LIVING ARCHITECURE:

urban planning as a science,
the metropolis,
&
COMPLEX ADAPTIVE SYSTEMS

MASTER'S THESIS
PROF. NOAH RESNICK

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school of architecture

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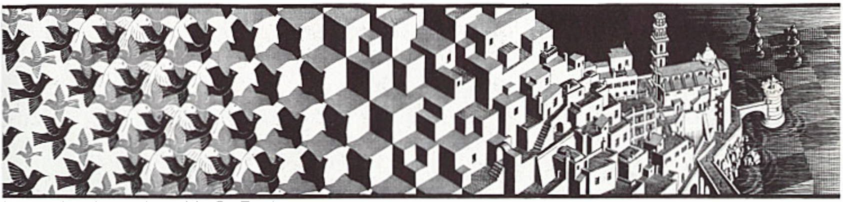

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urban planning as a science, the metropolis, and complex adaptive systems

by: David C. Kassab

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0 INTRODUCTION

0.1 PREFACE

Complex Adaptive Systems (C.A.S.), as theory, encompasses a vast quantity of other theories from multiple disciplines of science and mathematics. I set out on the impossible quest to interpret some of the most complex mathematical algorithms of genetic adaptation, biological growth, quantum mechanics, and many other disciplines. With the end goal of trying to develop an algorithm of my own for the city, I quickly realized that my surface-level knowledge of calculus, quantum theories, biological chemistry, and genetics could not support a sufficient thesis. So, in accordance with the advice of my professors, I decided to implement the knowledge and expertise afforded to me by my architectural education. Although I began with (and structured my thesis around) research, I sought to conclude with an emblematic architectural intervention as a sketch design problem. This decision did have an impact on the empiricism of developments. This is to say that, my slime mold research lacked a sense of the 'hard science' which it attempts to promote. I'll speak more on the limitations of my research in 'part iii.' It is sufficient to say that the empiricism of the topic of this book should not be judged based on my interpretations of it. The scientific validity of Complex Adaptive Systems as a theoretic foundation for urban growth, development, and planning shall require an extensive amount of research beyond the scope of my Thesis. Yet, I had to work within the constraints of an accelerated (* accelerated compared to most two-year Mater's programs) one-year Master's Thesis. I presume it would require many students, educators, and professionals working in collaboration with other to formulate testable theories, algorithms, and other 'tools.'

I stand by the contention that my Thesis intends to produce; specifically, the city is a bottom-up process that should be view in the context of Complex Adaptive Systems theory. My arguments here are derived from a culmination of research, observations, studies using the scientific method, graphical analysis, and the application of my architectural education. After my research arrived at a point in which I could understand the topic well enough, I began extrapolating C.A.S. into architectural diagrams, sections, elevations, urban maps, and site analysis. After all, this is my field of expertise; with five years of design/interdisciplinary studies at the University of Detroit Mercy and nearly three years of professional experience in the architectural industry (as an intern). Therefore, it was my goal to apply my newly found knowledge of C.A.S. to the typical architectural methods of analysis. This is to say, that the content of my sketch problem isn't nearly as exciting of an endeavor to me as the ability to use C.A.S. as a 'tool-kit' for the comprehension and development of truly informed decisions, in terms of urban planning and architecture as a profession.

I offer this Thesis book as a primer for the creation of an empirical, testable theory which applies C.A.S. to the urban condition. Cities, metropolises, and entire nations can benefit from a greater understanding of urban growth, divestment, and emergence. Once truly understood, C.A.S. theory could change the paradigm of modern infrastructure, transportation, energy systems (creation and distribution), weather systems, economics, computer science, genetics (of all organisms) and much more. With time (efficiency), money (productivity), and quality of life (health) at stake, everyone will gain from an advancement of our understanding, and application, of C.A.S. theory. It is the essence of my contentions that, like the colonies of ants and bees in my analogies, the entire human macro-population stands to benefit.

0.2 ACKNOWLEDGEMENTS

Due to the sophisticated nature of Complex Adaptive Systems, my journey of research has been influenced (in a positive way) by many of my academic cohorts – for which I am forever indebted. Tony Martinico, a 4th Year professor of mine, first introduced to the concept of multiplicity. Without the encouragement and guidance of Professor Martinico I would have never furthered my investigations on this topic and, thusly, I would have never arrived at C.A.S. as the framework of my intellectual endeavor during the next year and a half. Noah Resnick, my Thesis professor, assisted me as an academic advisor throughout the development of my Thesis process. Without Professor Resnick, my aspirations of developing a uniform and cohesive theory could never have properly emerged. Dr. Gregory Grabowski, my slime mold research advisor, afforded to me the invaluable resource of an academic biological perspective. Without Dr. Grabowski, my interest in developing a biological analogy and slime mold research could never have come to fruition. These interpersonal corroborations allowed me to have an academic foundation, without which this book would not have been created.

Collective human knowledge and the progression of science is never the result of one student, or university. Even more debt is owed, by me, to the fathers of knowledge and science. I acknowledge, wholeheartedly, that my development pales in comparison to the intellectual progression of mankind afforded by intellectuals such as: Gilles Deleuze, John Holland, Doulgas Hofstadter, Lewis Mumford, Sprio Kostof, D'arcy Thompson, et al. (plus countless others).

0.3 OVERVIEW

This book culminates two semesters (and one summer) of scholarly research. For fluidity, I have taken the liberty of organizing my research based on conversations (e.g. part i, part ii, part iii) rather than the chronology of my discoveries. In many ways, my Thesis development has been dynamic and non-linear (in likeness of the theory which it grounds itself upon). I will admit the intimidating breadth of information of which I've attempted to cover; but, I have attempted to arrange my analogies and arguments to combat this issue with shear logic.

First, 'part i' explains Complex Adaptive Systems theory from several different perspectives (e.g. analogies, scientific studies, etc.). A transition is then made from the theory, as a science, to its relationship with architecture and the city. Once the city (as a concept) is opened up, then the interrelationships between each of its systems can be elaborated. 'Part ii' begins with this elaboration and moves through to my design sketch as a response to rapid global urbanization. Thereafter, 'part iii' describes the direct implementation of an analytic tool which incorporates C.A.S., the scientific method, and urban design. Lastly, I wrap up the conversation in a post script intended to speculate on the future.

In a way, this book should be viewed in the image of Gilles Deleuze's "A Thousand Plateaus." Similar to the multiplicity our books intend to describe, the chapters and their relationship with the others are interconnected in such a way that you could begin reading on any page. There exists a common motif intertwined within every chapter, image, and analogy. It is inherent within the topic that this common thread exists. Douglas Hofstadter, in his famous work "Gödel, Escher, Bach," describes the links between symmetry, self-repetition, mathematical algorithms, and the emergence of intelligence as an "Eternal Golden Braid" (note: the G.E.B. – E.G.B. wordplay was fully intentional). With all of this

having been said, I have chosen not organized this book in a manner that could seem schizophrenic. The methodology of my writings errs on the side of cohesiveness rather than attempting to recreate the essence of a multiplicity through sporadic placements of interrelated conversations.

1

PART I: FOUNDATION

1.1 THESIS STATEMENT

"Dolorit, offic tem se offic to dolor as autem cum volupic imilliamus aborae doles sunt et aut fugia ium commo to quid quatior essinum apitiis et utatinv electatem voluptate invelestis est ea vendero ium core volorum, samet ute quas ex etus. Quiasse dionece peratiis voluptium quos et ilicabo"
-Quatior, ven 23

The postulate of my thesis and of the general theory of complex adaptive systems is: the emergence of high-level, complex behavior of a (biotic or abiotic) system can be abstracted as simple interactions between autonomous low-level agents. These abstractions can be manifest in a computational model, such as a computer software program, and analyzed in an explanative manner (as to understand that system in a definite and empirical way). Once this is achieved, a truly informed design can be fostered through the use of societal trends, information, and patterns (aesthetic and behavioral).

1.2 DEFINING C.A.S.

"Dolorit, offic tem se offic to dolor as autem cum volupic imilliamus aborae doles sunt et aut fugia ium commo to quid quatior essinum apitiis et utatinv electatem voluptate invelestis est ea vendero ium core volorum, samet ute quas ex etus. Quiasse dionece peratiis voluptium quos et ilicabo"
-Quatior, ven 23

1.2.1 Complex

My introduction to complexity theory began with Gilles Deleuze in "A Thousand Plateaus." In this work, Deleuze describes a multiplicity as "an entity that originates from a folding or twisting of simple elements. Like a sand dune, a multiplicity is in constant flux, though it attains some consistency for a short or long duration. A multiplicity has porous boundaries and is defined provisionally by its variations and dimensions." [2]. For me, multiplicity was able to answer the problem of chaotic phenomena exhibited by systems (later I came to the definition of this to be non-linearity), such as the weather/climate systems. In the case of classical scientific understanding, Newtonian physics was only able to describe that which was deterministic, or linear [8]. To illustrate, imagine a ball. This ball, in order to move, must have a force which propels it; likewise, in order for this ball to stop moving, there must be an opposing force experienced by the moving ball. Based on our knowledge of energy, force, and gravity, we can say that the ball is acting in a manner which is determinate. Yet, as mentioned earlier, weather systems are non-deterministic and cannot be described by classic Newtonian physics [8]. But how could this be? Weather is a system, and a seemingly well understood one. We know the cycles of climate and weather systems, types of clouds, and causes of change in the form of precipitation. Yet, we cannot forecast weather even hours away without a significant margin for error [8]. This is because weather systems are chaotic, non-linear, and non-deterministic in nature; even the crux of Chaos Theory, known as the butterfly effect, is based on and was derived from the idea that a butterfly flapping its wings on one side of the world can affect a weather system, such as a typhoon, on the other side of the world [8,9]. That is to say, that all movements in the high complex and integrated world of air movement are affective to each and all parts [8,9].

1.2.2 Adaptive

The first descriptions of adaptation came from biology [4]. Viewed within this context, adaptation can be seen as any process whereby a "structure is progressively modified to give better performance in its environment" [4]. Essentially, adaptive processes are optimization processes; but the difficulty in studying these processes and forming a unified theory lies in the complexity of the structures which constitutes that which is adapting [4]. Viewing adaptation in this sense (between all disciplines) entails "a commitment to viewing adaptation as a fundamental process, appearing in a variety of guises but still subject to unified study" [4]. John Holland, developer of a complex adaptive genetic algorithm and a professor at the University of Michigan, says, on the structures which constitute the adaptation process: "we can see that adaptation, whatever its context, involves a progressive modification of some structure or structures…(whereby)

"careful observation of successive structural modifications generally reveals a basic set of structural modifiers or operators; repeated actions of these operators then yield the observed modification"

[4]. In other words, the properties of a system (the structures) are modified by recurring rules (operators). An example of this is seen in genetics, where the chromosome structures are modified by the operations of mutation and recombination [4].

1.2.3 System

Systems theory has existed since the first man began describing the world as he saw it. A system (of some type) has been used to describe almost every facet of our universe, even before The Enlightenment or the industrial revolution. Humans are cleverly equipped to recognize patterns; not just in the aesthetic sense, but moreover, in the systematic sense [5]. Being able to recognize the climate patterns of seasons has allowed civilization to develop agriculture; which has been the single most important factor in the propagation of our exponentially expanding global population [10]. Systems are everywhere and our cognition has become keen on recognizing them [5]. The drawing of connections into networks is a major component to systems thinking; without it, these descriptions of properties and behaviors could not be unified. It is once the understanding of a thing's behavior can be described in this unified sense which it can be referred to as a system.

1.2.4 Complex Adaptive System Theory

An agent is a single entity within a system of many interacting agents [1]. The magnitude of each agent is scale based and provides for a unified understanding from macro-societal development to micro-cellular development. Each agent has three simple properties: each agent is autonomous, its behavior can be abstracted into simple rule-based actions/reactions (another way to say this is: if/then programs) and it has a very small, but quantifiable, difference between itself and another agent (that is, each agent is unique) [1]. Through these small differences, the interactions and communications between each agent becomes distinct and unique. When considering this on a macro-scale, it can be somewhat overwhelming to think of each of these interactions as having an influence on design and form of urban development. But, it is each of these low-level interactions which afford the high-level complexities [1]. Just as brains are made up of smaller,

GENETIC CODING

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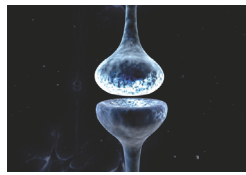
BIOLOGY

SYNAPSE



NEURO SCIENCE

BINARY CODING

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COMPUTER SCIENCE

BUY / SELL

ECONOMIC

Image 1.2.4E

simpler parts (called neurons) such is the city; made up of a collection of individual interactions [1]. The synergy of these interactions creates a situation whereby the sum of the parts no longer equals the whole [1]. The whole becomes transcendent of each individual part (just as the ant colony becomes transcendent of an individual ant). This transcendence is emergent, in that, nowhere within the rules that govern the agents is this high-level behavior programmed [1,5,9]. Rather, without a high-level program governing its behavior can foster even greater level of complexity, adaptation, and emergence [1,5,9]. This gives rise to a whole new meaning of intelligence. To that point, C.A.S. as a science was originated on the idea of artificial intelligence; an attempt to transform computer programming into an adaptive system which has the ability to learn and change its original programming to fit the evolving environmental needs [1,5,9]. It was then found that bottom-up programming (referred to as cybernetics, at the time) was the most feasible way to achieve their initial goals; and thus, laid the formwork for the foundation of the science that is now C.A.S. [5]. From this point forward, intelligence could no longer be viewed as explicitly coded (as if God had designed intelligence and prescribed it); but rather, intelligence could be described as being an emergent phenomena not found in nature but springing forth from it [1,5,9].

C.A.S. theory, despite beginning as an artificial intelligence science, has been extrapolated into a multitude of other scientific disciplines [5]. Economics [9], genetic/biological algorithms [9], symmetrical/fractal mathematics [3], and contemporary healthcare [5] all have begun to incorporate C.A.S. theory into their academic discussion. C.A.S. theory has an amazing ability to encompass, and be applied to, such a large portion of the everyday phenomena we encounter [8].

Patterns emerge from the natural behaviors of the system and it is the goal of scientific tools, such as computer software programming, to extrapolate these patterns into the link between non-linear, chaotic

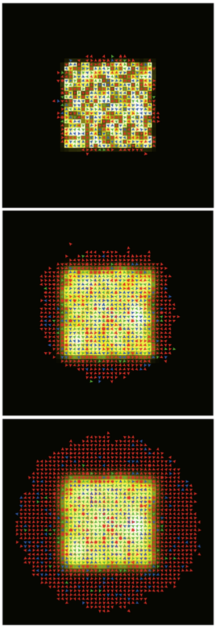

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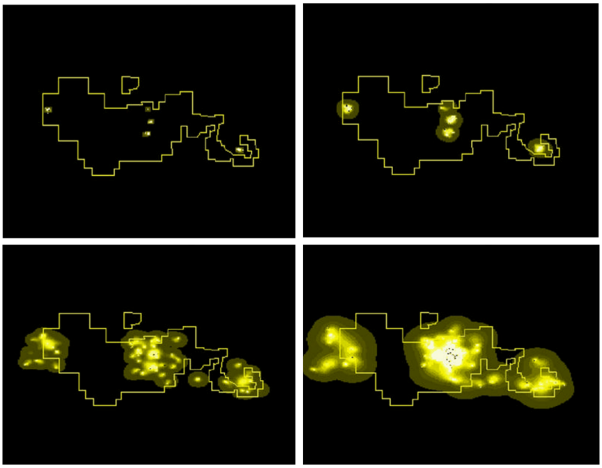
Image 1.2.4F



the crux of current C.A.S. theorist and analysts [1]. Whereby, computers are being used to model the interactions which take place between agents governed by simple algorithms [1]. Through this, academics are able to relate emergent (high-level) behaviors to simple (low-level) rules [1,5,9]. This science is still very much in its infancy; but the possibilities this type of modeling has to offer is enormous. It is, due to this infancy, that I was unable to utilize any of the free C.A.S. modeling software I found during my research. Yet, just knowing that this software had been created and made of public use proves the amazing pace at which technology and science propagates.

1.3 BIOLOGICAL ANALOGY

"Dolorit, offic tem se offic to dolor as autem cum volupic imilliamus aborae doles sunt et aut fugia ium commo to quid quatior essinum apitiis et utatinv electatem voluptate invelestis est ea vendero ium core volorum, samet ute quas ex etus. Quiasse dionece peratiis voluptium quos et ilicabo"
-Quatior, ven 23

1.3.1 Decentralization in Nature

It seems unintuitive to consider a flock of birds as being nonhierarchical. It's true that not all birds flock [8,9]. But, for those which do, just about every bird in a flock seems to act and react in an orchestrated manner. At first glance, one would be logically willing to delegate the behavior of the masses to the directive of a single alpha-bird. Yet, the research is overwhelmingly in favor of no such orchestra conductor existing in any bird species [8,9]. It's quite obvious to the scientific community that the ability to direct the behavior of an entire flock on command is an anthropomorphization of human societal-dictatorships being, improperly, imposed [8,9].

Similar to flocking birds, is the common misconception of ant colonies, bee colonies, termites and wasps. Of no fault to anyone specifically, these insects (particular more so with bees and ants) are commonly considered to be slaves to a Monarchy. Ants and bees are known to have a single mother which births most, if not all, of the colony and, traditionally, she's referred to as the queen [5]. The confusion for most may derive from this name, at least in the British Monarchical sense, because queens are generally considered to be the ruler and single body of governance over a colony. Yet, if that definition was to be applied properly to ant colonies then the queen-ant would be removed from the throne and replaced by … no one [5]! Similar to flocks of birds and schools of fish, these insects (classified as the insect order: Hymenoptera) are decentralized [5]. Considering the complex nature exhibited by these organisms the next logical corollary between their behaviors and their societal structures could be high-level intelligence of each individual organism. Must it be that each individual possesses the brainpower to be able to blueprint the entire colony simultaneously with performing their duties to that colony? This could help to explain how ants, for example are able to change their behavior based on the needs of the colony (such as the finding of a new food source or when there's danger) [5]. In actuality, this is also false; comparatively, birds, fish and hymenoptera insects have distinctly small nervous systems [5].

But each of these organisms, although relatively small-brained, have specialized functions used for communication [5]. It is this communication which defines the interconnectedness of these social systems. Signally through sounds, body language, and biochemical communication (such as pheromones) are tangible explanation of the blueprint of a colony [5]. It is through this blueprint (later to be referred to as, the rules which govern the agents of a system) which the hymenoptera colonies derive their functions [5]. Despite the fact that no single agent comprehends the large-scale blueprint, a colony of ants, for example, have been observed performing some amazing feats; such as, regulating the growth of symbiotically used fungi [5].

1.3.2 Biological Self-Organization

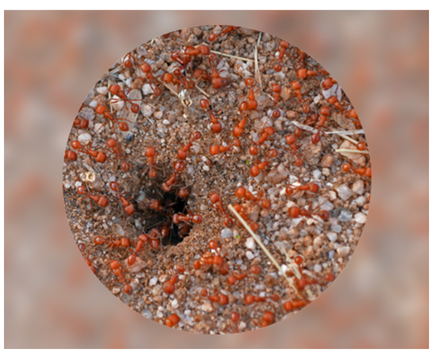
With little academic contest, it could be said that, organic life began with a simple organism; more specifically, most would argue, that this organism was only comprised of one cell [8,9]. The cloudiness of this dialogue, and of the evolution of life, occurs when trying to understand the advent of higher functions, such as consciousness, which derive their existence from a common ancestral cell [5,8,9]. The establishment of DNA within the ancestral cell provided a vehicle for propagated growth, adaptation and development which fostered generational progress; whereby, the successes of some mutations could be passed onto the offspring [5,8,9]. After the single celled organism came multi-cellular organisms [9]. Through this, simple cells were later able to self-organize to form tissues, veins, and organs [9]. All of these constructs then combine even further and form networks of systems which comprise the total system (i.e. ant colonies, our bodies, etc.) and have organized intercommunication [9]. Yet, the orchestrator of this constituted system isn't present within any of these colonies of cells [8,9]. The relationship between the cell networks, is the same device which its organization's genesis begot from [8].

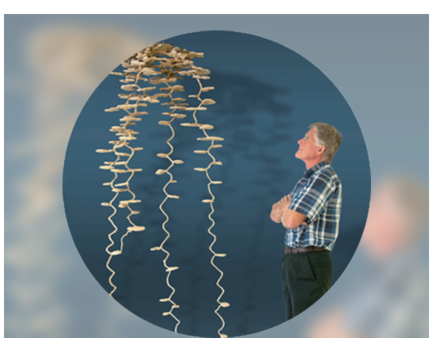
DNA and the Ür-organism (or, the conception of the first living thing) is now considered to have been self-organized during the emergence of its first iteration [9]. In the 1950s scientists were attempting to describe the earth's conditions during the advent of the first forms of life [9]. It was in 1953 that Stanley Miller and Harold Urey that an elaborate and clever demonstration was designed to describe the self-organization which could take place in a proto-life environment [9]. "Miller took molecules which were believed to represent the major components of the early Earth's atmosphere and put them into a closed system. The gases they used were methane (CH4), ammonia (NH3), hydrogen (H2), and water (H2O). Next, he ran a continuous electric current through the system, to simulate lightning storms believed to be common on the early earth. At the end of one week, Miller observed that as much as 10-15% of the carbon was now in the form of organic compounds. Two percent of the carbon had formed some of the amino acids which are used to make proteins. Perhaps most importantly,

> **"Miller's experiment showed that organic compounds such as amino acids, which are essential to cellular life, could be made easily under the conditions that scientists believed to be present on the early earth"**

[9]. It is this claim which begins the story of earthly, biological systems in the context of C.A.S. - but this only begin to tell the full storythe whole story (of which, could also begin to describe the cosmological universe as existing as an abiotic C.A.S.) [5,8,9]

Image 1.2.4E



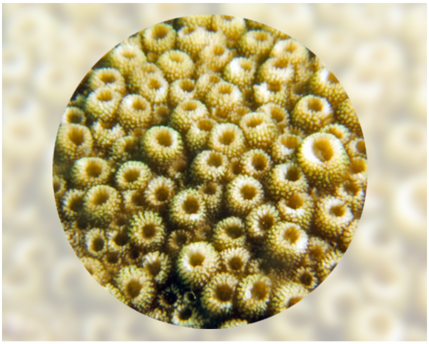


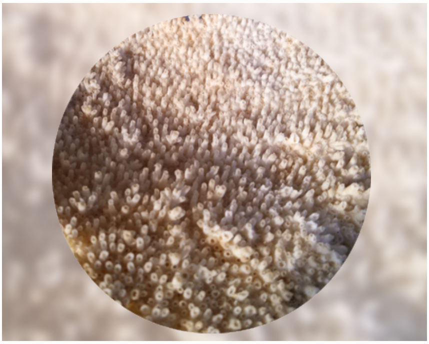
1.3.3 Living Architecture

Ants, bees, and coral are commonly known to organize themselves in the forms of colonies. But this concept of colony should not be interpreted casually. There seems to be an intrinsic nature to the (self) organization of such simple organisms, of which, is part of the "Eternal Golden Braid" which exists in all Complex Adaptive Systems [3,5]. Through our understanding and researching of such organisms (in my case, my research focused on the equally important slime mold colonies) we can develop the algorithms which govern these systems [8]. More importantly, once these algorithms are developed we can begin to manipulate them and affect them in an intentional and directed manner [8]. In doing so, we will have applied an empirical understanding of Complex Adaptive Systems resulting in an intentional outcome (with little or no unintended consequences... which cannot be said with societies current paradigm) [8]. Based on my current understanding of Complex Adaptive Systems, a simple/small change in the non-linear C.A.S. will result in a drastically different outcome (compared to what the system may have looked like or behaved if the simple/ small change hadn't occurred) [8]. Complexity emerges out of the simple low-level interactions; thusly, affecting these low-level rules creates a complex change [8]. Although I am speaking (currently) in terms of colonies of organisms, this analogy should be able to be directly applied to urban planning/theory, neuroscience, and many other disciplines.

The low-level nature of ants, bees, and (hard) coral afford the colonies an architectural expression of their own. These simple creatures, without centrally determining a blueprint, are able to collaboratively construct, harvest, and defend their architecture [5]. There emerges social order from the interactions of non-hierarchical beings [5]. The silent secret to ant and bee organization is sociochemical communication [5]. In the case of ants, a gradient of pheromones are used for nearly 400 different 'odor messages' [5]. Through their antenna, other ants pick up the scent of their brothers/sisters and act accordingly [5]. Like signals in the C.A.S. of the stock market, the

Image 1.2.4E





odors act as non-verbal communication mechanisms; this transfer of information is vital [5]. Without these signals, self-organization cannot occur [5]. Whenever an ant nest was disturbed, no one would come to help if the pheromone signals weren't sent out to the worker ants above ground. [5] Yet, if/when the worker ants recognize this signal, they are able to effective react and adapt to their colony's needs [5]. Emergent out of this, is a fully functional society of ants housed within a sub-subterranean architectural expression [5].

Slime mold, although not creating physical structures, do create architectural elements. Specifically, through the low-level interactions of these individual parts (agents) slime mold is able to create efficient networks between nodes. Similar to vehicular and pedestrian transit systems, these networks afford transportation and locomotion for the system's inhabitants and the nutrients which supply its growth. Hard coral is a certain type of coral which exudes a calcium skeleton during its development/growth. This hard exoskeleton protects the individual coral organisms which it houses. As the coral colony propagates through its environment, a direct affectivity takes place to the morphology of its architecture. Coral colonies, like ants, are also known to combat other colonies when seeking the same regions/nodes of sustenance [5]. These complex behaviors are not inherent within these organisms; they do not have any sophisticated intelligence mechanisms [5,9]. Rather, they abide by simple rules and interactions, through which, complex architecture and behaviors emerge [5,8,9].

Bees (despite having brains; unlike coral or slime mold) have relatively small brains, made up of neurological networks for their reward systems and fear/defense systems. "More Than Honey," a comprehensive documentary on bees, describes how the complexity of bee colonies emerge out of interactions/communications in the context of these simple neurological rules:

Image 1.2.4E

“The 50,000 little brains network in a super-organism; which is much more than a bustling of a brown mass. It’s 50,000 members of a family (the population of a medium sized town). Each bee, depending on its age, has a designated role. No one gives commands; and yet, everyone obeys. Even the honeycomb is a part of this sophisticated system: a communication network, full of information, pasted on in the dark hive’s odor. The bees have 60,000 smell receptors on each of their antennae, which allows them to smell in stereo. They also have gustatory hair on their legs. As they walk across the honeycomb, they receive a 3-demension odor image of the colony’s condition. Where’s the queen? Are enough eggs being laid? Are sufficient stocks being stored? Without its colony, the individual bee cannot survive. It must subordinate its personal freedom for the good of the colony. In each bee family, up to 2,000 bees die every day; and 2,000 new ones are born. Could it be that the individual bees are like the organs or cells of a body? Is the super-organism, as a whole, the actual animal?”

1.4 URBAN APPLICATION OF C.A.S.

"Dolorit, offic tem se offic to dolor as autem cum volupic imilliamus aborae doles sunt et aut fugia ium commo to quid quatior essinum apitiis et utatinv electatem voluptate invelestis est ea vendero ium core volorum, samet ute quas ex etus. Quiasse dionece peratiis voluptium quos et ilicabo"
-Quatior, ven 23

1.4.1 Extrapolating the Biological Analogy to the City

Over the years, I've heard architects describing the growth of the city as being "organic." This concept intrigued be, but lacked a sense of empiricism; that is, until I discovered the self-organizing properties of informal slum cities. After some research, I realized an organic pattern that emerged from the road systems which intertwined through the informal slum communities. Again, this was intriguing but lacked any empirical footing for which the nature of this pattern could describe. The form of the informal roadways, as compared to the top-down designed downtown city streets, was defined by input from each house. This is in stark contrast from the suburbs and inner-city streets, whereby, an urban designer predetermined a sufficient roadways system. This methodology of design is functional (as it's been used for centuries of urban planning and design) but doesn't truly speak to the complex nature of transit and interconnectivity throughout the city. This striation, in the Deleuzian sense, is arguably a non-natural form of the city due to its top-down design dictatorship [2]. Whereas, in the informal communities, each individual home has its own say on how the roads define the forms of the built environment; each home, as it's built, has a direct effect. This is bottom-up design.

It is this motif, of bottom-up self-organization, which I shall proclaim as being the true nature of the city; one of being organic, non-deterministic, and non-linear [1]. Whereby, the city cannot be described as having any centralized nature [1]. Rather, it is each citizen and each traveler of that city which, through their myriad of decisions made each day, is affecting the built urban form in a way which manifests into the form we are familiar with today [1]. This is in opposition to an 'all-powerful' urban designer as being the wieldier of design capabilities which can foster intended actions. Traditionally, an urban planner would designate portions of the city for specific purposes, such as a park or cultural centers. But ultimately, these decisions are either misguided by that designer's bias or are directly informed by a greater social force which goes beyond the capacity of a single designer's capabilities [1]. In the case of biases, it's fair to say that we are all subject to them; and the designer is the biggest culprit of them all. Good design is, arguably, one which takes into account as many factors as possible; or, to say this another (more direct way), good design is that which has as little bias as possible. The greater social force at large, then, is something which is outside of the designer/urban planner (rather than coming from within) [1]. It is this social force, comprised of the biases and truths of each and every individual, which converge and informs truly 'good' design [1]. The wisdom of the crowd, so to speak, takes into account the averages and the outliers; leaving no one behind so as to incorporate all perspectives in an egalitarian manner [1]. But where does the Urban Planner live within this decentralization? It is the contention of my thesis, and of Complex Adaptive Systems Theory, to describe urban form as being an intrinsically pattern forming entity. The nature of the city is one which can be informed and is informative to the designer. It is this feedback loop, along with the many other parallels, which link city development and C.A.S. Through this, we as designers can form a toolbox for informed design and begin fostering our design intentions within the paradigm of city evolution.

1.4.2 Contemporary Urban Theories

It is the nature of the city to be emergent. Mumford, in his work The City in History, directly and indirectly speaks on the topic of C.A.S. and the emergence of the city when he says [10]:

“The city came as a definite emergent in the paleo-lithic community: an emergent in the definite sense that Lloyd Morgan **and** William Morton Wheeler used that concept. In emergent evolution, the introduction of a new factor does not just add to the existing mass, but produces an over-all change, a new configuration, which alters its properties. Potentialities that could not be recognized in the pre-emergent stage, like the possibility of organic life developing from relatively stable and unorganized ‘dead’ matter, then for the first time become visible. So with the leap from village culture. On the new plane, the old components of the village were carried along and incorporated in the new urban unit; but through the action of anew factors, they were recomposed in a more complex and unstable pattern than that of the village – yet in a fashion that promoted further transformations and developments. The human composition of the new unit likewise became more complex: in addition to the hunter, the peasant, and the shepherd, other primitive types entered the city and made their contribution to its existence: the miner, the woodman, the fisherman, each bringing with them the tools and skills and habits of life formed under other pressures. “

1.4.3 Initial Study: The Megopolis and Metropolis

My understanding of modern cities began with studying the nature of the ’-polis.’ Derived from Greek origins, the ‘-polis’ literally means city but is often used to describe city-states [10]. This small, but significant, distinction adds the citizens of the city into the description of the city itself. Rather than separating the built urban form from the community (communities) which inhabit it, the '-polis' is a multiplicity of meanings, symbols, systems, and vernaculars [10]. In order to unfold this intertwined multiplicity I decided to research that which I was already somewhat familiar with (this decision recurs throughout my Thesis and can most simply be attributed to time constraints; which isn't to say that other options were of less merit). Due to my lack of, in-depth, knowledge/education regarding non-U.S. cities, I decided to research Manhattan and Detroit as my basis for theoretical development.

The genesis, development, and current situation of New York City and Detroit have strong commonalities; of which (if I had been able to research further), could be argued as being as being an archetypal metropolitan growth process. Yet, to best avoid making too broad of a contention, I digress from this to speak on behalf of only these two '-polies' (rather than making over-arching claims as C.A.S. often does). Both New York City and Detroit started as forts, strategically positioned on the local waterways. It is from this point of conception outward growth was able to be propagated. The fort, in the context of colonial America, is a mirror image of the citadels of ancient civilizations referred to by Lewis Mumford [cite]. Whereby, the citadel represents the stockade of agricultural surplus and a symbiotic relationship to a grand force (typically the gods, God, or a monarchy). The citadel is the architectural equivalent of a bee hive or ant nest; the fort, the citadel, the bee hive, and the ant nest are all: strategically located based on local environment, adapts to changes, and provide sustenance for the members of its colony.

Fort Amsterdam, on the southern top of present day Manhattan, is an even better example of organic growth resulting from the colonial establishment than Fort Detroit because remnants of that organic growth still exist within the urban form. In 'Figure XXX' I have overlaid three maps from which the protrusion of these urban forms recurs. The base map is a post-American Revolution (prior to the Commissioner's Plan of 1807), the white map is the original Fort Amsterdam layout, and the last overlay is a GPS image of the city in present day. Even the wall which enclosed the Fort on land remains as an American icon: the infamous, Wall Street.

Diagram 1.4A

Although Detroit and Manhattan were prescribed a top-down organizational design, it is the postulate of this Thesis that the genesis, internal growth, and outward growth of these cities were organic. Despite the top-down urban plan, nearly all processes/interactions/behaviors which take place within that context are best described in terms of Complex Adaptive Systems. Diagrams XXX and XXX attempts to describe this concept through the analogy of slime mold growth; whereby, the organism (i.e. the metropolis) goes through cyclical phases of growth, stasis, and divestment. The severity of these phases is dependent upon reactions within the C.A.S. of its macro-environment. In other words, not only does the development of the '-polis' depend

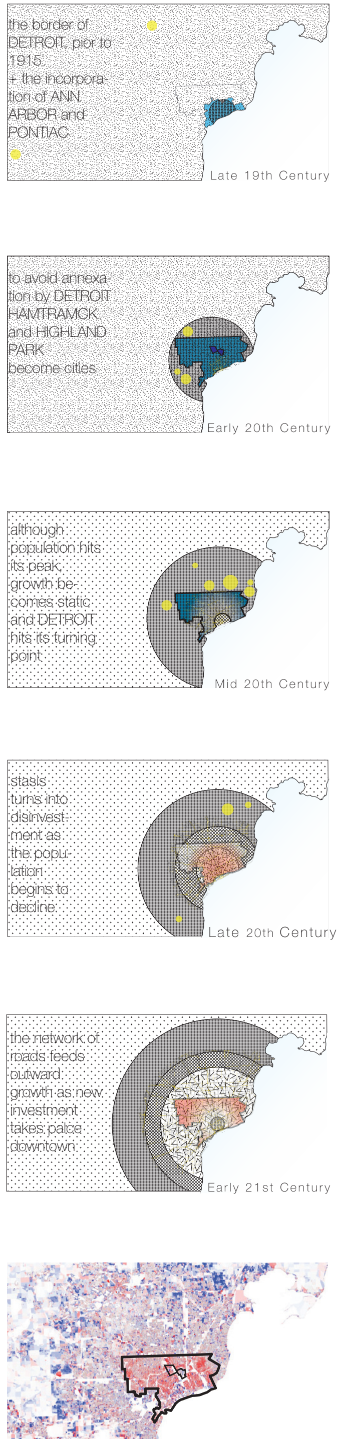
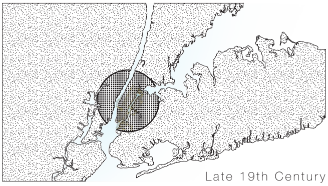
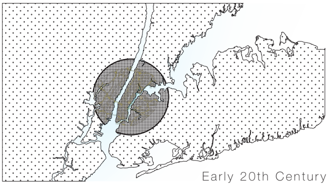
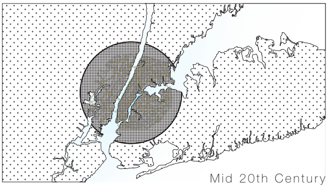
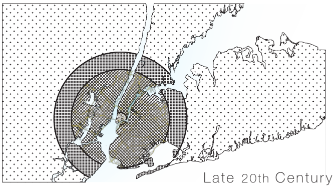

the border of DETROIT, pior to 1915
+ the incorpora-tion of ANN ARBOR and PONTIAC
Late 19th Century
to avoid annexa-tion by DETROIT HAMTRAMCK and HIGHLAND PARK become cities
Early 20th Century
although population hits its peak, growth be-comes static and DETROIT hits its turning point
Mid 20th Century
stasis turns into disinvest-ment as the popu-lation begins to decline
Late 20th Century
the network of roads feeds outward growth as new investment takes palce downtown
Early 21st Century

Diagram 1.4B


Late 19th Century


Early 20th Century


Mid 20th Century


Late 20th Century

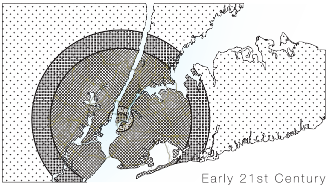
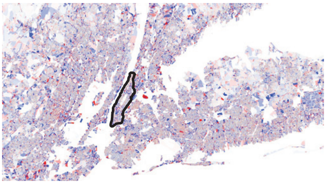

Early 21st Century

Diagram 1.4C



on the citizens (agents) which interact within it, but, also has a direct relationship to national economic recessions/surpluses. Like slime mold, my diagrams spread outward from their nodes of sustenance (their respective forts) and network toward other nodes (in the case of Metro-Detroit and New York City, these other nodes are cities such as the Bronx, NY or Pontiac, MI) which they latch onto for other means of sustenance.

2

PART II: SKETCH PROBLEM

2.1 C.A.S.o.S.

"Dolorit, offic tem se offic to dolor as autem cum volupic imilliamus aborae doles sunt et aut fugia ium commo to quid quatior essinum apitiis et utatinv electatem voluptate invelestis est ea vendero ium core volorum, samet ute quas ex etus. Quiasse dionece peratiis voluptium quos et ilicabo"
-Quatior, ven 23

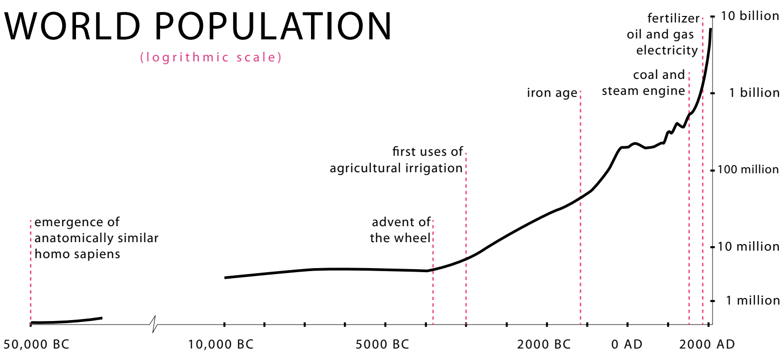
2.1.1 Biotic and Abiotic Infrastructure

Consider, as a basis for analogy, a road system. Firstly, roads are inherently systems because they are networks of transit. Road systems, as physical concrete/asphalt and as the quasi-physical phenomena of traffic, are constantly in flux. Additions, extensions, and maintenance are all examples of physical modifications. In most cases, a road system consists of a range of phenotypes: widths of lanes; number of lanes; speed limits; visibility; bends, twists, and turns – all of which have affectivity on the system's behavior. It is these behaviors which manifest themselves as traffic. A road system is abiotic, yet, it still has organic behaviors which emerge through the interactions of its many agents (i.e. cars, trucks, motorcycles, bicycles, and pedestrians). Although traffic may seem complex to someone unfamiliar with modern metropolitan transit, I do not intend to argue the complexity of city transit systems. Rather, I would describe traffic as being governed by relatively simple rules (written and unwritten... i.e. governmental laws and cultural laws). The authorities who govern the roads are able to adapt to the foreseeable – sports events, celebrity/politician convoys, festivals, parades, etc. – and the unforeseeable – e.g. accidents, weather emergencies, power outages, etc. Yet, adaptation isn't always a top-down process.

On a more typical basis, it is the 'flow' of traffic which governs road system behaviors. One must acknowledge the environment of law and regulation for traffic, but this ought to be viewed as simply the context (and not the behaviors themselves). The behaviors of the system are dependent upon a myriad of (nearly) simultaneous interactions between autonomous vehicles. These behaviors are intelligently complex, adaptive to its ever-changing environment, and display emergent behaviors unintended by the laws/rules which govern it. During, say, a bottle-necking of traffic on a highway, a change in behavior emerges for many vehicles apart of the system on their daily commute. It is this property which proves traffic/road system's ability to adapt and self-organize in a decentralized manner. Cars who receive information about the traffic jam will take detours. Cars stuck in the traffic jam will sometimes switch lanes or get off at an exit to take city streets rather than highway roads; and we can't forget about the motorcycle riding in between all the stopped cars. Traffic's flow is an 'invisible force' of self-organization within the Complex Adaptive System of transit systems. These ambiguous terms recur throughout many different disciplines (e.g. the 'invisible hand' in Adam Smith's Wealth of Nations) and, although it is not necessarily the goal of my thesis, I am willing to argue that these terms come from generations of observations of Complex Adaptive Systems' behaviors but previously lacked an empirical foundation (beyond simple observation). This conversation can also be easily extrapolated to bus routes, bicycles, trains, subways, boats, and airplanes. Even crowds of pedestrians can be viewed as traffic within a system of transit from which recurring patterns, algorithms, phenotypes, and behaviors emerge.

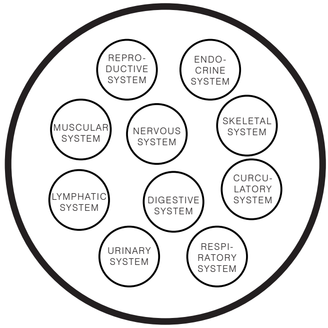
Transit, as a system which catalyzed the development and growth of the city, could not have been possible without energy. Harvesting energy has been one of mankind's greatest achievements since the advent of fire/the hearth (which is essentially controlling heat energy as a tool for the development of warmth/safety, cooked food, and tools). This relates, again, to Lewis Mumford's astute observation that technology was the true propagator of society and the city. Outward from the birth of fire came agriculture; this is, arguably, the most important achievement of society. Agriculture, the harvesting/control of food energy, afforded society (for the first time) a consistent influx of surplus. In agreement with Mumford, I would argue that it was this surplus which afforded citizens of larger communities the ability to develop their expertise in other chasms of development.

Blacksmiths, soldiers, bankers, scientist, philosophers, and monarchies could not have existed in medieval times without an agricultural surplus to support their endeavors.

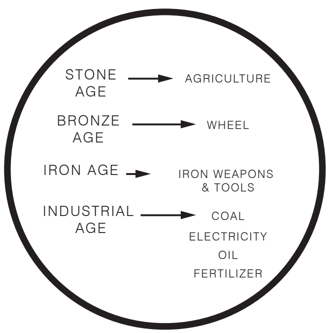


2.1.2 Complex Adaptive Systems of Systems

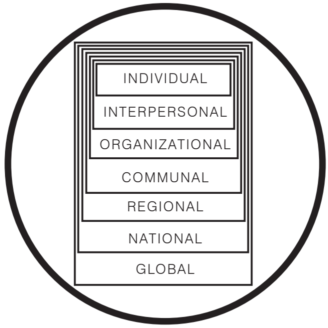
Consider, as an analogy, the contemporary power (grid) system. Electricity is demanded by a device when it's plugged into an outlet. This has a direct effect on the power plants supplying the power. Electricity, typically, requires that it be used (nearly) simultaneously once it's created. In other words, the power plants must predict the total demand at each moment and adjust the amount of electricity generated. If too much electricity is being generated, then it disperses; if too little electricity is being created, then the entire grid will short out (aka: brown-outs) or the entire system could shut down completely (aka: blackouts). In this way mechanical energy, fossil fuels, and renewable energy should also be considered Complex Adaptive Systems. Like the switches for light bulbs, other switches occur in Complex Adaptive Systems of other disciplines. Genes, for example, are a classic case of having switches which turn on and off based on its environment. Similar to the affective increase in demand on the energy system, the turning on/off of gene switches has a direct relationship with the overall system's reaction. The determining factors which govern when the switches turn on/off can, for all intents and purposes, be considered algorithmic. It is the nature of these algorithms which C.A.S. attempts to model and recreate. Once a



HUMAN BODY
SYSTEM



TECHNE-
CULTURAL
SYSTEM



SOCIAL
SYSTEM

meta-model of a C.A.S. algorithm is derived, the reactive behaviors of the overall system can be pre-supposed; this is an empirical tool with which we can make meaningful top-down decisions on inherently bottom-up systems.

With such a vast amount of systems the city and the human body, analogously, ought to be considered a Complex Adaptive System of Systems (CASoS). In this way, each macro-system is comprised of other C.A.S. These collective systems unify into one, but still follow the same principles as all other Complex Adaptive Systems. Through the interactions of each C.A.S., the behaviors and forms of the grander C.A.S.o.S. can be interpreted. The fractal-like relationship thusly occurs between each C.A.S.o.S.'s individual systems. To explain this example, I offer infrastructure as a catalyzing C.A.S. which fosters the grander system. The infrastructure of a city seems relatively intuitive and will be extrapolated in the sections following this one. Yet, the human body has analogous infrastructural systems as well: the circulatory system. The human circulatory system comprises less that 4% of total body mass, yet is never farther than 4 cells away from another tendril. To say this in other words, as our anatomy has evolved over millennia, the algorithms which governs the growth/development of our circulatory system has solved an intricate packaging problem. In order to get nutrients to every cell in the body, the circulatory system must be directly connected to each cell. The same can be said the city's circulatory system; which also requires the circulation of sustenance to all of its parts. In this way, the algorithms which comprise C.A.S.o.S. can be understood on a fundamental level and applied to many different disciplines.

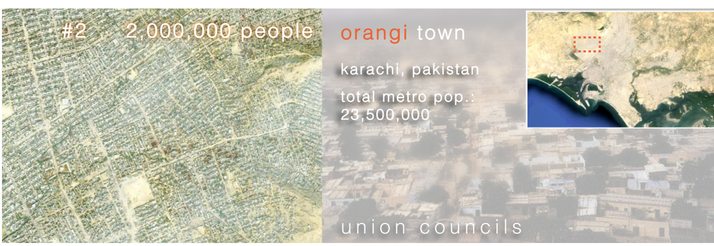
2.2 SITE CHOICE & ANALYSIS

2.2.1 Site Selection

Fully equipped with my ascertained knowledge, I was ready to begin the application of my research onto an architectural design sketch problem. To find a projects best suited for such an application, I turned toward an inherently decentralized, non-hierarchical urban environment: the informal city (or, what is more commonly referred to as, the slums). To best understand C.A.S. in the urban context, I wanted to avoid the intrusion of top-down prescriptions which exist in almost all industrialized cities. Yet, one by product of the industrialization of cities is the slum condition. A classic example of this is Manhattan's infamous slum communities in the mid/late 19th century. Like many developing nations of today's era, Manhattan's citizen (by in large) were mostly afforded some of the worst condition known to man. It's odd to think that a city, the essential node of sustenance for society for thousands of years, actually was the cause of poor living conditions for most of its citizens. These citizens were, ironically, the labors and "worker-bees" of the system; yet, they were afforded the worst of conditions.

As a reactionary intervention, I decided that an urban design sketch (with the integration of C.A.S. theory) in the third-world informal cities would be the best course of action to achieve a Thesis conclusion.


#1
4,000,000 people
neza chalco itza
mexico city, mexico
total metro pop.:
21,300,000
zonas marginales

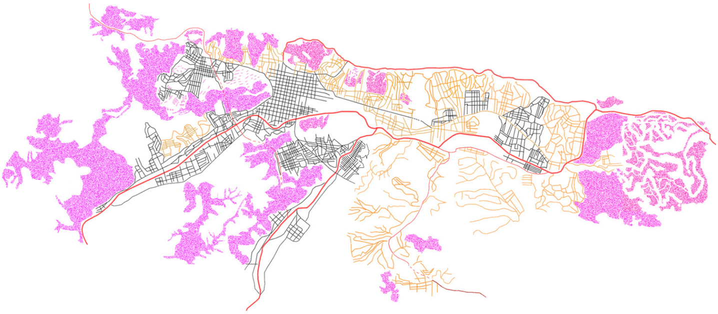

#2
2,000,000 people
orangi town
karachi, pakistan
total metro pop.:
23,500,000
union councils

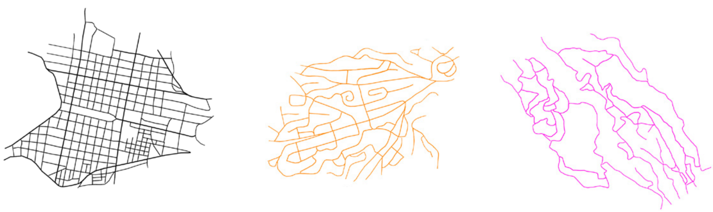

#3
1,000,000 people
petare, barrio de
caracas, venezuela
total metro pop.:
4,200,000
u.t.t. metro cable

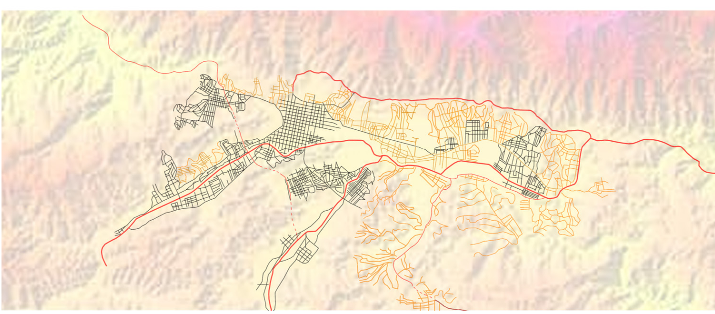
2.2.1 Third-World Informal Cities

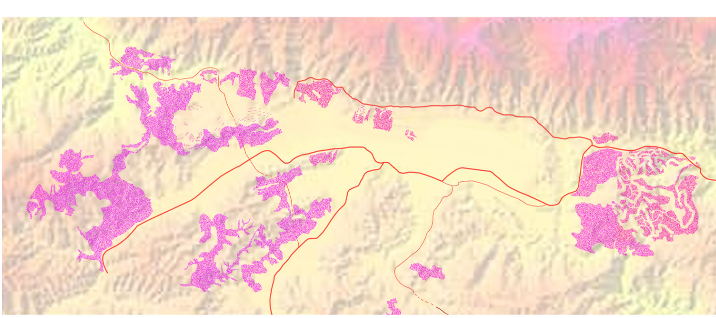
Neza Chalco Itza, Mexico City has a GPD that nears the top ranking of GDP by city. Thusly, there is a considerable amount more capital and investment afforded to these "marginalized zones." These informal settlements can be considered some of the well-funded of its sort; with a gridded infrastructure, (early stages of) government welfare programs, and over 50% literacy.

Orangi Town, in Karachi Pakistan is the desert's equivalent of urban sprawl. Yet, as the informal town has sprawled outside of its Karachi sister city, it has established a semi-grid system. I assume this was done for organizational purposes and, although this was mostly a bottom-up process, its organizational algorithm did not have to work within many environmental constraints. Orangi Town, thusly, does not require an immediate urban intervention in the same way some of the other third-world informal cities.









2.2.1 Caracas Overview

Caracas is a city of clashing dynamics. The informal slum fights for political and geographical control. While the formal city develops ordering systems and other control mechanisms which are intentionally employed to keep the masses impoverished thus retaining the aristocratic wealth and power systems.

The original conception of the city center was established by elitists after Venezuela's succession from Spain during the Napoleon Wars. The flat elevation and circulating fresh water rivers made Caracas a perfect location for its impending modernization and metropolitan growth. The rigid formal city attempts to provide control, yet truly only providing constraint.

Image 2.2K: The goal of this study was to investigate the nature of the hillside barrios. Whereby there seemed to exist, based on images of Petare, a pattern associated with the arrangement of houses. Yet, the interesting part (and one of the main reason I chose Caracas) of this pattern was that it was not designed in the traditional sense.

Rather, the arrangement came from a collective design by those who constructed it. To say another way, the pattern was formulated from the bottom-up (as opposed to the top-down).
My initial reaction was to start with the existing topography and base my algorithm off these lines. Quickly I realized the lack of complexity in my mode. There seemed to be a missing layer or, more likely, multiple missing layers.

My second addition to my model's pattern algorithm required a constrained transformation (see D'arcy Thompson) to align the topography to match the pattern of houses. This was my proof of the inhabitants intentionally manipulating the topography

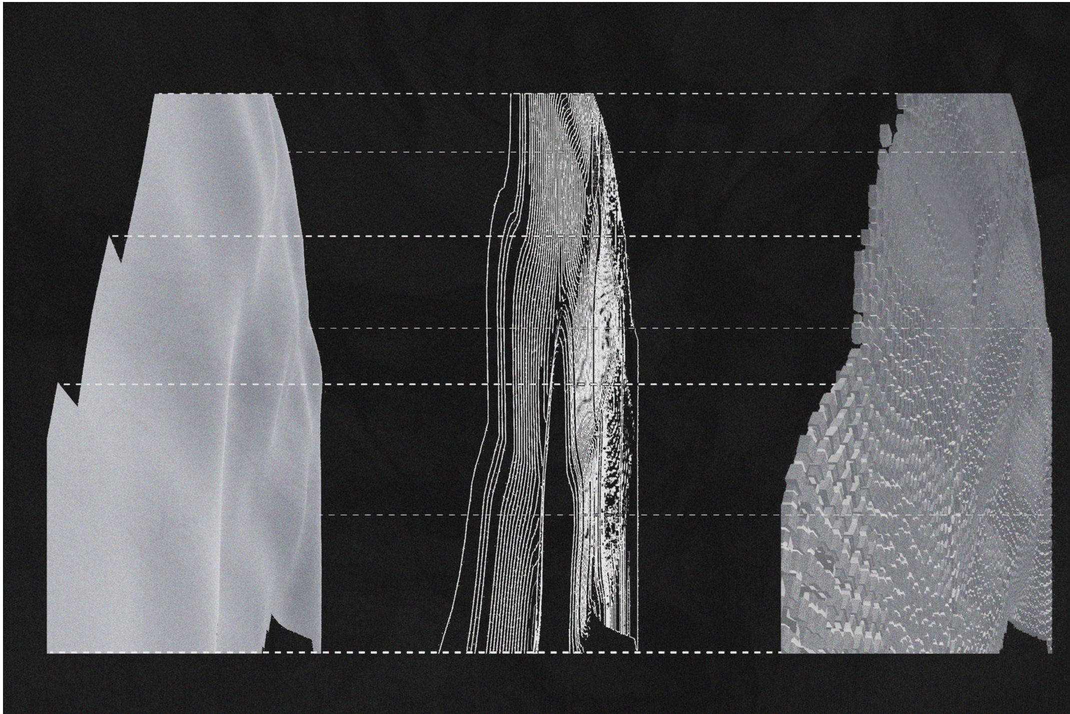
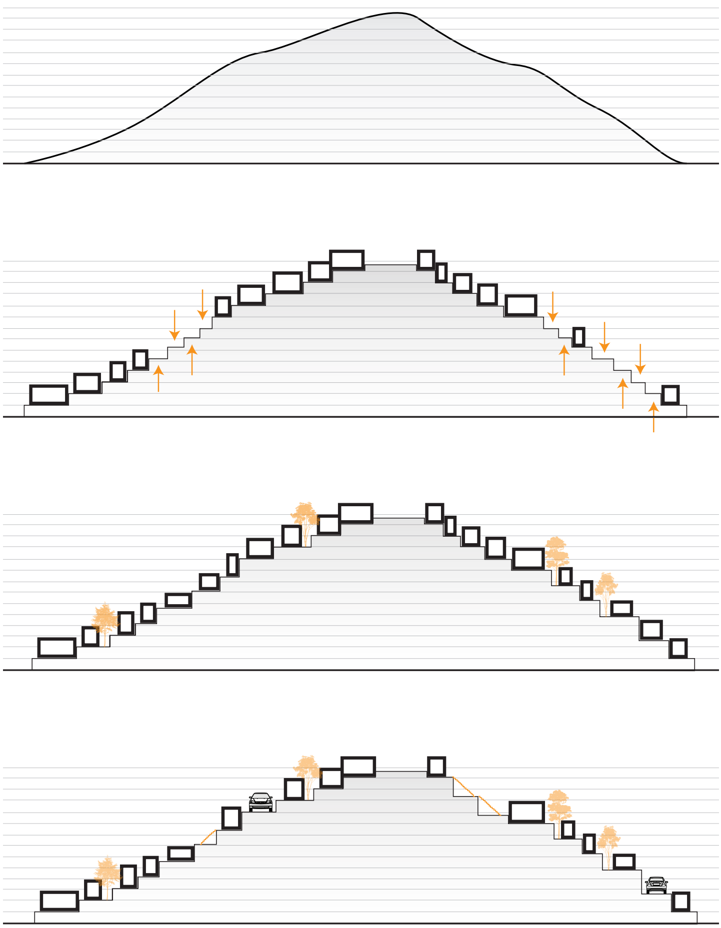


Image 2.2L: As the citizens of Barrio de Petare begin inhabiting the hillsides, they also produce a change within that system. Terracing, integration with the existing environment and the incorporation of vertical and horizontal circulation become a part of the system and the environment.



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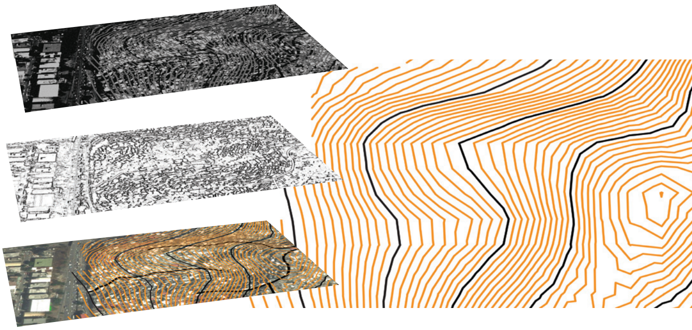
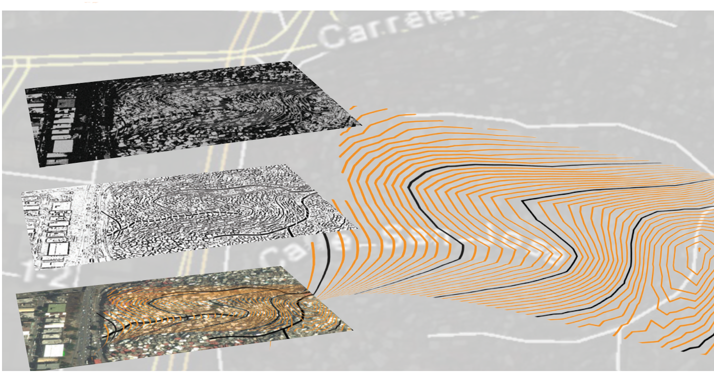
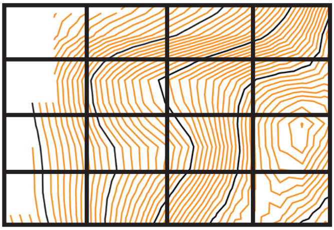
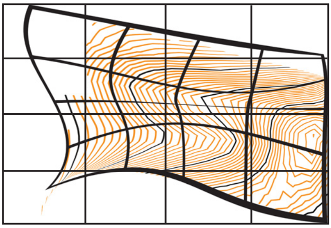








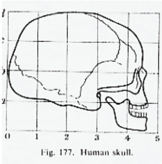
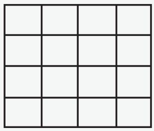


Fig. 177. Human skull.



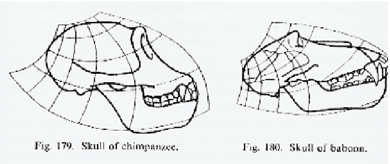


Fig. 179. Skull of chimpanzee.
Fig. 180. Skull of baboon.

2.3 BARRIO CABLE CAR

To best culminate my research and analysis, I incorporated the concepts and ideas from many different sources, diciplines, and pecedents.

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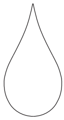
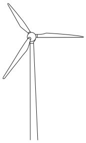
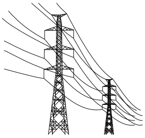
infrastructure



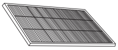
Potable water supply is a major problem in marginalized areas. Caracas' barrios are no exception; especially due to the difficult topography. Most citizens of Petare get their drinking water from the metropolis below and have no running or hot water in their homes. Sewer lines and sanitation are also a major luxury in the barrio and are found few and far between. I propose using the cable car stations and infrastructure as the basis for running new potable water and sewage lines through. Also, there is an opportunity to create catch basins within the cable care system and stations.



Caracas sits very near to its oceanic boarder to the north. Yet, much of this direct wind is blocked by the capital's shield of mountains. Due to the nature of Caracas' mountains there exists a huge opportunity within capturing the prevailing winds. Wind spilling down from the large mountain tops can be harness and converted into usable energy. But this energy doesn't have to go onto the grid - if generated from the cable car system and stations, this energy could be used to directly power the barrio underneath.



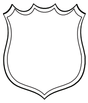
The grid is a complex adaptive system which responds to its myriad of users simultaneously. The interesting thing about electricity is that it must be used almost instantaneously after being created. There have been advancements in using this energy to heat water (which later can be converted to steam to generate electricity) and thus storing the electricity; but, this currently is a costly and inefficient technology. Distribution of this power is integral and is a major missing component in the barrios.



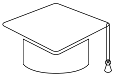
Similar to the wind turbines proposed above, there exists an opportunity to capture the sun's energy and convert it into electricity for the barrios. Again, due to the nature of the cable car system and stations, the columns for the cable car lines and tensile structure are perfect for attaching photovoltaic panels.

Just as the grid is a complex adaptive system, so is the internet. No one person controls and created the internet - rather, it is a self-organized system which is adaptive (to technology, social trends, and all other global realities) and comprised of a myriad of autonomous agents. Providing the barrio with access to this vast collection of human knowledge could be an amazing opportunity to give the barrio citizens autonomy in learning.

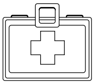
social amenities



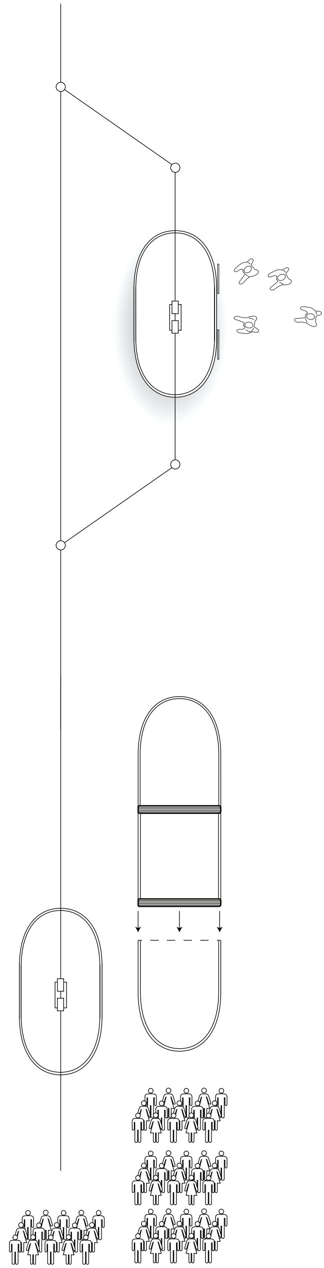
As with any impoverished area, crime and violence is a major issue in the barrios. Gangs run rampant in some areas and control much of the black market that exists in Caracas. Drugs, prostitution, and other illegal activities have been self-organized by groups of gangs and have become the sustenance they need to gain political and gorilla control. As stated in the diagram above, the third line (and/or fourth line) can be strictly used to harbor police cars. Station will also allow docking of these cars. If the demand for a long-standing police presence is required then the drop off station can be adapted into a station for the local militia to help control the local crime and violence.



Education and literacy is another major issue that can be addressed by the adaptable cable car system and stations. Cable cars can be used as classrooms; and, if the demand warrants it, stations can partially adapt into school stations.



Health care is almost non-existent for the barrio citizens. This is probably one of the most expensive social amenities and, for this reason, is commonly the first social welfare to be lost by marginalized citizens. Cable cars and stations can be adapted into health care cars to service the public. Emergencies and trauma victims can receive significantly quicker treatment; as well as, they have the option to be more expediently transported to the metropolis.



There are three season for choosing tensile structures for my stations.

The first, is the footprint of the structure. Compared to a traditional building, whose foundation and structure require a large amount of soil displacement and manipulation; whereas, the columns for tensile structures are minimal and don't require much, if any, displacement of the citizen underneath.

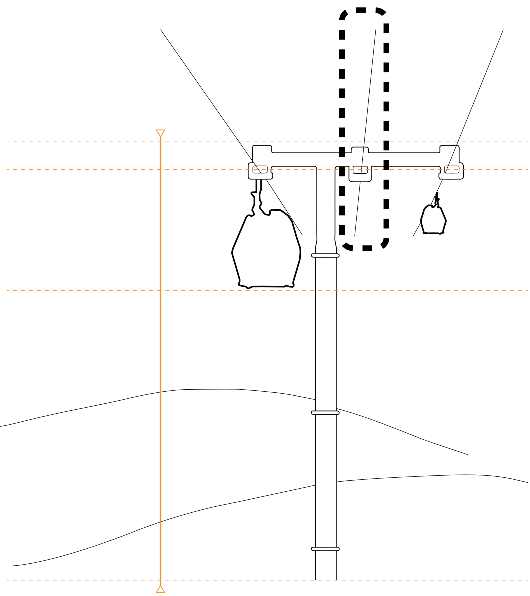
Second, is the concept of the gridded striated metropolis which produces rectilinear buildings versus the non-linear informal city in the barrios. This non-linear nature still produces discernable patterns, just in a completely different (bottom-up) method from that of the -polis.

My final reason for choosing tensile structures is the fact that it can be 100% designed and manufactured offsite. The only construction required on site would be the erection of the structure (which can be accomplished without traditional mechanical means is need be).

Also, as stated in earlier, each station and cable car ought to have the ability to adapt to the social needs of the barrio citizens occupying the local areas and using the transit system. Within the context of complex adaptive systems, it doesn't make sense to have a static building. Rather, there should be a mechanism built within the program of the cable car which allows the needs of the barrio citizens to be addressed.

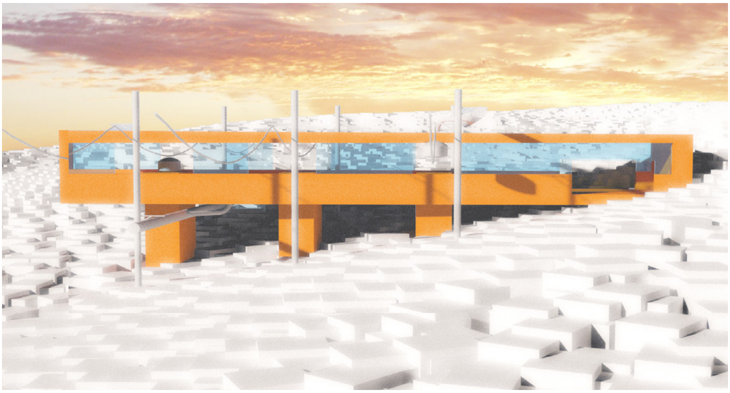
The column supporting the cable cars is a perfect opportunity to integrate more than just the cable car lines.

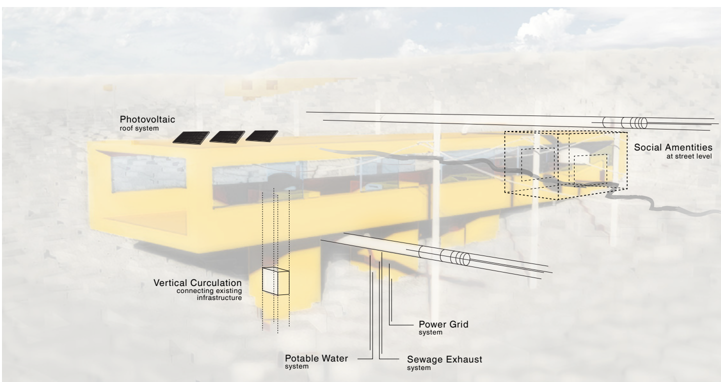
By adding a third, or even a fourth, cable car line it increases the capacity for municipal and social cars to exists on their own secure line.



Each cable car will be adaptable based on social need and economic availability. The hope would be to, over time, evolve the cable car system into an advanced mass transit and welfare system.

One of the reasons for choosing a cable car system (as opposed to other types of mass transit) is the small footprint required by each column. This allows the minimum amount of displacement for the barrio citizens occupying that space.




Photovoltaic
roof system
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at street level
Vertical Curculation
connecting existing
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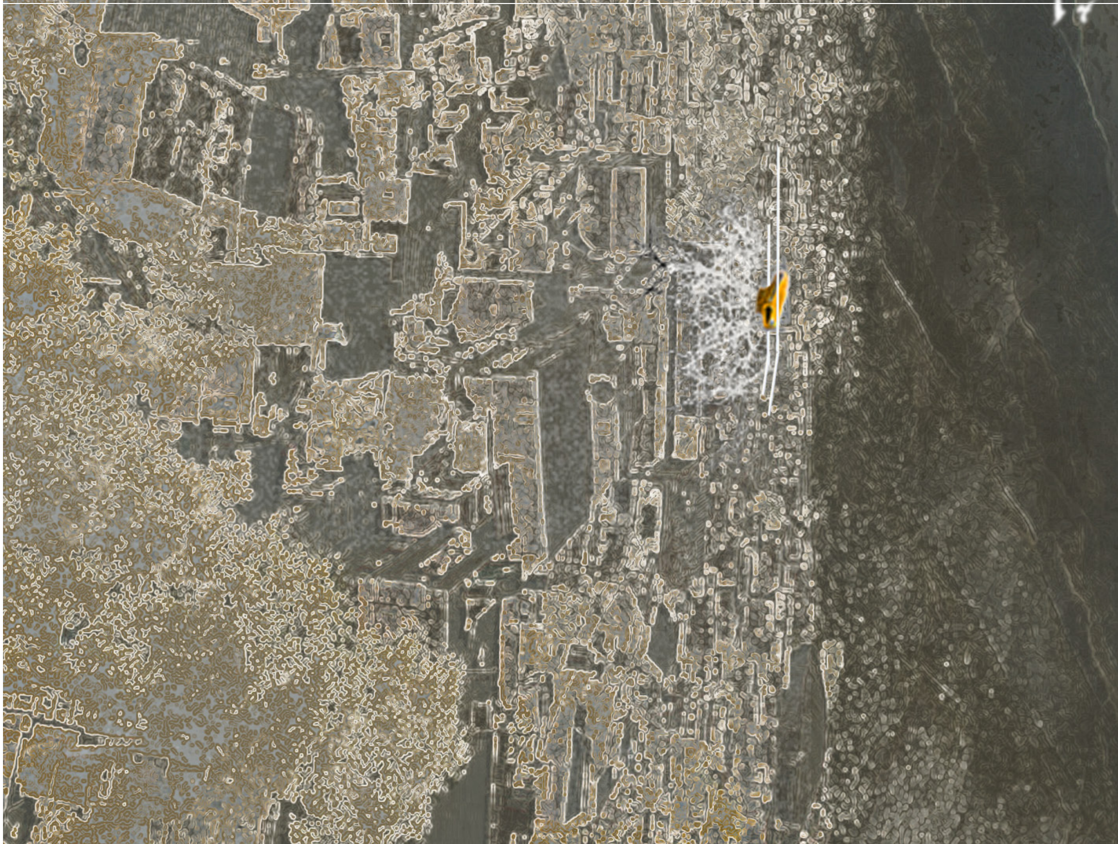
Power Grid
system
Potable Water
system
Sewage Exhaust
system



3

PART III: SLIME MOLD

3.1 ABSTRACT

Many of the issues which confront architects/urban planners faced with current trends of rapid urbanization (typically in industrializing third-world countries) ought to have a direct, empirical method of implementing meaningful interventions with as little unintended consequences as scientifically possible. In an effort to develop an analytical tool, rooted in Complex Adaptive Systems theory, the inherent nature of slime mold (Physarum polycephalum) was utilized as an analogy to the 'problem of the traveling salesman' exhibited by cable care stations arranged within Barrio de Patare. Using a topographic model of the hillside barrios in Caracas (Venezuela), nodes of oat acted as sustenance for the propagation of slime mold growth and as an analogy to the cable car stations; whereby, the changes in elevation mirror the increased need of economic resources to build at such steep elevations. Potato agar was used as a growing medium to activate the dormant sclerotium positioned onto the topography model. Once active, the slime mold was able to find the nodes and develop an efficient network between each oat pile. This networking is ubiquitous to both social and biological systems; in both cases, there exists a complex compromise involving cost, transport efficiency, and fault tolerance. This study does not resolve complex urban issues of design on a broad scale; although, it does prove that the use of tools, rooted in Complex Adaptive Systems theory, can aid in the design/development of urban matters.

3.2 EXPERIMENT

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3.2 Photo Narrative

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Image 3.2A

Image 3.2B: I was granted use of the General Biology Laboratory at the University of Detroit Mercy by Dr. Gregory Grabowski. With his assistant, and expertise, we were able to conduct initial experiments with slime mold, Chemotaxis, and topography.

Image 3.2C: As a sterilizer, we used 95% ethanol applied to a cotton pad to wipe down our tools, glassware, and work station.


CAROLINA
CAROLINA

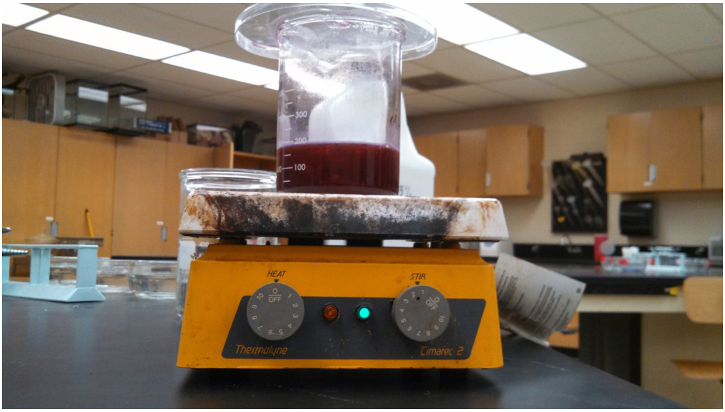

CAROLINA
CAROLINA


95%
ETOH
Dept of Biology
University of Detroit Mercy

Image 3.2D: MacConkey Agar was used as a growing medium in our first iteration. One part agar was boiled and mixed with five parts distilled water.

Image 3.2E: After being sufficiently boiled, the agar was chilled on ice so as to decrease its viscosity. This aided later when attempting to evenly pouring the agar onto the topographic model.

Image 3.2F


300
200
100
HEAT
OFF
STIR
Thermolyne
Cimarec 2


500
±5%
100
400
200
300

Image 3.2G: The glassware and topographic model was placed in a -79°C freezer for several mintutes.

Image 3.2H

Image 3.2J: With the model and agar sufficetly chilled, we began to slowly pour the growing medium. Careful attention was paid to covering the model as evenly as possible.


New Brunswick
Ultra-Low Temperature Freezer
C760
Innova

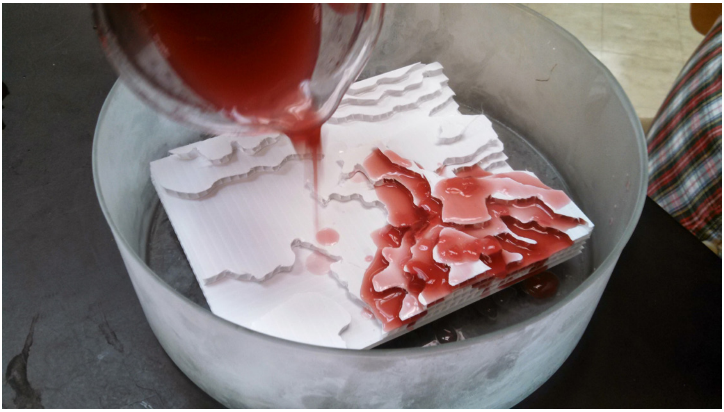
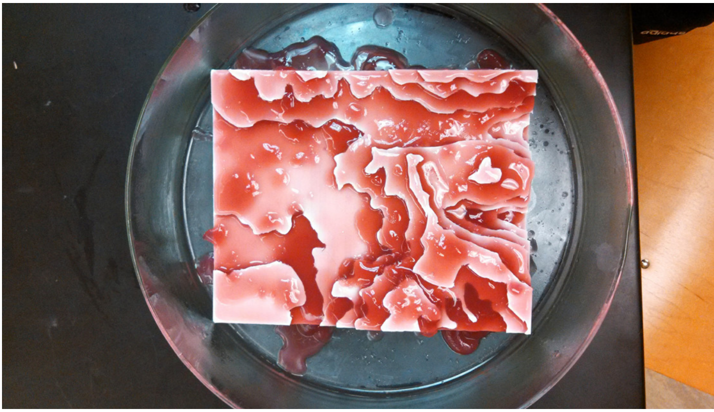


Image 3.2K

Image 3.2L: A second, and identical, glassware was placed on top of the other glassware to form a sealable environment. Demarcations of oat (food) and slime mold locations were assigned.

Image 3.2M: As the lid was lifted, one item was placed at a time. The lid was then covered. We assumed this would be the best way to avoiding airborne contamination.



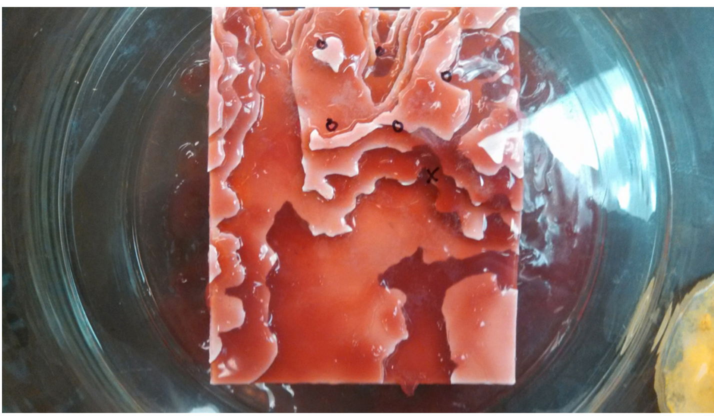


Image 3.2N

Image 3.2P: The gap between the beveled edges of the glassware were sealed using sterile wax paper.

Image 3.2Q

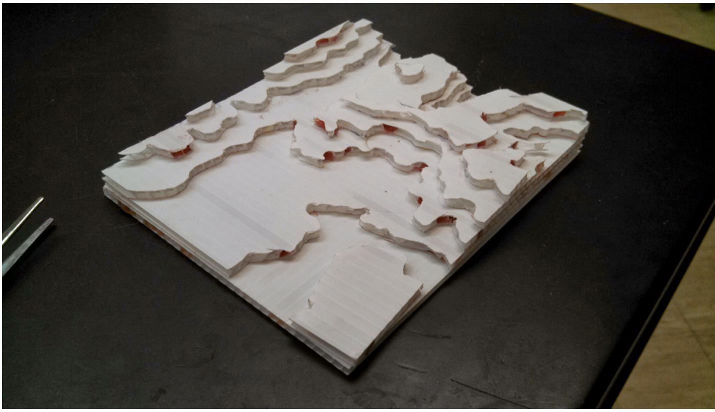

www.carolina.com


Sharpie

Image 3.2R: Alas, like many experiments before it - this one failed within the first few days. It was suspected (by Dr. G and I) that the agar mixture did not support slime mold growth. The MacConyeys was then removed from the model.

Image 3.2S: A potao agar was mixed for the next iteration.

Image 3.2T



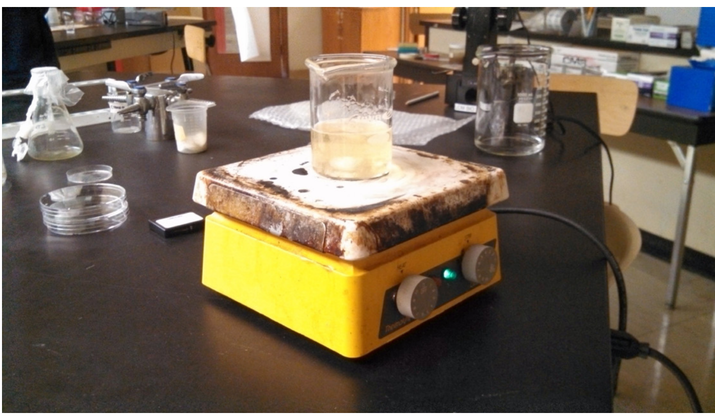


Image 3.2U

Image 3.2V

Image 3.2W

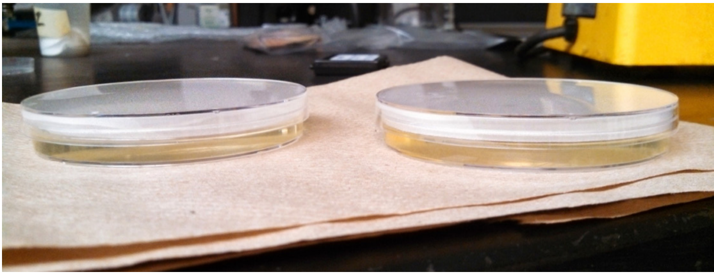
Image 3.2X

Image 3.2Y: Using the potato agar, we made (2) typical pretri dishes. From these, we intended to begin the growth cycle of the slime mold (during the couple days it took to prepare the model) and transfer it whilst in mid-cycle.

Image 3.2Z

Image 3.2AA: The fractal network of the slime molds 'eating' phase emerges after a day's worth of growth.

Image 3.2AB: The organism finds the (2) nodes of food, but only after traversing nearly the entire petri dish.



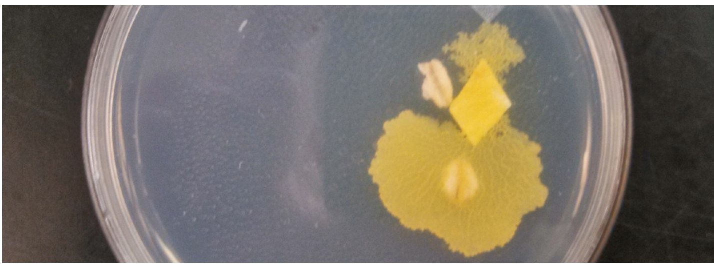
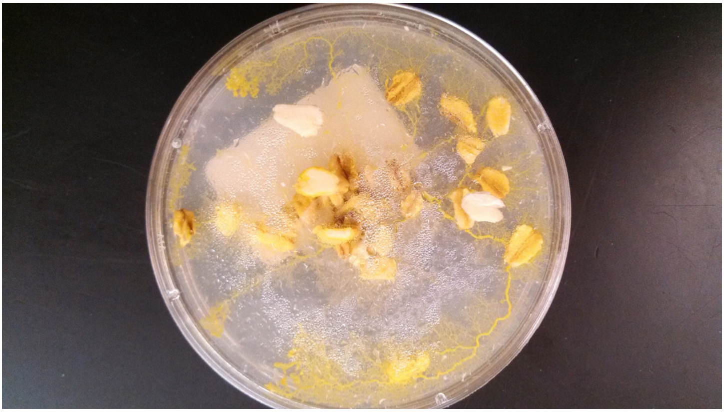
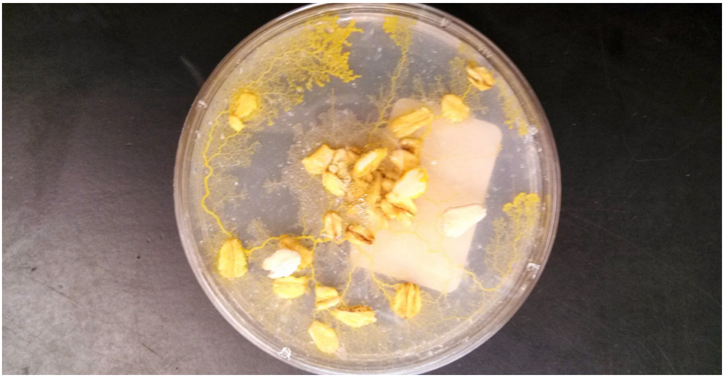


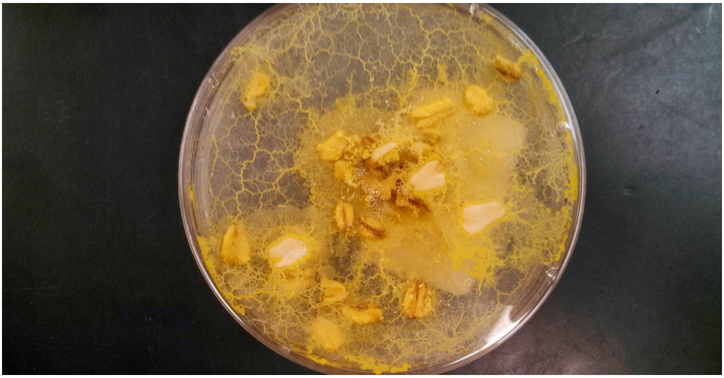
Image 3.2AC

Image 3.2AD

Image 3.2AE







3.3 LIMITATIONS

This book culminates two semesters (and one summer) of scholarly research. For fluidity, I have taken the liberty of organizing my research based on conversations (e.g. part i, part ii, part iii) rather than the chronology of my discoveries. In many ways, my Thesis development has been dynamic and non-linear (in likeness of the theory which it grounds itself upon). I will admit the intimidating breadth of information of which I've attempted to cover; but, I have attempted to arrange my analogies and arguments to combat this issue with shear logic.

First, 'part i' explains Complex Adaptive Systems theory from several different perspectives (e.g. analogies, scientific studies, etc.). A transition is then made from the theory, as a science, to its relationship with architecture and the city. Once the city (as a concept) is opened up, then the interrelationships between each of its systems can be elaborated. 'Part ii' begins with this elaboration and moves through to my design sketch as a response to rapid global urbanization. Thereafter, 'part iii' describes the direct implementation of an analytic tool which incorporates C.A.S., the scientific method, and urban design. Lastly, I wrap up the conversation in a post script intended to speculate on the future.

In a way, this book should be viewed in the image of Gilles Deleuze's "A Thousand Plateaus." Similar to the multiplicity our books intend to describe, the chapters and their relationship with the others are interconnected in such a way that you could begin reading on any page. There exists a common motif intertwined within every chapter, image, and analogy. It is inherent within the topic that this common thread exists. Douglas Hofstadter, in his famous work "Gödel, Escher, Bach," describes the links between symmetry, self-repetition, mathematical algorithms, and the emergence of intelligence as an "Eternal Golden Braid" (note: the G.E.B. – E.G.B. wordplay was fully intentional). With all of this

4 POSTSCRIPT

4.1 CONCLUSIONS

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having been said, I have chosen not organized this book in a manner that could seem schizophrenic. The methodology of my writings errs on the side of cohesiveness rather than attempting to recreate the essence of a multiplicity through sporadic placements of interrelated conversations.

4.2 SPECULATIONS

This book culminates two semesters (and one summer) of scholarly research. For fluidity, I have taken the liberty of organizing my research based on conversations (e.g. part i, part ii, part iii) rather than the chronology of my discoveries. In many ways, my Thesis development has been dynamic and non-linear (in likeness of the theory which it grounds itself upon). I will admit the intimidating breadth of information of which I've attempted to cover; but, I have attempted to arrange my analogies and arguments to combat this issue with shear logic.

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