31 Global cities and infectious disease

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INTRODUCTION

Throughout history it may be said that cities have been global to some extent: they have always been provisioned from far-away places, they have always been refuge for scattered populations, they have always been centres of commerce and finance, geopolitical hubs, imperial(ist) way stations, (post)colonial *entrepôts* and melting pots of (multi)cultures. Notably, in recent decades, however, a number of major metropolises have increasingly transcended their respective national urban systems and have come to articulate their localized economic, demographic and sociocultural processes into a broader, globalized configuration of capitalism. Hierarchized, networked or otherwise tightly interconnected, these 'world-city node[s]' (Friedmann, 2002, p. 9) arguably constitute an important part of the global economic architecture that has emerged since the economic crises of the 1970s, most notably through what has since been described as the emergence (and crisis again) of neoliberalization, globalization and a shift from Fordism to post-Fordism. With these developments, urban regions have become increasingly tied into networks that make the globalizing economy material and recognizable (Friedmann and Wolff, 2006, p. 58). In this light, a remarkable and distinguishing feature of today's urban–global relationships is the nature and extent to which the 'global city' localities are intertwined with each other in a myriad of ways to create a new and unique type of networked topology that essentially serves as the backbone of an integrated world economy. It is within this emergent networked topology that critical defining features of global cities and their associated relationships may be found – features, as we shall see, that have significant implications for the spread of infectious diseases today.

A crucial element in understanding what makes today's cities 'global' is to recognize that global cities are constitutive of a complex, multi-scaled and topologically connected network space. That is, global cities should no longer be conceptualized as bounded entities that function in a relatively autonomous and independent manner like the walled cities of the past. Rather, today the borders between global cities are quite permeable, allowing flows of all sorts to tie together global cities in varied ways and over different scales, especially under political pressures for trade liberalization, privatization and deregulation. The resulting network of global cities that arises under such circumstances tends to be much more complex than in the past and it becomes difficult to parse out, delimit and compartmentalize the entering and exiting of flows of one global city to and from the next. That is, because of the increased volume and intensity of real time linkages that are an important dimension of contemporary globalization, we now have a situation where global cities, although they may be quite distant as measured through the traditional metric of physical distance, are in fact quite close together if measured through the network metric of connectivity (Smith, 2003). Global cities now merge into one another because of their networked flows in a topological space where the degree or intensity of connectivity and not physical distance matters in terms of defining the nature and types of relationships between global cities.

Although facilitating the relations upon which the global economy now depends, the emergence of this globalized networked topology does not necessarily translate into better conditions for all world citizens. This is because the global cities network is hierarchically segmented as certain globalized cities articulate national and regional economies into the world economy to a greater extent than others (i.e. there are variations in the level of connectivity of a particular place with the rest of the world), and by performing a bundle of certain functions and not others (based on the different needs of the different fractions of capital – finance, mercantile, cultural, retail, etc.), as is reminiscent of world-systems core–periphery conceptualizations. In this manner, global cities are not only networked but they are arranged somewhat hierarchically, as a function of overall wealth and influence as well as in terms of their level of connectivity.

Today, it is worth noting that while some global urban networks are tangible and material – as would be described by traditional core–periphery models – others are virtual, in turn depending on the maintenance of advanced information and communications infrastructures for their continued existence (Graham, 2006, p. 119). Consequently different types of unevenness and inequalities develop based on the degree to which particular global cities are integrated or connected into the world economy on the basis of their respective material and virtual levels of flow (e.g. capital, labour, information, etc.). Such inequalities are in essence manifested in terms of differential access to goods and services. The consequences of this are two-fold. First, such inequalities due to differential connectivity with the world economy may create notable sites of social polarization and differentiation *within* these cities themselves, and in so doing exacerbate social problems within them – especially under post-Fordism and neoliberalization, such as for example divisions between a 'creative class' and the traditional proletariat, or between globally mobile fractions of capital that jet-set across the world while staying in hotels where global city hospitality and tourism service workers labour to ensure that another – often overlooked – dimension of the global cities network is maintained (Major, 2008). At the same time, such inequalities arising from the inability to access and connect to the global flows which undergird the world economy may lead to inequalities *between* different regions of the world that are, in turn, based on the differential influence of particular global cities on the regional, national and global economy. Yet, besides the general recognition that each city's level and type of integration into the global city network and hierarchy may entail polarization, the other downsides of this connectivity have garnered little analytical attention. Neither the boosterist nor the dystopian literatures say much about the pitfalls that lie in the network itself, nor do they pay much attention to other than economic connectivity, such as those involving the social, ecological and technological connectivity. That is, we have no sustained understanding of the dangers and opportunities that lie in being networked *per se*. It is to issues of networked vulnerability that this chapter speaks: the relationship of systemic networked connectivity with new forms of vulnerability in the global city system. To illustrate such new types of relationships we draw from the experience of the outbreaks of Severe Acute Respiratory Syndrome (SARS) in 2003 as a point of reference – bearing in mind that our discussion is also relevant for many other types of contemporary disease spread, including for example HIV/AIDS and the resurgence of (multi-drug resistant) tuberculosis.

NETWORKS, CONNECTIVITY AND VULNERABILITY

According to a networked approach, cities may be thought of as nodes that are connected to each other, either directly or indirectly, through various types of flows, such as: information bytes, the migration patterns of people, the trade in commodities, the flow of money in transactions, the flights of airplanes or the movement of viruses. By conceptualizing the relationships between cities in this way we can draw upon insights from the new and emerging interdisciplinary field of 'network science' (Buchanan, 2002; Barabasi, 2003; Watts, 2003). Research on networks and complexity has found that systems based on networked connections share certain defining characteristics, including: the systems' ability to self-organize (i.e. ability to adapt to local environmental circumstances and change), upheavals at the edge of chaos (such as cascades that occur once critical threshold tipping points are exceeded), the existence of feedback loops and, most importantly for our discussions, nonlinearity, that is, the idea that very small changes in the systems may have unpredictably large effects (Pearce and Merletti, 2006) – a phenomenon commonly referred to as the 'butterfly effect' in chaos theory where small differences in the initial conditions of a dynamical system produce large variations in the long-term behaviour of the system. If the connections amongst global cities do indeed lead to the formation of a hierarchical and segmented network, as noted by global city theorists, then some of the properties identified by complexity researchers will be useful for our understanding of how networked connectivity (i.e. interconnectivity) between global cities is related to infectious disease vulnerability.

The advantages of any network stem from its ability to effectively link up different elements, so that whatever flows through the links is able to efficiently go from any one node to another. In this light, much research in network science has focused on the network architecture – that is, the particular configuration through which nodes are linked[1] and how this influences the degree to which the nodes are linked together (i.e. their level of connectivity), thereby giving some indication of how efficiently the network operates in terms of transmitting flows. For many networks of interest to social scientists, the nodes are usually defined as individual persons and the links between these persons may take the form of ideas, such as the spread of rumours amongst a group of people at a party, or the adoption of a new technological gadget (e.g. fax machines, cell phones, etc.) in a population. Other human-based social networks that have been studied involve collaborations between scientists (that may be charted through citation indexes that reveal the co-authors of a given paper), the interlocking networks of the directors that sit on different boards of companies, and the network of Hollywood actors – as popularized by the 'Six Degrees of Kevin Bacon' game in which the challenge is to link any actor through his/her roles in movies to the actor Kevin Bacon within six linkages (i.e. two actors working in the same movie represent one link). Also studied have been various human-made networks such as the World Wide Web and infrastructure networks such as the electrical grid, sewage systems and the airport system (Buchanan, 2002; Barabasi, 2003; Watts, 2003).

A fundamental aspect of most networks is the role that hubs play in their maintenance. Hubs are essentially connector nodes that have an anomalously large number of links. As a result of the large number of connections that are made through them, the functioning of the overall network is very dependent on the proper functioning of hubs. In essence, through their connection to an unusually large number of nodes, hubs serve a critically important function in network operation by effectively creating shorter paths between any two nodes in the system, thereby increasing the efficiency of the flows that channel through the network. An important corollary of this dependency relation, however, is that the failure of a hub may lead to a crippling of the network. That is, since the contribution of a hub to the overall functioning of the network is much greater than that of other smaller nodes, the failure of the hub node will have a much more devastating effect on the proper overall functioning of the network. By the same token, the malfunctioning of smaller nodes in the network will have very little effect on the overall network functioning because their contribution to the overall integrity of the network is much less. Studies have found that in most real world networks in both the natural and social world, the number of smaller nodes far outnumber the hubs, and as a consequence, there is a greater likelihood that a smaller node rather than a hub will fail at any given time (all other factors being equal of course). This means that although a lot of smaller nodes may fail, this will not necessarily lead to overall network failure because the network will be able to compensate by developing alternative links/pathways/connectivities to keep the flows going. For example, in a roadway network a minor traffic mishap may force cars to follow alternative routes without necessarily leading to problems everywhere in the roadway network. Sometimes failure will however cascade and resonate throughout the network system. Why such catastrophic failure occurs on certain occasions and not others and how precisely it cascades through the system depend on the architecture of the network, particularly the ratio of highly connected to less well connected nodes (Graham, 2010; Little, 2010).

The type of network arrangement that we have been referring to thus far, that is, those consisting of a large number of smaller nodes with much fewer hubs, are known as scale-free networks (Barabasi, 2003). The natural advantage of scale-free networks is their ability to withstand complete network breakdown due to random failures – a property referred to as the robustness or resilience of the network. This type of resiliency however may be offset by the Achilles heel of the scale-free network alluded to above, namely the network's dependency on hubs. Thus although hubs contribute to flow efficiency within the network, thereby strengthening the integrity of the overall network, they also represent points of vulnerability, since failure of hubs will more likely lead to overall network failure. Thus non-random or deliberate targeting of hubs (such as through sabotage) will increase the likelihood of network collapse.

Another fundamental characteristic of scale-free networks is that they exhibit what is known as the 'small world' property (Barabasi, 2003; Watts, 2003). The term is used in the same sense as in situations where we are surprised to learn that a complete stranger we have just met knows someone that we know, at which time we declare 'wow, what a small world we live in'. Mathematically it has been proven that we are indeed linked to anyone else in the world through a maximum of six common acquaintances (Barabasi, 2003; Watts, 2003). On a more general level, applicable to all scale-free networks, mathematical work has proven that what accounts for making worlds small is the presence of long-range links that serve as crucial shortcuts that drastically shorten the average separation between nodes (Barabasi, 2003, p. 45). In today's interconnected world, it is clear that global city hubs serve as the facilitating mechanism for long-range linkages between all parts of the world. Let us now consider in more detail some of the implications of these characteristics of networks for understanding the relationship between infectious disease spread and global cities.

THE GLOBAL CITIES NETWORK AND VULNERABILITY TO INFECTIOUS DISEASE: THE CASE OF SARS

From a conventional epidemiological perspective, the nodes of the network in which a given disease spreads consist of individuals, and the links are the physical contacts. Physical contact links, in turn, need to be defined with reference to the contextually embedded characteristics of the disease in question, and will vary according to the specific factors involved: for example, physical proximity (i.e. the sharing of common space), level of intimate contact (i.e. conversation, sexual relations) or some other form of interaction (such as the sharing of needles); as well as the capability of the pathogen to survive in the physical environment for prolonged periods. Getting an idea about the specific connectivity between people is of great importance in epidemiological investigations and responses to outbreaks, and much attention and resources are directed by public health officials towards activities related to contact tracing. It is on the basis of contact tracing that social distancing strategies such as quarantine and isolation are adopted to break the chain of disease transmission. It will be argued now that such epidemiological orientations may benefit from a broader approach that takes into account some basic principles of global cities and network theory. It should be noted at this point that our approach to the application of network theory is based on a more broadened orientation that is intended to be much more sensitive to context, that is, the political and social dimensions of the settings in which networks operate, rather than more narrowly defined mathematical analyses that have thus far dominated network analyses. As we shall see, the ability to contain (or facilitate) the flow of infectious diseases within human networks will vary according to contextual factors, not the least of which include other networks – that is, *human-made* networks, such as information and communication infrastructures and political organizations.

The spread of SARS through the global cities network began at the Metropole Hotel in Hong Kong, where a physician from Ghuangzhou infected with the disease was staying in February 2003. From here the virus spread to 11 hotel guests who continued their respective travels to various cities around the world, including Toronto, Singapore, Taipei, and Hanoi, and to other parts of Hong Kong (Abraham, 2004). The exact mode of transmission in the Metropole Hotel has not been conclusively determined as some of the guests who became infected may not have had direct contact with the index case. The prevailing theories propose that the virus contaminated an elevator or travelled through the ventilation system (NACSPH, 2003). Such suspicions would be in line with another phenomenon observed during the SARS outbreaks, namely the phenomenon of 'superspreader', where an individual exhibits an unusually high tendency to infect others, possibly because of the production of higher viral loads or a greater amount of respiratory secretions that may linger in the surroundings (Centers for Disease Control and Prevention, 2003).

In considering the international spread of SARS, it was clear that a networked infection was involved with global cities serving as hub-nodes that were linked together through air travel (Ali and Keil, 2006, 2008; Bowen and Laroe, 2006). Indeed, it was on the basis of this implicit recognition that the World Health Organization (WHO) 'regard[ed] every country with an international airport, or bordering an area having recent local transmission, as a potential risk for an outbreak' (cited by Gostin et al., 2003, p. 3231). And it was also partly on this basis that the WHO, violating the long-standing Westphalian-based governance principle that public health actions should not interfere with international commerce, issued travel advisories to SARS-affected areas, thereby resulting in significant economic repercussions for those areas.

A question that arises in understanding the spread of SARS as a reflection of the network of global cities is why it was that certain global cities such as Toronto, Singapore and Hong Kong were affected while other more major hub global cities such as Tokyo, New York and London were not? The answer to this question lies in considering the human-based capillary networks that lie within each particular global city itself. Such capillary networks are quite unique and hard to capture because they reflect the diversity of human experience and individuality involved in their constitution. This diversity can be seen by comparing, for example, the social contact networks of the spread of SARS in Vancouver versus Toronto (Meyers et al., 2005). In Vancouver, the SARS patient zero returned from the Metropole Hotel with his wife to an empty abode, and was almost immediately hospitalized thereafter. In Toronto, the SARS patient zero, returning from the same epicentre Hong Kong hotel, was the matriarch of a large extended, multi-generational family who died at home as an unrecognized case of SARS (Meyers et al., 2005). Subsequently ten members of her family were infected, which in turn led to a chain of transmission involving 200 cases, including health care workers, patients and their families. These two very different situations highlight the fact that spread of disease requires the simultaneous consideration of two distinct kinds of structure – social structure and network structure (Watts, 2003, p. 116). According to Watts, a key notion in understanding the relationship between the two is the idea of affiliation network (2003, p. 118). Two nodes may be said to be affiliated if they participate in the same group or context. Thus we return to the important consideration of context in the spread of disease. The context for a given phenomenon may be conceptualized in many ways; the challenge is to identify the most salient for the particular phenomenon under study. And for the spread of SARS it was clear that the global cities context was important in network terms because global cities tend to form affiliation clusters based on various shared characteristics, including economic interests and migration settlement patterns of diaspora communities (Ali and Keil, 2006), such as, for instance, the affiliation network of Hong Kong and Toronto.[2]

Another dimension of context that is sometimes neglected is the role of various infrastructures, such as information, air travel and hospital infrastructures, in containing or channelling the flow of infectious diseases both within and between global cities. The maintenance and operation of such infrastructures, it is important to note, are influenced in significant ways by political (e.g. neoliberal) and cultural factors which inform the context in which disease spread takes place (Sanford and Ali, 2005; Salehi and Ali, 2006; Keil and Ali, 2007; Hooker and Ali, 2009). We will briefly turn to such considerations below, noting that fuller accounts are given elsewhere – see, for example, the following in relation to SARS and information, airport and hospital infrastructures, respectively: Ali (2009); Ali and Keil (2010); Ali and Keil (2009).

NETWORKS AND THE RESPONSE TO SARS

Prior to its global spread, the initial outbreaks of SARS occurred in various cities within Southern China over a period of several weeks starting from November 2002. The full extent of the burgeoning pandemic was not known to the global public health community during these early stages because the Chinese national government did not make any public announcements concerning the outbreaks (Saich, 2006). Indeed, under Chinese law, epidemics were defined as state secrets, thus barring local public health officials from commenting on the outbreaks until permission to do so was granted by national authorities. But this permission was not forthcoming for various political reasons, not the least of which related to fears that news of the outbreaks would disrupt the recent leadership transition occurring in the Chinese government at the time (Saich, 2006). Such nondisclosure actions were later interpreted as part of a systematic cover-up and denial concerning the extent of the outbreaks on the part of the Chinese government; actions which subsequently received admonishment from the global public health community and the WHO (Eckholm, 2006). Information about the outbreak nevertheless spread throughout the country and to the outside world through alternative channels as messages were exchanged via new technologies such as cell phones and the Internet (Heymann, 2006). What is noteworthy about these developments is that they illustrate the self-adaptive quality of networks. In the pre-Internet era, information flows could be more tightly controlled by local and national government agencies, as these would serve as hub nodes that formed the backbone of the information network. With the explosion of the Internet, the number of nodes and linkages likewise exploded, as anyone possessing Internet or cell phone technologies would now be nodes in an expanding network of newly possible, and previously unavailable, linkages. Thus the conveying of information through the network no longer depended on government hubs, as information flows between nodes could circumvent these hub nodes. What this meant was that the citizenry no longer had to rely on official government channels to receive information.

Recent changes in the architecture of the information network also had dramatic implications for surveillance and response by the global public health community. Most notably, knowledge of disease outbreaks could no longer be solely contained to and by the particular nation state affected. Previously, the WHO had to rely on outbreak information that was forwarded to them through official channels, namely from nation state governments. Disease outbreak information from non-governmental sources, if available at all, would not be considered. The WHO response to SARS illustrates how new types of networked relations have changed the way surveillance and response now take place. In the year 2000, the WHO recognized the potential for other source nodes of outbreak information to be accessed. In this light, the WHO established the Global Outbreak Alert and Response Network (GOARN) – a network of 120 partners (including national government agencies and scientific institutions having expertise in infectious disease) located across the world (Levy and Fischetti, 2003, p. 7). One of GOARN's members was the Health Canada based Global Public Health Information Network (GPHIN), a computer application that continuously and systematically trawls web sites, news wires, local online newspapers, public health e-mail services and electronic discussion groups in six languages (English, French, Spanish, Russian, Arabic and Chinese) for reports of infectious disease outbreaks using key words or phrases (Heymann, 2006, p. 350). And it was GPHIN that first alerted the WHO about suspected outbreaks of 'atypical pneumonia' in Southern China in late November 2002, which in turn served as the impetus for the subsequent requests by the WHO for information about the suspected outbreak from China on 5 and 11 December 2002 (Heymann, 2006).

Another information network of great significance in the SARS outbreak response was the network of scientists. Again, due to the introduction of new communications and information, laboratory scientists from around the world temporarily put aside their competitive interests in order to link up in virtual networks whereby satellite broadcasts, teleconferencing and Webcasts were used to share laboratory results (Levy and Fischetti, 2003, p. 14). It was on the basis of this rapid real-time information sharing and analyses that the viral agent and its genetic code were identified in the unprecedented span of several weeks (as opposed to the past experiences of at least several months) (Levy and Fischetti, 2003) – one of the greatest successes of the global outbreak response (Ali, 2008).

It is important to note that just as the global response to the spread of SARS was based on the spread of information through networks and was influenced by various domestic and international political and cultural machinations, so too was the local response within the global city. Consider for example the particular nature and functioning of local public health infrastructures in each global city and how this differed in comparing the Toronto, Hong Kong and Singapore contexts.[3] Toronto and Hong Kong experienced similar problems in their respective public health response to SARS. Many of the problems both cities faced involved information handling and communication difficulties. In the case of Toronto, such difficulties arose from the cumulative neoliberal-inspired disassembly of the public health infrastructure, especially in relation to a lack of investment in updating the computer platform required to share epidemiological data required to trace the contact pattern involved in the disease diffusion. This was coupled with a seriously inadequate level of surge capacity that resulted from recently imposed cost saving efforts to decrease the personnel involved in public health and the specialization of infectious diseases, as well as through the continual casualization of the nursing profession in Ontario (Affonso et al., 2004; Ali and Keil, 2009). In Hong Kong, the terse political relationship between the central government in China and the local government in Hong Kong led to a level of distrust and bureaucratic wrangling that severely hindered an effective and coordinated response to SARS (Ng, 2008). In contrast, the Singapore government's response was praised by the WHO for its high level of effectiveness (Teo et al., 2008). The successful Singapore response to SARS has been attributed to a uniquely defined global-city state governance style based on an unusual mix of authoritarianism and paternalism. That is, a governance style that arose from the particular historical and colonial circumstances of the island nation resulting in a strong emphasis on protection from outside threats (e.g. Britain, Malaysia). This was coupled with the development of an efficient bureaucratic organization based on an urban-national structure in which resources could be readily mobilized and deployed in response to emergencies such as disease outbreaks due to a lack of a provincial or middle layer of bureaucracy (Teo et al., 2008).

CONCLUSION

To understand the contemporary spread of infectious diseases requires an understanding of the uniquely interconnected nature of the globalized world in which we live. We have argued that the recent work on network analysis and its application to global-city theory is particularly well suited to this task. Pathogens spread through social networks of people, while the strategies used to combat their spread involve other types of network, such as the information networks we have discussed in this chapter. What is often missing from the analysis of networks and disease spread is the consideration of the context in which social and information networks implicated in the spread and response to infectious disease are embedded. It is in addressing this deficiency that the work of global cities researchers becomes paramount. Interestingly, the context in which social and information networks operate is situated or embedded within a network itself – the global cities network. Not only that, but each global city itself forms a complex capillary network of its own, and in turn is linked to other global cities networks through various flows, including, as the SARS experience has dramatically revealed – flows of pathogens. We are therefore dealing with a situation of embedded and cross-cutting networks, leading to a folding of time and space and therefore a new topology in which the degree of connectivity rather than distance is increasingly becoming the defining characteristic of not only the relationships between global cities, but the relationship between global cities and disease. For example, the spread of SARS has revealed how vulnerability to infectious disease is one consequence of the development of a 'small world' due to the connectivity of global cities through various flows, the most obvious of which is air travel. Not recognizing the developments and dynamics of modern networks is to ignore two major insights of the science of networks as related to life in our connected age. First, as Duncan Watts (2003, p. 301) notes, 'we may all have our own burdens, but like it or not, we must bear each other's burdens as well'. Secondly, the recognition that, in complex networks, cause and effect are often related in a complicated and quite misleading way. Consequently, at times small changes may have major implications, while at other moments major shocks can be absorbed with remarkably little disruption (Watts, 2003). The outbreak of SARS in the global cities network revealed both aspects. Thus, we see, for example, how the stay of only one individual at a particular global city hotel led to the international spread of a disease, while the potential disruption was far less than it could have been because of the international public health response facilitated by the rise of new types of extensive information sharing networks made possible by recent technological advancements in communications. What should not be forgotten, however, is that the (relatively) effective response that we saw in the case of SARS occurred because the disease affected those global cities that had in place the advanced technologies required to collect and share epidemiological and clinical information – at least to some level of adequacy. These global cities were well connected with the global flows of information; other global cities, however, especially the megacities of the Global South, may not be so well connected to the flows running through the developed world's global city network. Their ability to respond effectively to infectious disease spread will therefore be limited. Remembering however that in a 'small world' all nodes are connected to each other through a surprisingly small number of connections, the vulnerability of a major Global South city renders the whole global city network vulnerable to disease spread. This situation of networked vulnerability is exacerbated by the global inequalities resulting from the broader social and political forces that drove the emergence of the global cities network in the first place – namely colonialism, neoliberalization, post-Fordism – which, somewhat ironically, constrain the very nature of the networks involved in the public health response to the spread of infectious disease in the contemporary era.

NOTES

1. Some examples of how nodes can be linked together (referred to as network topologies) include: a star shape where each node is linked to a central hub; a line model where nodes are linked to each other in a linear sequence; and nodes that have multiple linkages to each other forming a mesh.
2. See Keil and Ali (2008) for further elaboration on the implications of the connections of global city diaspora communities to issues of 'othering' and the racialization of disease in the context of Canadian multiculturalism.
3. For a full account of the SARS response in these three global cities, see Ali and Keil (2008).

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