Gone Viral: Comparing Information Flow in Biological Systems and in Online Social Networks

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"The basic pattern of life is a network pattern"

Capra, 1996, p. 298

Introduction

This essay and art-based inquiry examines whether there are similarities in how information flows are understood in biological systems and in online social networks. The essay will review the historical background and key theories that enable us to compare such different phenomena under the same lens. Information theory, cybernetics, systems thinking and actor network theory will guide this research, complemented by the work of visual artists Saraceno and Mehretu. Several other studies and relevant visual references will be used as part of the creative process and literature review. A reflection about my creative process and art statement will conclude the research. Examples of visual references and my creative work are included in the Appendix.

The Initial Question

It seems that there are patterns in our life that resemble those of other systems. As a visual artist I find it fascinating to search for parallels between microscopic life forms and larger phenomena in nature. A few years ago, while observing human cancer cells and learning about their seemingly chaotic yet organized behaviour, it occurred to me that there could be similarities in how diseases spread in living organisms and the way information moves through social media.

Dr. Lakshmi Puttagunta, a pathologist from the University of Alberta, explained to me that for cancer cells to spread they look for ways to create connections with clusters of healthy cells. It is by getting into the bloodstream or lymphatic system that they can reach these clusters and create chaos among them, eventually overwhelming them and enabling the cancer to grow (personal correspondence, March 3, 2010). It appeared to me that this organic yet strategic behaviour of creating connections to spread is not exclusive of cancer cells. Similar language and descriptions are often applied to the properties of non-biological systems such as, for example, online social networks (OSNs).

Defined as "any web-based network where users can create profiles to express themselves or to engage in social interactions" (Trinkle, Crossler, & Warkentin, 2014, p. 308), OSNs are used by nearly one in four people worldwide ("social networking," 2013). The existence of these networks depends on the participation of their members, who in turn use them to further grow their connections and spread their news. Nowadays, the extent of OSNs is such that news sharing is no longer limited by geographic boundaries or controlled by the traditional gatekeepers of media broadcast (Shirky, 2008). Instead, we have learned to use our networks — and the networks of our networks — to move information.

The fact that expressions such as *viral* or *contagious* are part of our vernacular when referring to popular online content is an indication that at a larger cultural level we borrow language from biology to describe these phenomena. Lakoff & Johnson (1980/2003) state that "our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature" and "language is an important source of evidence for what that system is like" (p. 3). In this sense, to say that something has "*gone viral"* is more than an expression; it is an active metaphor that draws on biological reference to help us perceive and understand OSNs as a social phenomenon in which information transfer resembles the spread of a virus.

This perception is embedded in us to the point that making information "*go viral*" is often a goal. And understandably so, especially considering that about 890 million people log on to Facebook daily uploading 300 million photos (Zephoria, 2015) and that over 500 million tweets are posted on any given day (Twitter, 2015). Some researchers have looked at ways to apply epidemiological methods to predict the *virality* of online content (Freeman, McVittie, Sivak & Wu, 2014; Jin, Turner, Lee, Zhong & He, 2012), while others have focused on identifying the circumstances that facilitate the diffusion of a message as a contagious disease (Karnik, Saroop, & Borkar, 2013).

The purpose of this essay and art-based inquiry is to examine how information flows in living organisms and in online social networks are understood using similar concepts, expressions, and ultimately shared metaphors. This research asks what are the possibilities and limitations inherent in presenting these different phenomena using similar metaphors and if it is possible to apply knowledge from one domain to another. I am interested in the possibility that there could be common patterns in the way information travels through biological and social phenomena. If there are, is it possible, for example, to look at social interactions to prevent epidemics.

On the other hand, I wonder if our understanding of how diseases behave has helped shape the way we communicate and share news online, or vice versa, if our notions of communications and networks have shaped our understanding of diseases. Lakoff & Johnson (1980/2003) observe that while metaphors help us comprehend one concept in terms of another, they can also conceal aspects that are inconsistent with the metaphor (p. 10). If that is the case, what are we missing when we look at information flow under metaphors such as *gone viral?*

From an artistic perspective, I am interested in how our conceptual understanding of these systems and the language we use to describe them informs how we represent them. Art, like any other metaphor, aims at "understanding and experiencing one kind of thing in terms of another" (p. 5) and through my creative process I aim to explore, understand and interpret the dynamics of these diverse phenomena. The artistic process provides the opportunity to borrow and use elements of these systems as a foundation to develop a new visual language.

This essay will review four theories that have made it possible to compare different systems using similar metaphors: cybernetics, information theory, systems thinking and actor network theory. The essay will touch on the historical background that led to these theories and some key research that followed specifically in the area of networks and diffusion. Although there are many theories and studies in this topic, the literature review focused on those that acknowledge a possible relation between the two systems.

Information theory and cybernetics allow us to conceive of any system as an information system. The theory of systems thinking proposes a holistic view of life that observes that most systems in life are interconnected and follow a network pattern. Actor network theory invites us to trace the movements of participants in a network to get a sense of how the network works.

This theoretical background complemented with the work of artists Saraceno and Mehretu and other visual references, such as network mapping and social media visualization tools, inform and guide my creative work. This research intends to include an autoethnographic element, in the sense that it is about the process of personal reflection and investigation, and how it relates to culture in the larger context (Ellis, 2004, p. 37).

The next section will look at the historical and theoretical background that allows us to compare biological and social phenomena under the same lens.

Background

The Path to Systems Thinking

During the 1920s a conceptual shift from the Cartesian view of the world as a machine to a more holistic way of thinking started taking place. Fritjof Capra will later name this new approach *systems thinking* and it refers to an ecological vision of the world as an interconnected network of living systems that regulate themselves (Capra, 1996; Capra & Luigi, 2014). Here, systems are “an integrated whole whose essential properties arise from the relationships between its parts” (Capra, 1996, p. 27).

According to Capra, the tension between mechanism and holism has happened throughout history. On one side those who propose a mechanic view of life explained by scientific discoveries like those of Galileo Galilei and Newton and supported by Descartes’ method of analytic thinking, which breaks “complex phenomena into pieces to understand the behaviour of the whole from the property of its parts” (p.19). On the other hand those like Aristotle and Goethe who believe on a unified and whole notion of an organic and living spiritual world that could be traced back to Gaia and Neolithic times, and in which philosopher’s like Kant saw living organisms as “self-reproducing and self-organizing wholes”(p. 22).

But this time a simultaneous shift pioneered by ecologists and organismic biologists who emphasized a view of living organisms as interdependent systems and the discoveries of quantum physics showing that “subatomic particles are not ‘things’ but interconnections among things” (p. 30), started taking place. Also around this time Gestalt psychologists emphasized “that the whole is more than the sum of its parts” (p. 31) and that living organisms “perceive things not in terms of isolated elements, but as integrated perceptual patterns – meaningful organized wholes, which exhibit qualities that are absent in their parts" (p. 32).

In other words, scientists started to conceive the world as a network of connections both physical and informational. This allows us to conceptualize everything under the metaphor of networks, whether we look at cells in a biological system or connections between people in social environments.

As World War II came to an end, these lines of thought were complemented by the work of Ludwig von Betarlanffy who developed the general systems theory and proposed that there are principles that apply to any system be it social or ecological (p. 48). He also noted that open systems constantly feed on their environment to stay alive (p. 48), initiating discussions around feedback – a key concept for cybernetics, mainly in the foundational work of Norbert Wiener.

Cybernetics as an intellectual movement spawned an interdisciplinary group interested in the mechanics of the brain, patterns of organization, communication, feedback, self-regulation and self-organization of systems (p. 52). Norbert Wiener borrowed the word *cybernetics*, which means steer-man in Greek, to define the field that studies control and communication in animals and machines (Wiener, 1961, p. 11). The cybernetics developed their theoretical framework during the Macy Conferences in New York City during the 1940's, where mathematicians, engineers and neuroscientists (like Norbert Wiener, Claude Shannon, John von Neumann and Warren McCulloch), along with philosophers and humanities theorists (like Gregory Bateson and Margaret Mead) looked for creative ways of thinking and interdisciplinary discussions (Capra, 1996, p. 53).

Their initial interest in the processes of the human brain and analogies with the computer led them to different paths. Von Neumann focused on control, programs, structures and messages, and later went on to develop game theory. Wiener focused on communication and patterns of organization in biological organisms, and the concept of feedback (p. 55). Bateson went to develop an understanding of the mind as a systems phenomenon (p. 55). The work of Wiener and Bateson are particularly relevant to this research, because in their search for principles and larger patterns of organization, they applied concepts of communication and control to other areas like biological, social and cultural systems.

Information Theory – Information as The Essential Unit

It was Claude Shannon's (Shannon & Weaver, 1949) studies in mathematics, probabilities and cryptology that triggered one of the biggest breakthroughs in communications and information, and that as a result allows us to understand information as a universal measurable concept that can be applied to any system. Shannon's information theory conceived of information not as it relates to meaning, but as a signal that can be defined and quantified (Capra, 1996, p. 64). By disregarding the meaning in the message, Shannon focused on the physical aspects of information and came up with an essential measure for information: the bit (Gleick, 2011, p. 4). Shannon's information theory was discussed during the Macy Conferences and as the theory spread it was applied to many fields including computing, information processing, neuroscience and even cognitive studies, specifically in how people handle information (p. 260).

It is interesting that by making information measurable and purposely ignoring the meaning of the content being transferred, researchers from different fields started to look at patterns of organization in the brain, machines and even in social behaviours. Gleick says that once information was simplified, measurable and understood as an essential unit, scientists saw in the bit "the vital principle …the irreducible kernel… the very core of existence… the unit of life" (p. 8 - 10). Shannon's theory liberates us to be able to see information everywhere and to consider that biological systems, social systems, computer systems, are all essentially information systems. Even evolutionary theorist Richard Dawkins said:

> "what lies at the heart of every living thing is not a fire, not warm breath, not a 'spark of life…. It is information, words, instructions… If you want to understand life, don't think about vibrant throbbing gels and oozes, think about information technology." (As quoted by Gleick, 2011, p. 8)

The advent of information theory inevitably made scientists, mathematicians and philosophers question existing concepts. For example, under this theory genes started to be understood as information (p. 309) and DNA was given two essential functions: to preserve information (by copying itself from generation to generation) and to send information outward making new organisms (p. 296).

But in the body, just like in all other living systems, the whole is more than the sum of its parts. According to Gleick biologists have learned that "the genes composing the human genome are only a fraction of the genes carried around in any one person, because humans (like other species) host an entire ecosystem of microbes – bacteria, especially from our skin to our digestive systems" (p. 305). All these organisms cohabitate and evolve in our bodies. Seiler's (2007) cites research that says that Prokaryote (such as bacteria) "may constitute a third of the planet's biomass" and that "their constructive evolution resulted in the formation of a worldwide web of genetic information, and a global bacterial superbiosystem" (p. 255).

Not only is the information of bacteria present in our bodies and prominent on the planet, but its communication systems resemble our systems, too. Citing Walter & Bassler, Seiler talks about how bacteria communicate using chemical signal molecules. The information supplied is used to monitor the environment and organize the behaviour of larger populations of cells (2007, p. 255). Apparently, bacteria have access to a pool of information from which they can exchange genes between species, a resource that Nobel Laureate Joshua Lederberg described as "a DNA-based worldwide web" (as quoted by Seiler, 2007, p. 256). Be it human genes or bacteria, in information systems "life spreads by networking" (Gleick, 2011, p. 8).

Feedback in Systems

For Capra, the concept of feedback as developed by Wiener is one of the key contributions of cybernetics to the new way of systems thinking. In simple terms, feedback is "the return of energy from a circuit's output back to its input" (Gleick, 2011, p. 238), but Wiener saw it as a way to control a desired outcome (using the difference between a desired motion and the actual motion to control the correctness of the next motion) (1961, p. 6).

By applying feedback principles to biological patterns, the cybernetics "recognized feedback as the essential mechanism of homeostasis, the self-regulation that allows living organisms to maintain themselves in a state of dynamic balance" (Capra, 1996, p. 58). Feedback loops helped understand how living systems self-regulate to maintain the system working while at the same time changing. It also made evident that these processes happen ubiquitously in nature, and as we will see a few decades later with the arrival of online social networks, they also happen in social systems because their communications networks have self-regulation and feedback loops (Capra & Luigi, 2014, p. 96).

Prior to the development of this new conceptual metaphor brought by organismic biologists, ecologists, Gestalt psychologists, quantum physics, systems theory, cybernetics and information theory, it would not have been possible to look at social and biological phenomena as information systems. To recognize that what flows through the systems is essentially information is key to my creative process, because it frees me to look at the dynamics and patterns without the limitations of content. Be it DNA, tweets, bacteria or a growing forest, I am interested in how information spreads through networks and how that can be represented visually adding another layer of metaphor.

Systems Thinking

Leveraging this theoretical and historical background, Capra (1996) and Capra & Luigi (2014) propose a framework for a sustainable way of living based on the principles of organization of living systems. *Systems thinking* or *a systems view of life* "sees the world not as a collection of isolated objects, but as a network of phenomena that are fundamentally interconnected and interdependent … and views humans as just one particular strand in the web of life" (Capra, 1996, p. 7). Under this thinking, the actions of every node in the network are felt throughout because everything is interconnected.

Borrowing from other disciplines, systems thinking theory identifies three key principles of organization: interdependence of its parts, a network pattern in which "the whole is more important than the sum of its parts" (p. 25) and the presence of feedback loop processes (p. 298) as elaborated by Wiener. These principles are crucial for my research as they provide a foundation for the creative process. They provide, for example, visual insights and references into how things are connected and information is transferred within the system. But most importantly, they provide a framing metaphor that allows me to think about and compare different systems.

Throughout nature there are systems living within other systems, and interdependence – "the mutual dependence of all life processes to one another" (p. 298) – is an essential characteristic. In interconnected communities, members derive their existence from the relationships with others and coordinated behaviour is what keeps the system working. In his search for "the pattern that connects all living creatures," Bateson (1979, p. 8) found that relationships are the essential element of biological form.

System thinkers do not believe in viewing life as a machine made out of parts. Neither do they believe in the *vitalists'* approach that there is something separate from the matter that gives living organisms the spark of life. Rather, they believe that life happens in the network, when the parts interact to create a whole system. "The essential properties of an organism, or living system, are properties of the whole, which none of the parts have. They arise from the interactions and relationships among the parts" (Capra, 1996, p. 29).

Capra & Luigi's (2014) systems thinking is a fundamental metaphorical shift from one that sees the world as a machine to a vision of the world as a network (p. 4). This vision integrates biological, cognitive, social and ecological dimensions (p. xii). In this sense, OSNs are also part of this web of life and as a social system they follow the previously mentioned principles of organization: interdependence of the parts, a network pattern and presence of feedback mechanisms. Some OSNs are self-regulating and might even have what Maturana & Varela (1980) described as the key characteristic that differentiates living from non-living systems: *autopoiesis*. This term, which means self-making, refers to the capacity of the network to continually remake itself while maintaining its general structure.

Luhmann, who developed the concept of social autopoiesis or second order cybernetics, believed that "social systems use communication as their particular mode of autopoietic reproduction. Their elements are communications that are produced and reproduced by a network of communications and that cannot exist outside of such a network" (as quoted by Capra & Luigi, 2014, p. 307). Much the same as it happens in other interdependent systems, social systems need of the interactions of their parts to exist. In social systems interactions take the shape of communication.

Studies About Information Diffusion and Networks

One important contribution of systems thinking is the observation that "the basic pattern of life is a network pattern" (Capra, 1996, p. 298) and hence everything happens in the network including information transfer. As the purpose of this research is to examine if there are similarities in how information moves in living organisms and in OSNs, we will look at some studies that have applied network and/or diffusion theories to compare both systems.

Diffusion theory is at the core of most studies that look at networks, because it is the "process through which elements are transferred, borrowed, or adopted into a social system" (Kadushin, 2012. p. 137). Anything that passes through a network including innovations, diseases, opinions and behaviours depends on the shape of the network, its density, the connections between members, and the presence of influencing leaders (or key nodes).

Diffusion theory proposes that when something spreads in a network it follows an "s" shaped pattern, in which a few early adopters initiate the process, then others follow until it reaches leaders who in turn adopt the behaviour and influence others to try it, at which point diffusion takes off. Malcolm Gladwell calls it "the tipping point [which] is that magic moment when an idea, trend, or social behavior crosses a threshold, tips and spreads like fire" (as quoted by Kadushin, 2012, p. 155). Diseases also follow the "s" shaped pattern, infecting people and potentially creating contagion, which "is the spreading of an entity or influence between individuals in a population, via direct or indirect contact" (Dodds & Watts, 2005).

Online information diffusion can take the form of contagion and several studies have looked at ways to emulate and/or prevent it (Berger & Milkman, 2013; Borge-Holthoefer, Rivero, & Moreno, 2012; Centola & Macy, 2007; Dodds & Watts, 2005; Mills, 2012; Wu, Huberman, Adamic, & Tyler, 2004). “Identifying key aspects of the spreading phenomena facilitates the prevention (e.g., minimizing the impact of a disease) or the optimization (e.g., the enhancement of viral marketing) of diffusion processes that can reach system-wide scales” (Borge-Holthoefer et al., 2012, p. 1). While some of these studies focus on the identification of the nodes in the network that have the potential of spreading contagion, Wu (2013) observes that network circumstances like homophily and social influence among members could be more crucial (p. 20).

With access to technologies capable of dissecting quantitative data from Twitter, Wu (2013) focuses on “the flow of information (and activity) in an on-line environment at a large scale” (p. 3). This technology measures and traces who is influencing who, what the life span of different types of content is and how the network structure impacts the diffusion process. Wu found that these components operate together: Opinion leaders who know their content are more influential than famous personalities (p. 9), and positive messages with rich content such as music and videos have a longer lifespan than negative information (p. 11).

Wu (2013) observes that although several studies “have exploited the similarity between the spread of information and epidemics through social contacts, and adopted a series of epidemic models to describe social contagions” (p. 24), they have ignored that these models “assume a constant propagation across the network” and have not accounted for individual dynamics of diffusion (p. 24). This refers to an individual’s intent or choice to share information with others and speaks to the limitations of using biological metaphors to explain social systems. Furthermore, “the complexity and fuzziness of real world diffusion process is innately inadequate to be fully captured by epidemic models" (p. 28) and data alone cannot explain how diffusion happens in online social networks.

Sun, Rosenn, Marlow, & Lento (2009) question whether diffusion is the best theory to approach the spread of information in social media. By analyzing data from Facebook's newsfeed, Sun et al. observed that social media diffusion does not follow the traditional "S" shape of contagion. They noticed that "global cascades are in fact events that begin at a large number of nodes who initiate short chains; each of these chains quickly collide into a large single structure" (p. 153). Centola & Macy (2007) arrived at a similar observation, as they noticed that while weak ties are ideal for simple contagions, multiple points of contact are required to trigger social movements.

One of the most influential studies is the work of Christakis & Fowler (2010) who propose that it is possible to predict epidemics by mapping how people are connected in social networks and their level of influence (see Appendix A for reference images). According to their research, health epidemics behave much like social contagions such as *memes*. "In cultural evolution, a meme is a replicator and propagator – an idea, a fashion, a chain letter or a conspiracy theory. On a bad day, a meme is a virus" (Gleick, 2011, p. 9). Being able to distinguish the key nodes on a social network increases the chances of managing social contagions, either to spread them or stop them.

By being able to render and visualize relationships and epidemics as information, it is possible to map their patterns and compare different phenomena. These kinds of studies that trace patterns of behaviour to understand how disease or information travels have their root in John Snow's epidemiological work. Snow, who identified a water pump that supplied drinkable water as the source of the cholera outbreak in London in 1854 (Cameron & Jones, 1983, p. 393), did this by codifying and mapping the cases of cholera as units of information, revealing a pattern in the spread. Although network theory did not yet exist, a lithographic image of the original map shows how most cases of cholera were clustered around the water pump (John Snow Matrix, n.d.).

Barabasi (2002), who believes we are all linked to each other and that "networks are everywhere…all we need is an eye for them" (p. 7), also believes "the construction and structure of graphs or networks is the key to understanding the complex world around us" (p. 12). For Barabasi, although several characteristics of networks such as *small worlds*, clustering, Granovetter's *strength of weak ties* and the popular *six degrees of separation,* help explain how we are connected, he finds this last one "deeply misleading because it suggest that things are easy to find" (p. 37). Instead of feeding the popular myth initiated by a play that says six people separate everybody in the world, he goes to the original Hungarian 1929 short story "Chains" and to the 1967 Milgram study about interconnectivity in North America. From here he then shows that it is through mapping connections, links and possible paths that we can get a glimpse of how removed or close we are in our ever-changing networks. Gleick illustrates it beautifully: "the network has a structure, and that structure stands upon a paradox. Everything is close, and everything is far, at the same time…you can drop a stone into a well and never hear a splash" (2011, p. 425).

Visual Research: Saraceno, Mehretu and Slime Mold

There is no shortage of tools that allow us to visualize how our online social networks are structured, to see which potential influential connections are only a few links away or to know how many people have been exposed to our news. This is possible, in part, thanks to Shannon's information theory, because by counting every person or interaction in the network as a unit of information, we can now measure and even map information in the network.

It is truly fascinating to be able to capture how the network looks at a moment in time and remove ourselves to see where we stand in the larger picture. Visualization tools are ideal for presenting data and hence facilitating comparisons and analysis, but at the same time this is their limitation. Unlike art, visualization tools present data, they do not interpret it. Art has the ability to go beyond this as it can freely interpret and apply concepts or metaphors to that data. Moreover, art itself is a metaphor that can potentially help understand one phenomenon in terms of another.

The work of Tomas Saraceno and Julie Mehretu are two examples of how art creates its own metaphor, because through their artwork we can arrive at a better awareness of how systems and networks work.

Saraceno's Webs: An Example of Actor Network Theory

Argentinian visual artist and architect Tomas Saraceno provides his audience the experience of being immersed in an interconnected environment through his installations and sculptures. Known for "constructing habitable networks based upon complex geometries and interconnectivities that aim to transcend the sensorial effect" (Saraceno, 2012), his artwork grasps the essence of networks and principles of systems thinking. For images, see Appendix B.

Saraceno's work has been called ecological art (Latour, 2011), because it studies how organisms relate with their environment. His spider web installations capture the patterns, spaces and structure of a web, as created by black widow spiders in a controlled box in his studio. Using 3D technology, Saraceno reconstructs these webs but enlarges them to fill an entire room, allowing the viewers to enter the web and participate. These installations, which are made of elastic tensors fixed to the walls and connecting wires, create “comfortable and enclosed spherical sites which are nonetheless entirely made of networks” (p. 801).

I once had the opportunity to view and experience one of Saraceno’s spider web works entitled Flying Garden/Air-Port-City (2007). What I found most interesting was that by softly pulling on one of the wires I experienced how the entire web was connected, as my action – regardless of how soft my touch – activated the web and resonated throughout. More than visualizing a network, these installations allow us to experience the “metaphor of networks” with our bodies and senses.

Saraceno’s work is consistent with Capra & Luigi’s (2014) systems view of life, which proposes a shift in how we interact with our world in favour of a more sustainable way that respects the limited self-regeneration capabilities of the world. Saraceno’s “floating sculptures and interactive installations propose new, sustainable ways of inhabiting the environment” (Tanya Bonakdar Gallery, n.d.) and he does this by making the viewer aware that we live in ecosystems in which everything is interconnected.

His projects “cloud cities” and “giant bubble” are large floating environments mostly made up of layers of plastic, wires and compressed air. As participants enter these spaces, they soon realize that everybody else’s actions have an impact on them. Saraceno playfully explains that when someone opens a door in the lower layer of the bubble, a few seconds later you can hear people on the upper layers shouting as the loss on air pressure makes them fall from the bubbles (Saraceno, 2012). Interdependence, feedback and interconnectedness with the environment, which are three essential characteristics of living systems, are beautifully recreated here. Saraceno says “I have always been fascinated by the butterfly effect…A butterfly’s movement here will make a storm somewhere else” (as quoted by Austen, 2012, p. 46).

Bruno Latour (2011), who developed Actor Network Theory (ANT), found in Saraceno's spider webs a much sought after visual representation of networks as habitable spaces. Far from the usual simplistic representation of networks as nodes and edges (links), Latour says that by "changing the density of connections until a net ends up being undistinguishable from a cloth" (p. 801), Saraceno creates a space or "envelope" where participants can be. Latour also points out that the artwork is neither the spheres nor the nets, but the spaces they create. In other words, in these art installations, similar to systems, the whole is more than the sum of its parts.

Latour's ANT proposes that networks are made of relationships regardless if they are those of insects, humans or technology. Latour is interested in understanding how networks form not why they form, and for this purpose he proposes following the trail of associations and interactions between elements in the network.

Saraceno's creative process is fascinating, as he builds whole systems by following the paths and connections created by the black widow spiders. This process relates well with Latour's (2005) ANT, which focuses on the social qualities of systems. For Latour "social" is about following the actors regardless if they are human or not, tracing their association and the formation of assemblages (p. 7). In this sense, Saraceno's work is about the process of following social paths of action of black widows. Flew & Smith (2011) highlight that in ANT, relationships in the network are in constant change "being remade every time the actors interact" (p. 102). By tracing the paths of the black widows and photographing the web at a certain point, Saraceno captures the network in a specific instance as the network keeps changing while elements interact with it. This is one of the reasons photographs are a key element of Saraceno's work.

This process informs my own art process because it shows how following the actors in the system allows one to get a sense of how information flows in networks. This artwork also helps me understand that it is the participation of someone or something in the environment (a bug trapped in a web or a participant in an installation) that activates the network and in so doing, completes the artwork. Without participants interacting with the artwork, these installations would just be wires, elastics, plastic and compressed air. There would be no movement or information flow.

Budick (2012) observed that in Saraceno's work "the line between the biological and inanimate worlds seems more permeable." I believe this is because his work with inanimate materials reminds us that systems can be found at all levels and within each other: in the micro and the macro, and in the biological, social and technical world. Von Bertalanffy would add that "certain principles apply to systems irrespective of their nature" (Capra, 1996, p. 49). The cybernetics also observed this, but instead of calling them "principles" they called them "patterns of organization" (p. 64).

Information Layering Creates New Spaces: Mehretu's Paintings

Similar to Snow's use of London's street maps to follow the cases of cholera, Ethiopian - American artist Julie Mehretu uses maps, architectural drawings and blue prints of cities with historical sites as starting point for her artwork. Her paintings have been "described by curator Douglas Fogle as 'perfect metaphors for the increasingly interconnected and complex character of the 21st century" (White Cube, 2013). For images, see Appendix C.

Like Saraceno, Mehretu's work is about the process of tracing a path of social action, but instead of following people or spiders, she follows the changes of our spaces from a geographical, political and historical perspective. She says "I am interested in the multifaceted layers of place, space, and time that impact the formation of personal and communal identity" (as quoted by White Cube, 2013).

Mehretu's large paintings and drawings are made of layers upon layers of maps, historical references, architectural symbols like columns and arches, and her own mark-making. She creates new spaces that feel like large interconnected systems and resemble busy urban and social environments. The paintings are "a kind of unpeeling of the layers that make-up a city itself" (White Cube, 2002).

The creative and mark-making processes play a key role in Mehretu's work. With the help of computers she mixes views and maps of cities removing all sense of traditional perspective or proportion. Mehretu's gestural mark-making results in "imploded and chaotic images that seem driven by an internal force, their explosive lines of colour and urgent marks spreading over the canvas from a central, energetic core" (White Cube, 2002). Most interestingly is that the act of erasing is an essential part of Mehretu's mark-making, not only as part of the creative process but also as a political and historical commentary. This is evident when she removes symbolic sites or historical areas of cities.

To me, Mehretu's paintings create interconnected systems that are moving and changing. The mark-making gestures behave like organisms that form their path of action and exist in a living environment. I am interested in how Mehretu talks about "the behaviour of the mark" (White Cube, 2011) as if it was a social agent, because in my creative process I aim to follow and trace connections, but I intend to do it through my own mark-making gestures.

Mehretu's use of maps is another aspect that interests me. Ljungberg (2009) says "maps make meaning by locating us as agents in the world" (p. 308), which fits in with Latour's (2005) call to "redefine the notion of social by going back to its original meaning and making it able to trace connections again" (p. 1). But Ljungberg (2009), sees in Mehretu's use of maps something that goes beyond locating and tracing to instead "suggest poetic ways for agents to alter a chaotic present by creating new sensibilities and sensualities that … are built on collective actions and desire for social change" (p. 314). This makes me reflect on my process as there is a difference between using mapping software to visualize information without intervention, and using it as foundation to create a whole new visual language from it, a metaphor. The intention of my work is not to create a representation of an existing network but to follow Latour's notion of social by tracing connections, but allowing for interpretation, for the participation of artistic gestures and the creation of visual spaces.

Slime Mold: Not a Simple Actor

While Mehretu uses maps and blue prints as a starting point in her creative process, artist Heather Barnett and other artists of the "Slime Mold Collective" (Slime Mold Collective, n.d.) have found inspiration in slime mold. This single cell organism has the ability to map its territory, leave a trail behind to recognize where it has been and build networks to create connections between food sources (Barnett, 2014). According to Barnett, several studies have tested the ability of this organism to find the shortest and most efficient route in a maze. One of the most noteworthy studies found that by motivating slime mold with food – pieces of oats which were placed in a similar configuration as key cities around Tokyo, – they mapped in only 26 hours what has taken engineers many years to design: Tokyo's rail system (Tero, et al., 2010). See images in Appendix D.

The work of Barnett and her colleagues is another example of how ANT can be applied to art, but in this case the actor is slime mold (see images in Appendix E). Barnett, whose artwork explores microbiological topics, uses time-lapse photography and video to capture how the slime mold builds complex networks. She also photographs the trails that the slime mold leaves as it searches for food, and she has learned to work with slime mold to produce specific artistic outcomes. Other members of the Slime Mold Collective are working on projects that try to solve urban problems with the help of the slime mold's network building ability.

Earlier in the essay I asked if there are opportunities to learn from looking at different systems under the same metaphor. I believe these projects that connect urban challenges, art and the pattern of organization of living organisms are an example of how there is indeed a potential benefit. The work of Christakis & Fowler (2010) is another example; in their research they apply what they learn from the dynamics of social networks to the prevention of epidemics. However, this would not be possible if we were not able to look at and compare these different phenomena as information systems.

Creative Process and Art Statement

My creative work examines how we understand and represent information flow in living organisms and in online social networks. The goal is to create a visual language that serves as a metaphor about how information flows in these systems. The theories covered in this essay have informed the process in various ways.

Information theory allowed me to look at different systems under the principle that what moves through them is information. Cybernetics helped me understand that there are common patterns of organization within different systems, and how feedback loops keep them changing while maintaining their core structure. Systems thinking opened my eyes to a holistic approach where "life is a network of living systems" (Capra, 1996, p. 5), gaining a "sense of interwoveness and interdependence of all phenomena" (p. 4).

After learning about the systems view of life, my creative focus changed from looking for common elements in different networks and trying to illustrate them, to accepting that everything is connected. Now my creative process takes inspiration in that feeling of belonging, flow, layers of systems within systems and natural wholeness.

ANT plays an essential role in my visual research. It was through the examples of Saraceno and Barnett that I realized what it means to trace the path of an actor to understand the network. Latour's observation of Saraceno's ability to create habitable spaces out of networks, drove me to try to capture the flow and space within systems by following the movements of an actor. The creative work that accompanies this essay follows three social actors: cancer cells, Twitter conversations and the Chikungunya mosquito.

I used a variety of sources to understand how those actors move. For cancer cells I had the benefit of having worked with Dr. Lakshmi Puttagunta, who shared photographs and knowledge of how cancer cells spread. To visualize Twitter conversations I took advantage of Geographic Information Systems (GIS) like CartoDB (CartoDB, 2015) which allowed me to map where, and in what sequence, conversations took place in a period of time. I also found striking maps of Twitter conversations (NY.spatial.ly, n.d.) that inspired my search. But the research I found most useful came from Pew's Research Centre and their use of software NodeXL1 (Smith, Rainie, Shneiderman, & Himelboim, 2014). This research provided interactive visualizations of different types of Twitter conversations, which allowed me to zoom in and out and examine how the network looked from different degrees of immersion.

Chikungunya is "a viral disease transmitted by the bite of infected mosquitoes such as Aedes aegypti and Aedes albopictus" (Pan American Health Organization, 2015). To study the Chikungunya mosquito as an actor presented an interesting challenge as I found myself looking at studies of how mosquitoes move ("A 3D analysis of mosquito flight," 2013), looking at maps that show how the virus has and continues to transmit (Chikungunya autochthonous transmission in the Americas, 2015), and visualizing where the hashtag #Chikungunya was used and how it moved in a period of time (with the help of CartoDB). The idea behind this was to get a sense of how the virus spread, but also how the source itself (the mosquito) moved.

The purpose of my artwork is to capture the sense of flow and interconnectedness that takes place in these biological and social systems. Using mainly layers, lines and organic forms, I try to recreate with my own mark-making the clustering, density and patterns that take part in networks.

I believe the "gone viral" metaphor that permeates our conceptual understanding of how online information is transferred is also present in my artwork. This is partly due to the fact that most of the research done (theories, practical studies and visual references) was geared towards a comparison of information spread in biological and social systems. But also because this cybernetic metaphor that sees similar patterns of organization in both systems is culturally engrained in my understanding of information, systems and communications. If a different metaphor would have guided my understanding, then my artwork would look and feel different. "Metaphors are "capable of giving us a new understanding of our experience…they can give new meaning to our pasts, to our daily activity, and to what we know and believe" (Lakoff & Johnson, (1980/2003, p. 139). For images of my artwork see Appendix F.

Conclusions

Following the intuition that there could be similarities in how diseases spread in living organisms and the way information moves through online social networks, this essay and art-based inquiry set out to compare our understanding of how information flows in biological and social systems. The theoretical framework that guided the research and allowed me to compare such different phenomena under the same lens were the theories of information, cybernetics, systems thinking and actor network. The intention was not to compare the systems per se, but our understanding of them as information systems.

This research asked what are the possibilities and limitations inherent in presenting these different phenomena using similar metaphors or concepts. Several related metaphors were touched upon in this essay, but the predominant one was a cybernetics view, which sees common patterns of organization in living organisms and social phenomena. This view is complemented by an awareness of information as a universal measurable unit that can be applied to any system. In the online culture these metaphors translate into commonly used expressions such as “gone viral” or “contagious” to refer to content.

As we have seen, looking at different phenomena under the same metaphors provides several opportunities. We can find common patterns of organization –like the observation that in living and social systems everything happens in the network – and apply what we learn in one system to the other. The work of Christakis & Fowler with epidemics and the projects of the Slime Mold Collective with urban challenges are an example of that. From an ecological perspective, to compare micro living organisms and macro social systems presents a holistic view in which we can learn about sustainability by observing the interconnectedness and interdependence of systems.

In addition to this, examining these phenomena through my creative process allowed me to focus on how information flows in systems and how everything is connected. It also facilitated immersing and removing oneself from the networks to be able to distinguish patterns. It is my hope that it also permitted the creation of a new metaphor, an artistic metaphor that brings to light how these systems might or might not relate to each other and create new forms of awareness.

Finally, the most interesting possible outcome of comparing the two systems is that we can start to question if and how one system informs the other. Have we developed our communication systems to resemble living organisms? Or are we framing our studies of living organisms to fit the principles of our communication systems? As noted earlier, metaphors help understand one concept in terms of another, but they also steer our perception and can hide aspects that do not fit with their fundamental concepts. This makes me wonder how our communications systems would look if different metaphors had prevailed during the last few decades. And this is precisely the biggest limitation of looking at different phenomena under the same metaphor; we could be framing our understandings and ignoring other possible interpretations.

The theories, studies and artwork covered in this research seem to corroborate that there are similarities in how we share news and information in online social networks and how we understand information flows in living systems. But as noted above, that can only be said with the caveat that our understanding of these systems is influenced by conceptual metaphors that have prevailed in history.

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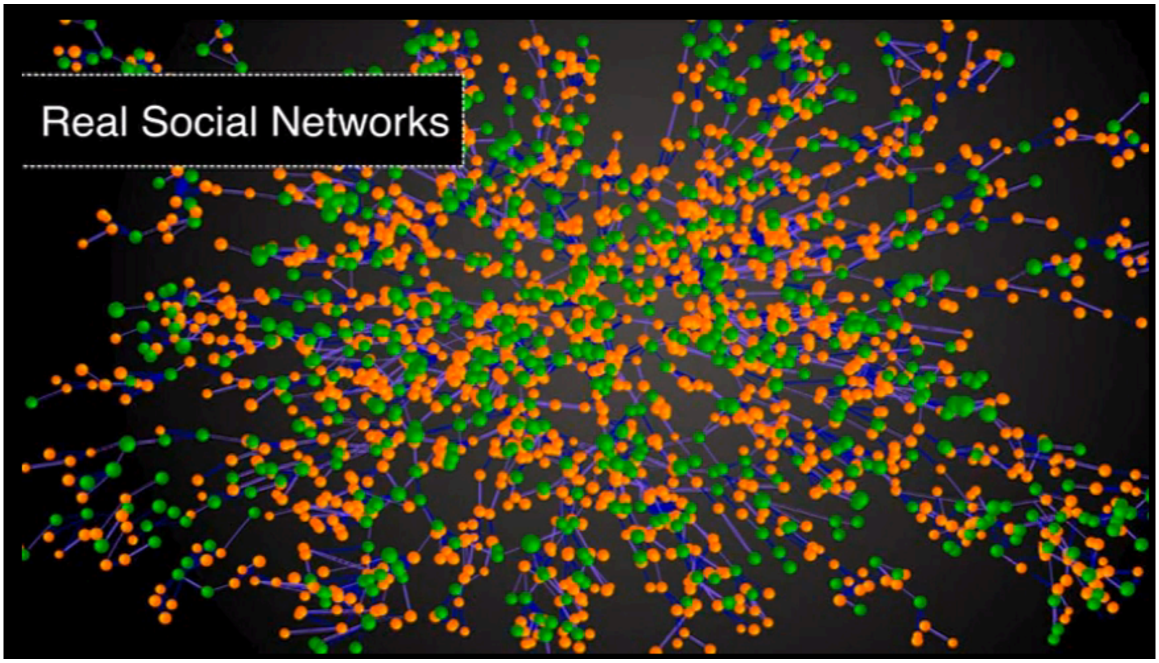
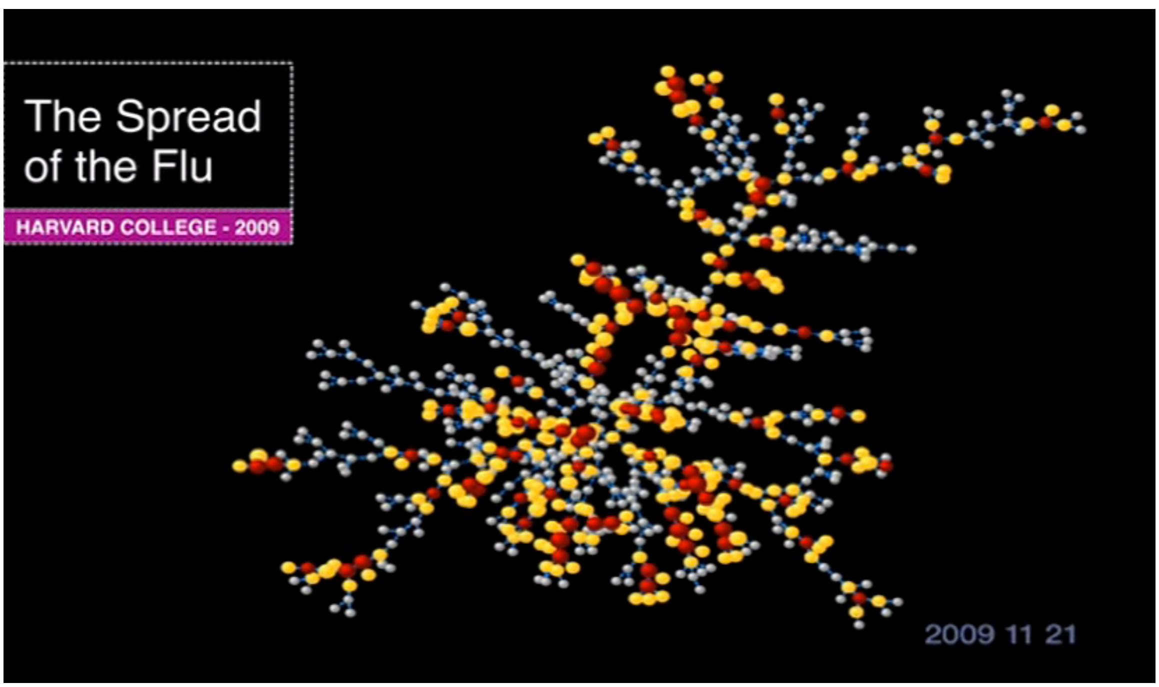
Appendix A

Nicholas Christakis & James Fowler: How social networks predict epidemics

(Images retrieved from Christakis & Fowler, 2010)





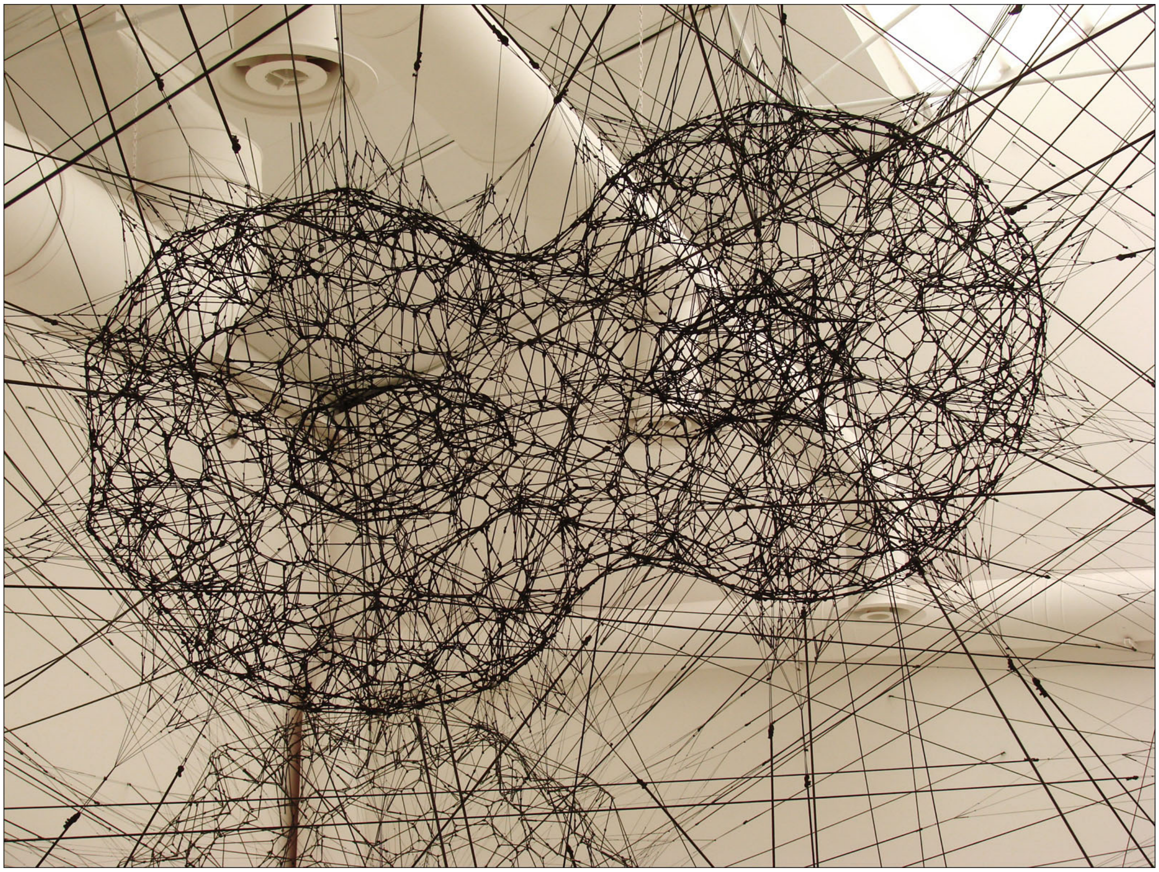
Appendix B

Tomas Saraceno installations and photographs

In Orbit, K21 Düsseldorf (2013) - Photo by Trevor Patt – CC License

In Orbit, K21 Düsseldorf (2013). Photo by Trevor Patt – CC License

Observatory, Air-port-city. Photo by emmajc – CC License



Galaxies forming along Filaments, like droplets along the strands of a spider's web (2009). Photo by Jean-Pierre Dalbéra - CC License

Appendix C

Julie Mehretu's paintings and drawings

Stadia 1 (2004). Photo from White Cube Gallery.

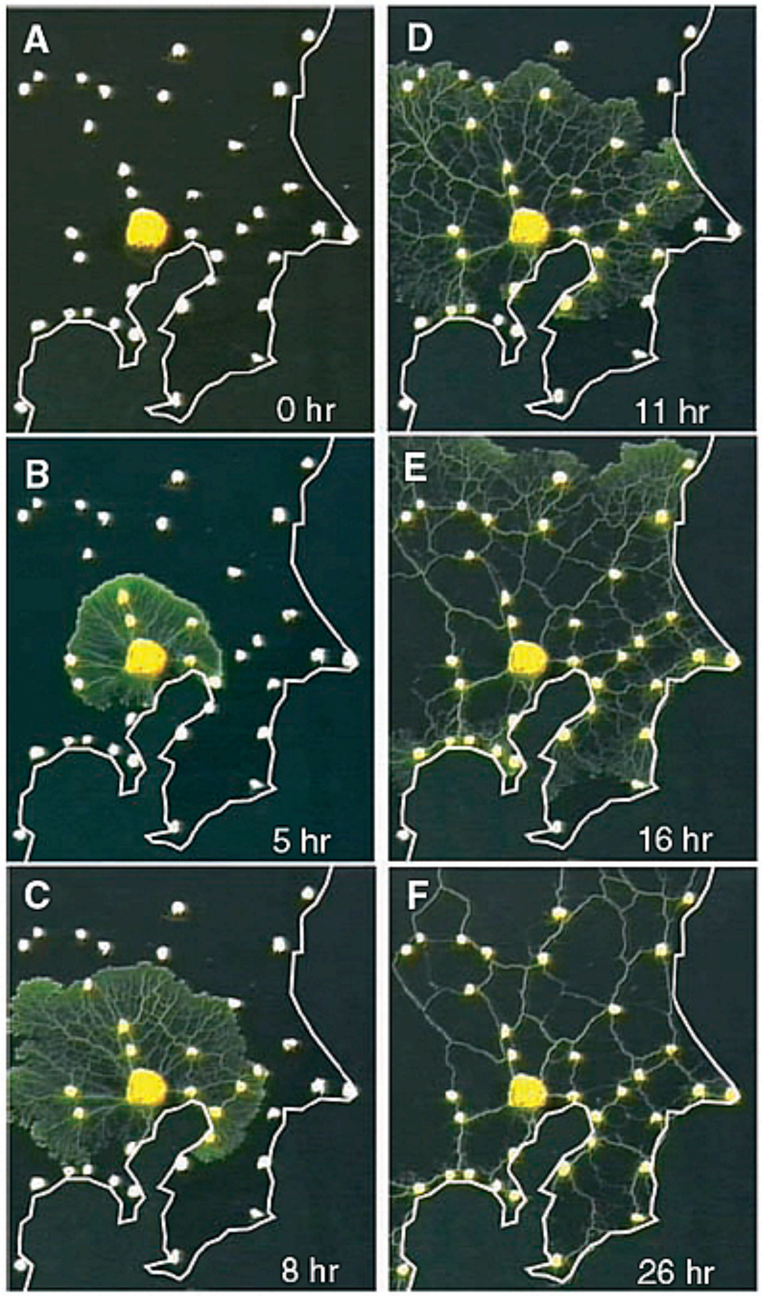
Renagade Delirium (2002). Photo from White Cube Gallery.

Amulet (desire drawing) (2008). Photo from White Cube Gallery.

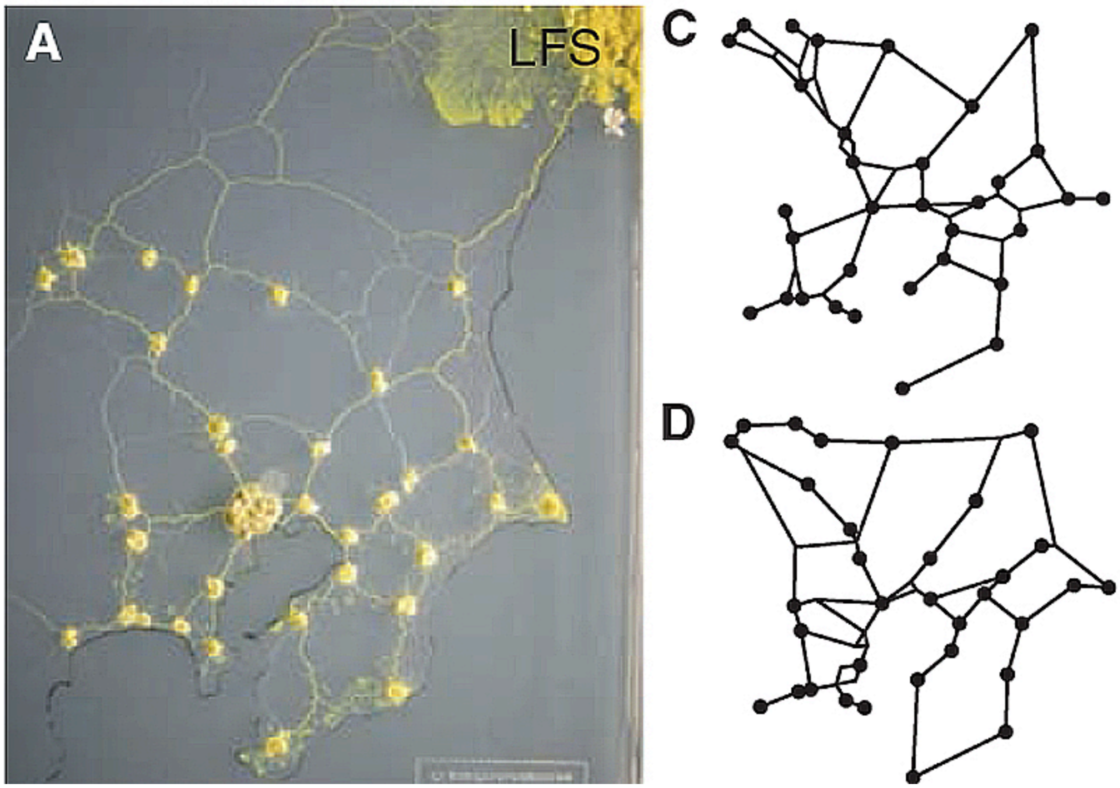
Untitled (2001). Photo from White Cube Gallery.

Appendix D

Slime Mold oat patterns vs Tokyo's rail system (Images taken from Tero, et al., 2010)



Tero, et al., (2010) capture the network building process of the slime mold with oats positioned similarly to main cities around Tokyo. The large oat is Tokyo.



Tero, et al., (2010) compare the network built by slime mold (A & C) to Tokyo's rail system (D)

Appendix E

Heather Barnett's work with slime mold

(Images retrieved from Barnett's videos: http://www.heatherbarnett.co.uk/physarum.htm)

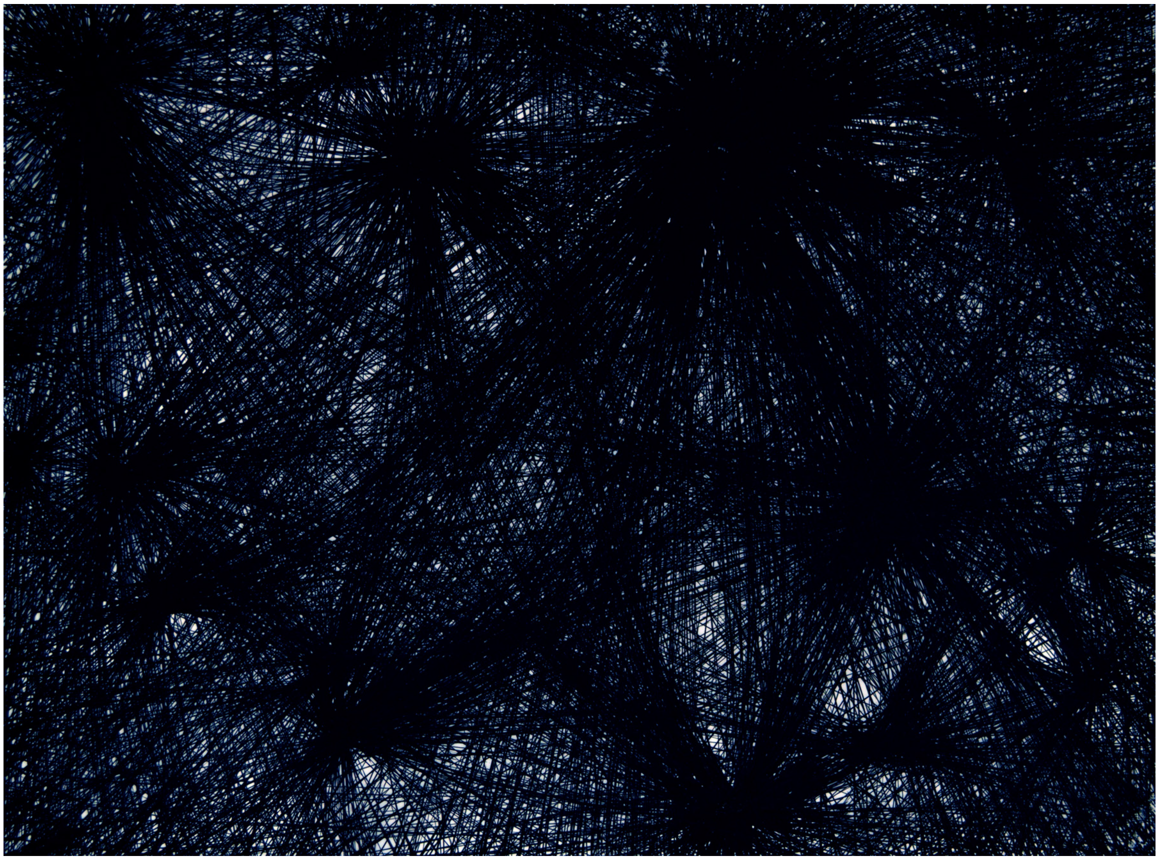
The Physarum Experiment No. 013 - The Spelling Exercise

The Physarum Experiment No. 011

Appendix F

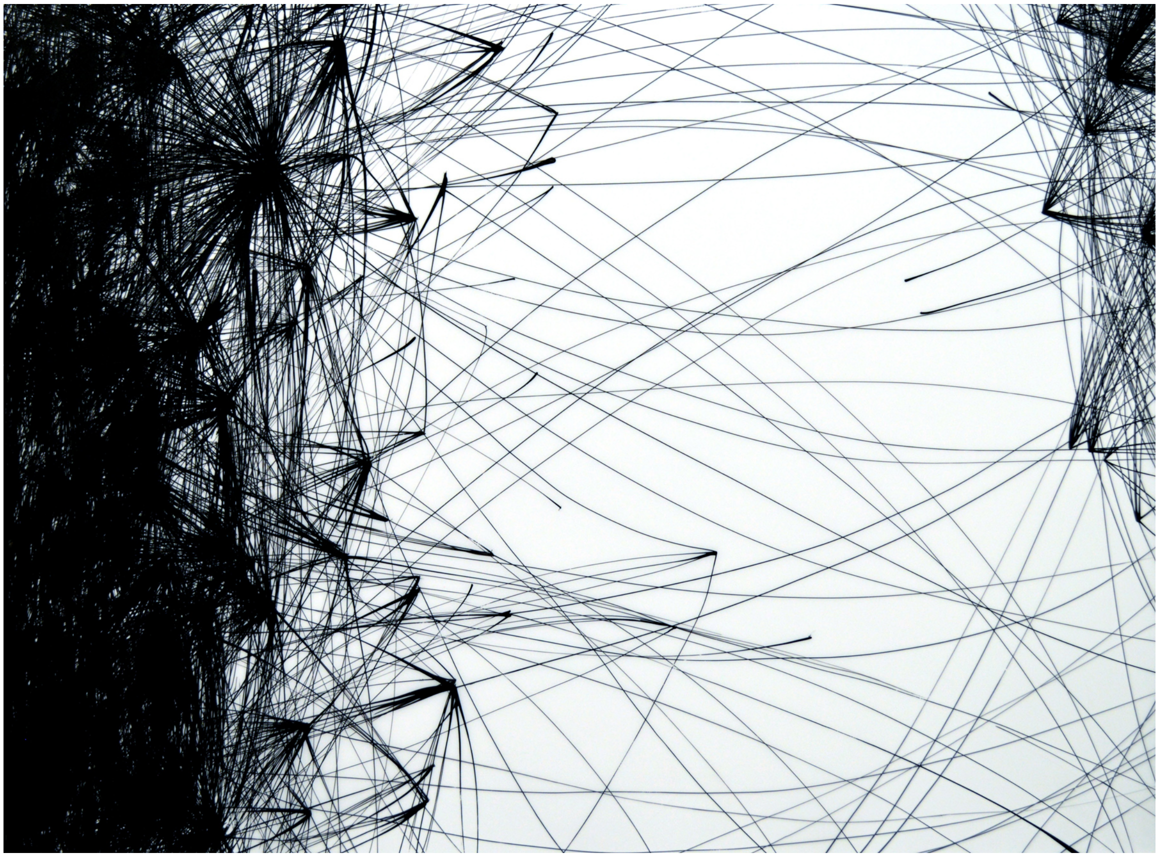
"Gone Viral" by Andrea Soler

As displayed at the University of Alberta in August 14, 2015

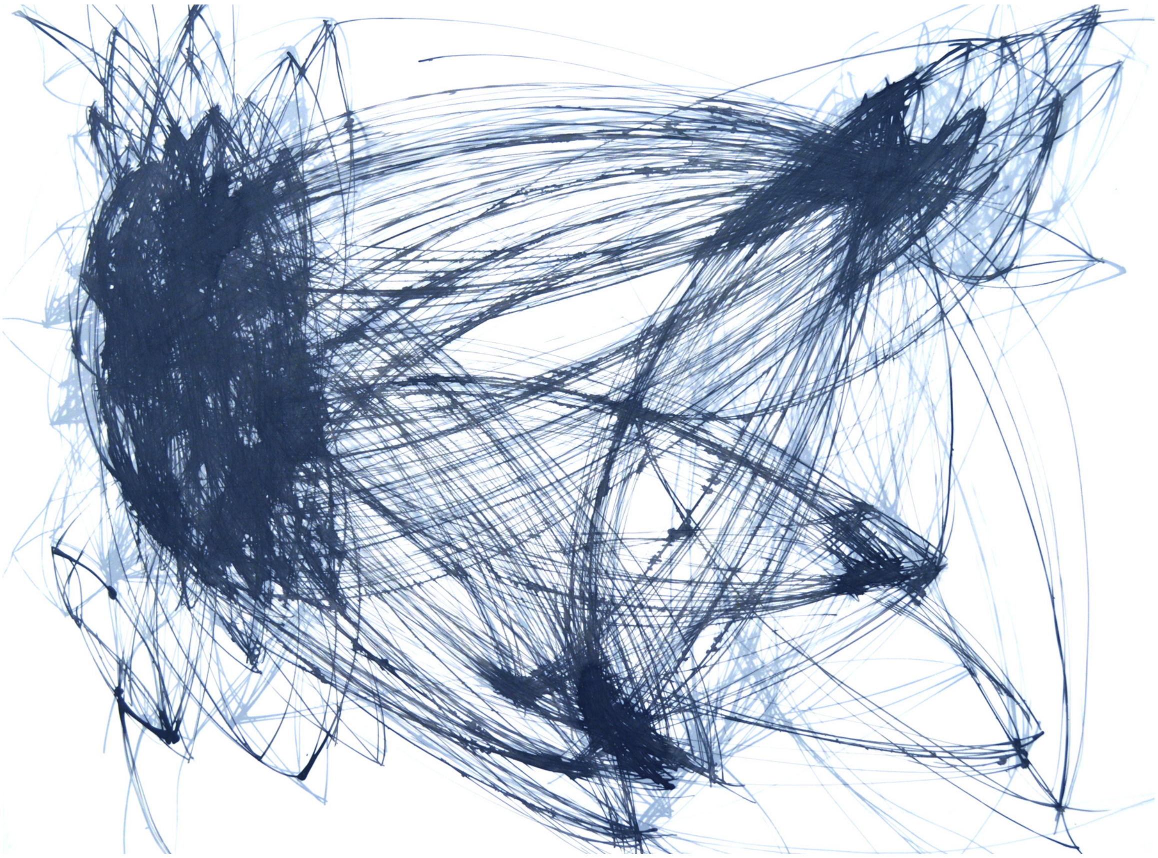


Gone Viral No. 1
Ink on drafting film
18" x 24"
2015

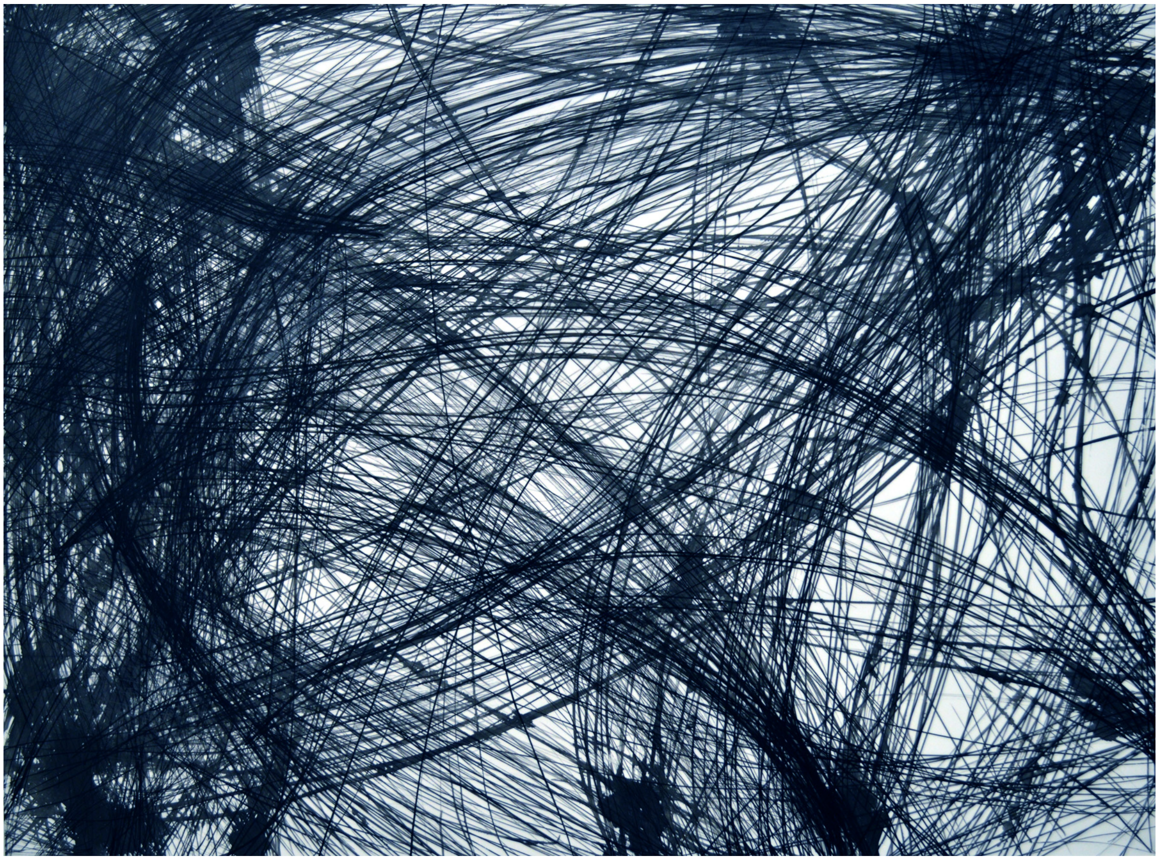
Gone Viral No. 2
Ink on drafting film
18" x 24"
2015



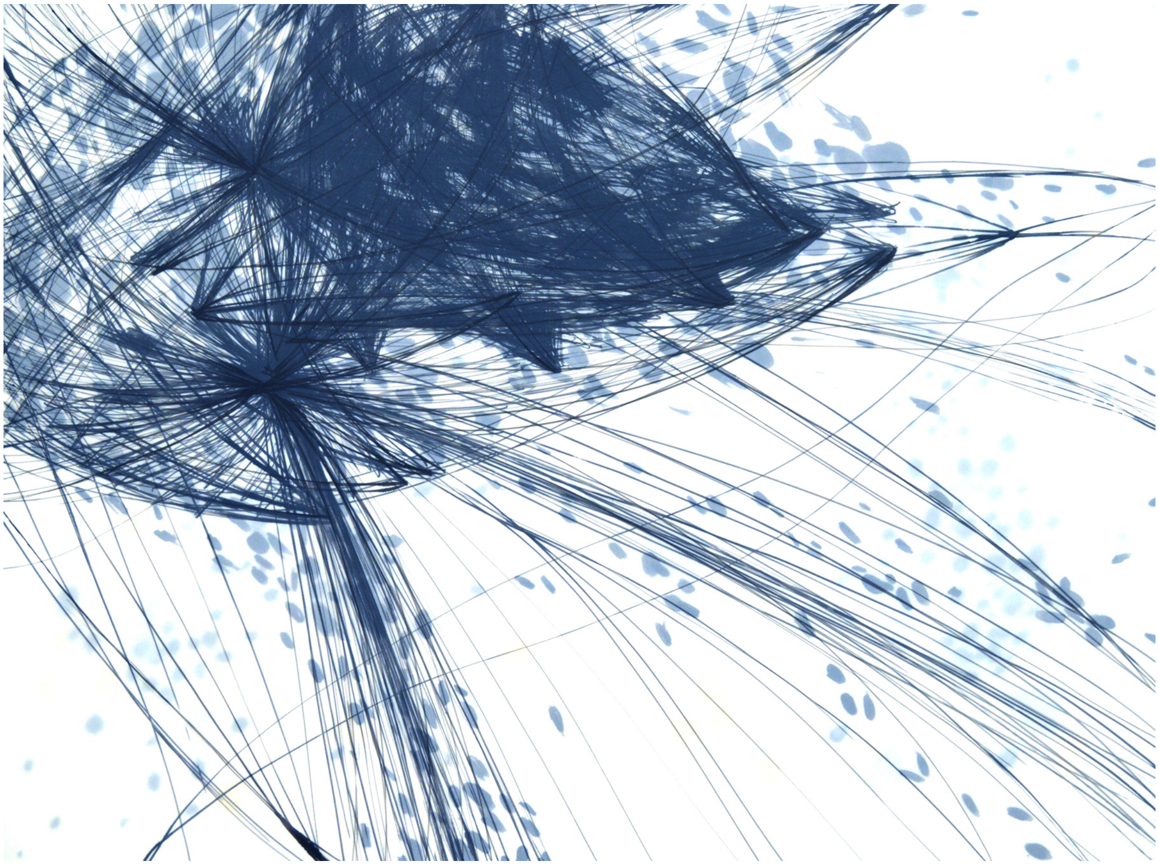
Gone Viral No. 3
Ink on drafting film
18" x 24"
2015



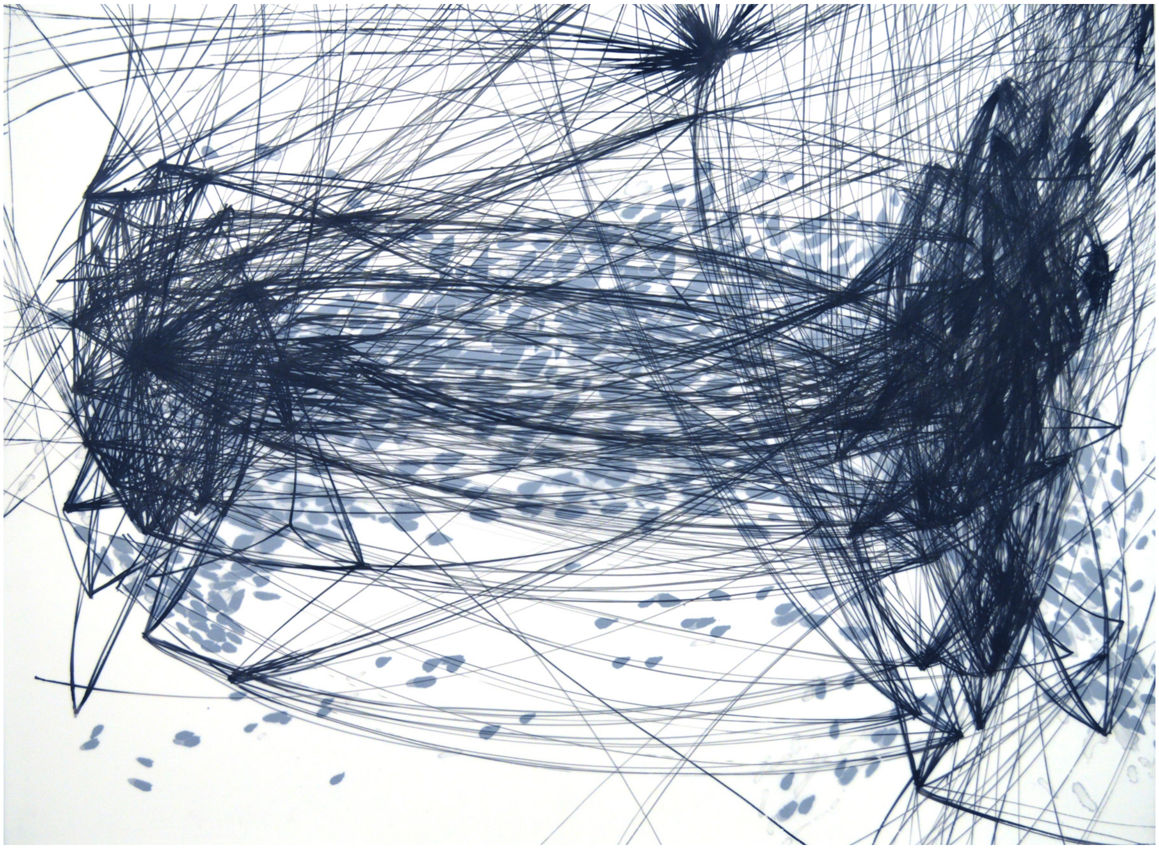
Gone Viral No. 4
Ink on drafting film
18" x 24"
2015



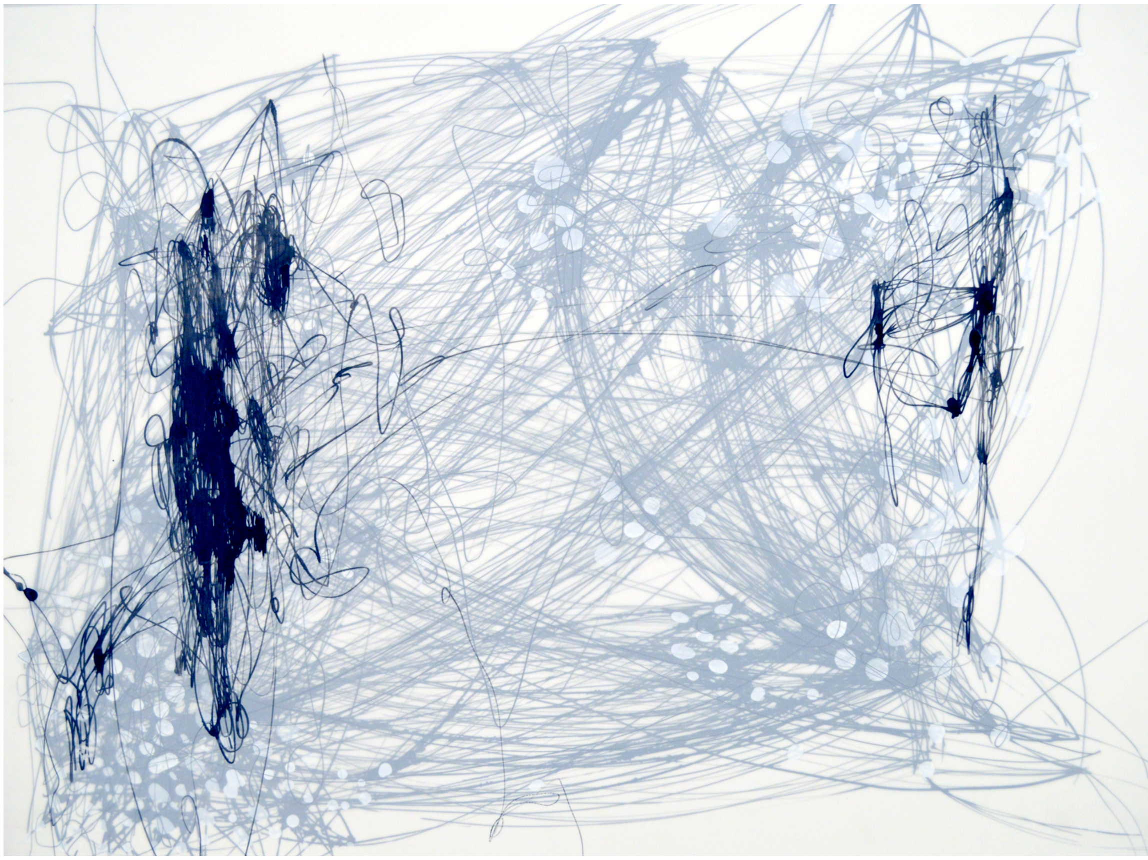
Gone Viral No. 5
Ink on drafting film
18" x 24"
2015



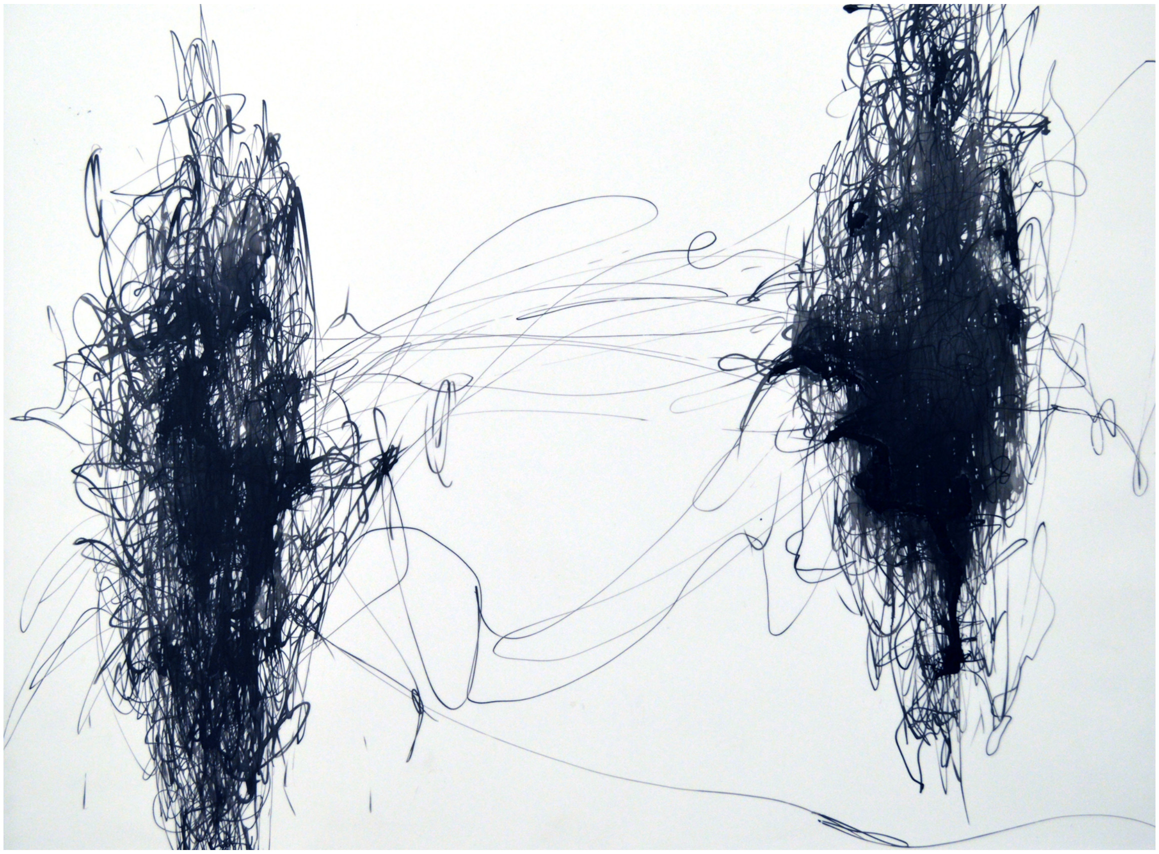
Gone Viral No. 6
Ink on drafting film
18" x 24"
2015



Gone Viral No. 7
Ink on drafting film
18" x 24"
2015



Gone Viral No. 8
Ink on drafting film
18" x 24"
2015



Gone Viral No. 9
Ink on drafting film
18" x 24"
2015