or by distributing biomass proportionally between protein and carbohydrate sources



the ability to transfer learned behavior to naive slime molds by fusing with them

the ability to form tendrils and pump nutrients from extremities to the core of the organism

the ability to form networks that optimize intake of nutrients from multiple source nodes on a two-dimensional plane – with redundancy for resilience – and to reroute when conditions change

the ability to avoid light by temporary fragmentation into smaller multicellular units or by sporing

the ability to remember previous activity by leaving and later detecting chemical markers

the ability to remember recurring stimuli and to anticipate future iterations of those stimuli by reacting preemptively

the ability to search for nutrients in a labyrinthine two-dimensional spaces

the ability to optimize routes for minimal metabolic expenditure, including calculation of distance and sloping

the ability to distinguish and respond differently to different colors within the visible light spectrum

the ability to determine previous activity by other plasmodia by detecting foreign chemical markers

the ability to evolve quickly through rapid and regular mutation of DNA

Based on the above capabilities, global problems can be translated into terms meaningful to slime molds by modulating factors within a petri dish including the following:

- direct manipulation of plasmodium
- placement and distribution of multiple plasmodium colonies
- placement and proportional distribution of food sources
- arrangement of physical barriers to food sources
- arrangement of chemical barriers to food sources
- arrangement and masking of light sources
- color modulation of light sources
- proportional distribution of protein and carbohydrate sources
- movement and redistribution of food sources
- regularities and irregularities in feedings
- manipulation of ambient warmth and humidity
- distribution of slime and use of slime-resistant surfaces
- three-dimensional modeling of environment

Slime mold responses can be monitored based on behaviors including the following:

- speed and direction of movement
- proportional distribution of biomass after a fixed time period
- shape of multicellular networks after a fixed time period
- changes to networks over time
- fragmentation/aggregation of biomass
- sporing
- learned behavior and memory

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Thom Long - Exhibit/Content Designer
Ray Mendel - Documentary Photographer

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