Perspective

Welcome to the revolution: COVID-19 and the democratization of spatial-temporal data

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THE BIGGER PICTURE   Availability of data during the current pandemic has been facilitated by open access databases summarized in dashboard maps, tables, and charts. This provided an unprecedented opportunity for not only academic research but popular reportage. Dashboard data have increasingly been joined to demographic data provided by census and other digitally stored socioeconomic data in a manner permitting journalists and researchers to analyze local and regional outbreaks and the demographics that have propelled specific outbreaks. This democratization has permitted unprecedented public exposure to the realities of the pandemic, and its propellants, at every scale. In the future, the likelihood is that the type of deep investigation of an epidemic or pandemic will be as much a matter of journalistic examination as it has been, in the past, of professional research. What once took perhaps a year for analysis and journal publication is now occurring over weeks of public analysis. The effect has been immense on the public presentation of pandemic news and the realities of local outbreaks. Its focus on socioeconomic forces encouraging intense local outbreaks—for example, in long-term facilities—are arguments for political focus on structural failures in the social safety net. This is revolutionary and … evolutionary. It is the newest phase of a "digital revolution" begun in the 1960s and a long history in public health explorations of disease events and the socioeconomic sources that propel them. For the latter, books like my *Cartographies of Disease: Maps, Mapping and Medicine* or *Disease Maps: Epidemics on the Ground* attempt to both trace the history of epidemics through their mapping and public data from yellow fever (in the 18th century) and cholera (in the 19th century) through this century's Ebola epidemic in West Africa.

1 2 3 4 5   **Mainstream: Data science output is well understood and (nearly) universally adopted**

SUMMARY

On January 22, 2020, Johns Hopkins University launched its online COVID-19 dashboard to track in real time what began in December as the regional outbreak of a novel coronavirus first identified in Wuhan, China. The dashboard and its format were quickly adopted by other organizations, making global, national, and regional data on the pandemic available to all. The wealth of data freely offered in this way was collected by syndromic programs whose precise algorithms search official and popular sources for data on COVID-19 and other diseases. The dashboard signals a new phase in the maturation of the "digital revolution" from paper resources and, in their popular employ, a "democratizion" of data and their presentation. This perspective thus uses the COVID-19 experience as an example of the effect of this digital revolution on both expert and popular audiences. Understanding it permits a broader perspective on not simply the pandemic but also the cultural and socioeconomic context in which it has occurred.

INTRODUCTION

Revolutions are funny things. They seem to appear out of nowhere, changing everything. Afterward, we think, nothing will be the same. But with a bit of time and thought it becomes clear that revolutions are rarely the beginning of something new but instead the conclusion of event processes long in the making.

Every revolution stands as a point in an evolutionary progression, a radical change with antecedents. Here, the dashboards and maps of COVID-19 are presented as just such a revolution, one in which both public access and comment were transformed by the increased accessibility of global, national, and regional data in a digital format that is comprehensible and available to all.
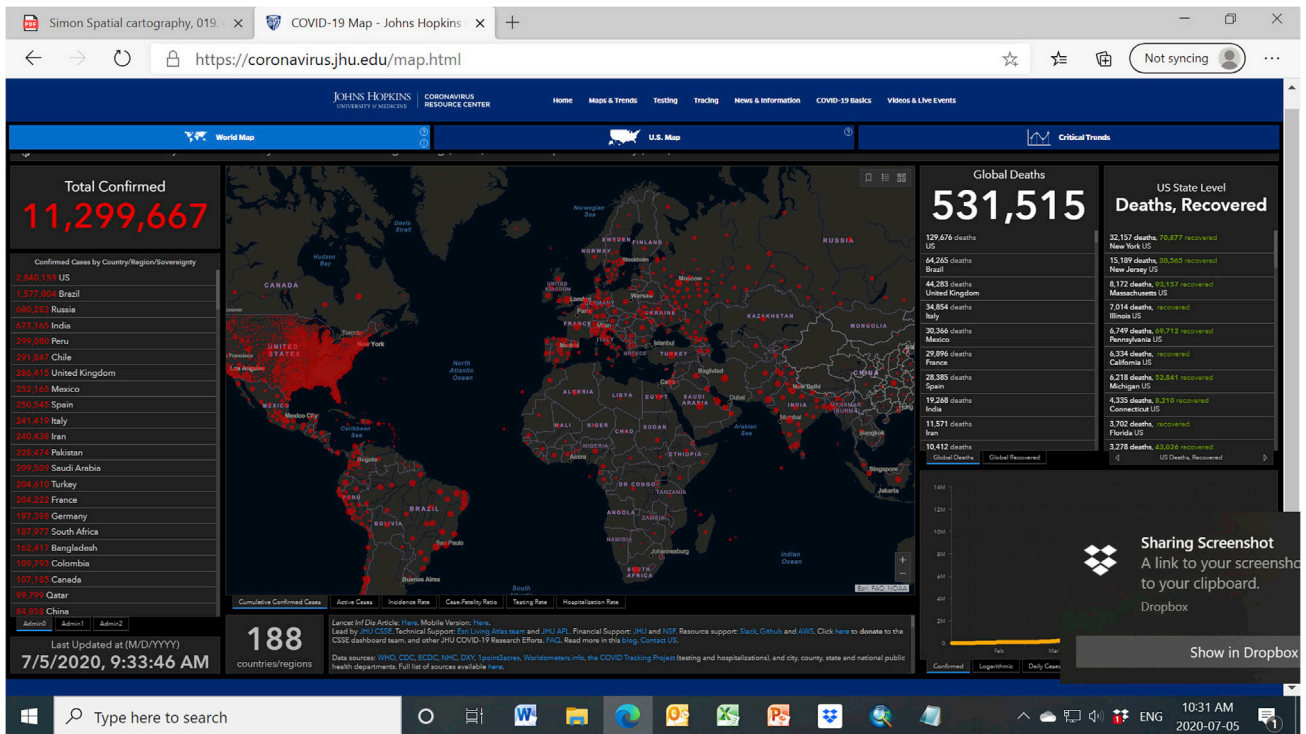
Figure 1. Johns Hopkins dashboard
From its early incarnation in January 2020, the Johns Hopkins dashboard evolved into a global and regional database. While a scalable dot map is its centerpiece, it can be modified by the different data types listed below the map. Changes of focus, resolution, and scale will also change the data tables and charts included on the page.

On January 22, 2020, Johns Hopkins University launched its online COVID-19 dashboard to track in real time what began as a regional outbreak of a novel coronavirus first identified in Wuhan, China. Figure 1 is the general view, and Figure 7 gives a specific portrait of early expansion in China.[1] Designed by the Johns Hopkins Center for Systems Science and Engineering, by late February the dashboard was reporting more than 70,000 confirmed cases across 28 countries and regions. As the virus's reach expanded geographically so, too, did the dashboard. What began as a "centralized repository of individual-level information on patients with laboratory-confirmed COVID-19" became a publicly accessible, universally trusted, truly global database.[2]

The Johns Hopkins dashboard evolved to offer data at two distinct scales and resolutions. The first was global and the second national with data, where available, on state or provincial incidence in various countries and especially the US.[1] As it matured, data presented was parsed into different categories including the total number of active cases per region or nation; case fatality ratios; and in some cases the number of tests performed and hospitalization rates for a city, county, or region.

For the first time in history everyone had immediate access to continually updated, expansive details of a dynamic pandemic's progress. While downloadable datasets and maps of disease had been previously available—for example, during the 2014 West African Ebola epidemic—the global scale of these dashboards and their daily updating was unique. The result defined the truly pandemic nature of the global pandemic and invited the engagement of people everywhere to consider its effect in their home and nation in relation to the virus's effect internationally. Finally, because the data used in maps and carts was available for download it gave unprecedented popular access to evolving data, inviting its use by journalists and researchers in new and imaginative ways.

Here, dashboards like that of Johns Hopkins are considered both in their own right and as springboards that encouraged similar public presentations of pandemic data, and its effects at national, regional and county levels. These new resources are part of a far longer history of epidemic and pandemic data collection and distribution. The goal, here, is to both review the effect of the dashboards on public data, explore their methods of data collection, and describe the broader effect of the international dashboard on local and regional public investigation into local and regional epidemic experiences.

Datasets on disease occurrence had been available before but never at this scale and potential for further popular exploration. This democratization expanded to all what had previously often been typically restricted to specific researchers and officials. In doing so it expanded the ability of journalists to investigate not only the progress of the disease but elements propelling infection in their own jurisdictions. All this was enabled by systems of automatic digital data collection and dissemination in a manner encouraging analyses including census and other data in stories on the pandemic at global, regional, and local scales of interest.
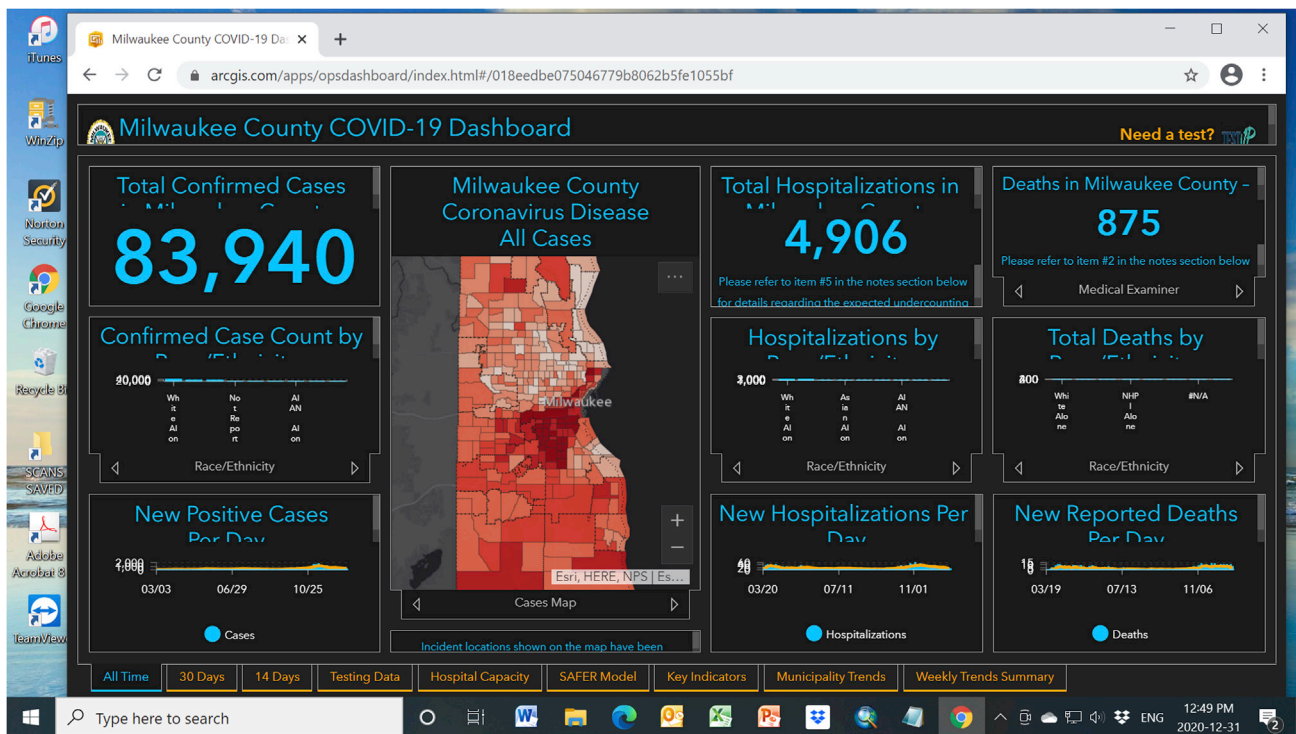
Figure 2. Map Milwaukee County
This dashboard for Milwaukee County, WI, is an example of the manner in which the Johns Hopkins dashboard format was adopted by a number of local or regional jurisdictions. The local focus requires different data categories, such as hospital capacity.

The centerpiece of dashboards were maps of viral activity at once locating and tallying confirmed infections (and resulting deaths) surrounded by charts, graphs, and tables detailing data summarized in the cartographic portrait.[3] Dashboard mapping presented an intuitively easy summary of data then broken down in the tables and charts that framed the maps. The world map can be localized by clicking on a specific country for a national focus with regionally specific data. Day by day, these "pandemic cartographies" posted the extent of the pandemic's progress and, at national or greater scales, the degree of local viral engagement.[4] The dashboards, day by day, thus served both as independent statements of viral activity and as a data source available for download that could be localized.

This *was* revolutionary, a summary of viral activity that could be instantly and intuitively grasped by average persons. No wonder, then, that the Johns Hopkins dashboard was posted daily, in part or its entirety, in newspapers and on television broadcast programs around the world. The general format was adopted (and adapted) quickly by other institutions, public and private. On January 26, for example, the World Health Organization (WHO) posted its own dashboard similarly replete with map and tables of data on laboratory-confirmed cases worldwide.[5] ESRI, which pioneered the idea of dashboards mixing cartographic and statistical data, soon had its own automated COVID-19 resource online.[6]

Others focused on national (for instance, Canadian)[7] or more regional scales of data. Most, like Ourworldindata.org, similarly included downloadable data as well as charts, maps, tables, and data source lists informing the COVID-19-related map.[8]

The New York Times offered public access[9] to its databases on Github.[10] Its data included county-level US data, a resource quickly adopted by epidemiologists, medical professionals, local government officials, and many US newspapers.[11] Some provinces, states, and counties (Figure 2) in Canada and the US published their own, localized dashboards with data similarly updated daily.

"Democratization"

I describe the expansion of the dashboard medium as both revolutionary—a break with the past—and "democratizing." Colloquially, democratization describes a process or activity previously to be restricted to an elite or privileged group that becomes available to a wider audience and potentially to all.[12] Democratizing programs thus remove or at least diminish traditional barriers separating the resources of "elites"—academics and bureaucrats—and the general public. Here, it describes an expansion of epidemiologic data that previously would have been unavailable to most. Some call this a "neogeography" in which control over the production and use of spatial data shifts from a handful of experts to large groups of users who may choose to employ it in new ways.[13]

The result is not "libertarian," radically individual—a term some apply to many online resources[14]—but populous in its universal, public presentation of data on both the progress of COVID-19 and, at some resolutions, the socioeconomic factors (housing density, income inequality, etc.) that have propelled its progress. This occurs at three levels unique to the modern digital environment of today. First, the replication of dashboards and
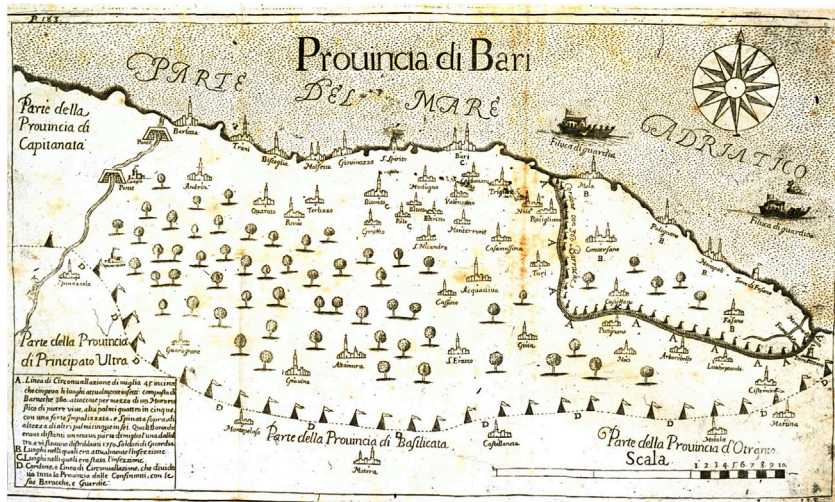
their use in broadcast and print media make evolving pandemic data available to all. Second, the universal data cache can be downloaded, providing a free source of previously restricted data to any with even modest expertise in mapping and statistics. Finally, the data are so ordered that they can be efficiently joined to material from other digital sources to craft cartographic, statistical, and textual arguments beyond the limited focus of data available on the dashboards alone.

From print to digital

Like most revolutions, this one is a new point in a long history of change and evolution. From the 1600s into the 18th century, data on disease incidence was typically collected only by and for officials charged with organizing a governmental response to a local or regional epidemic. Primarily descriptive, these were administrative documents detailing the incidence of pandemic deaths, the dispersal of troops to enforce quarantines and identify necessities for care—the location of lazarettos, for example—in provincial cities and towns.[15] Among those that survive perhaps the most notable and complete is a 1691 report by Filipe Arrieta, royal auditor and military governor of the province of Bari, Italy.[16] In the text he described, and mapped, a comprehensive, multistage containment program with quarantine zones created not only at provincial boundaries (including a maritime embargo) but also within the province around cities where plague was active (to stop disease spread) as well as isolating other cites that had yet to experience an outbreak (limiting the likelihood of plague's introduction) (Figure 3).

Few maps or reports from this era survive. They were administrative in nature and not publicly available in the early days of the print revolution. Advances in print technologies through the late 18th century permitted researchers to present disease-related studies, including maps, in the then new media of medical journals. This enabled a new kind of "scientific" study in which disease incidence was associated with environmental factors presumed to promote local outbreaks. Among the first examples was Valentine Seaman's 1798 study of yellow fever in New York City.[17]

Published in the *Medical Repository*, the first clinical journal in the US, Seaman mapped a select number of yellow fever cases in one copperplate map and, in another, posted a set of odorous human and animal waste sites.[18] The apparent proximity of cases to waste sites served, he believed, as proof of the miasmatic origins of the outbreak. That, in turn, argued for urban sanitation measures to prevent future outbreaks. As a physician and member of the New York Health Committee, a forerunner of the New York Board of Health, Seaman acknowledged that, while he knew of more cases, copperplate printing technology was limited in what could be graphically presented. Still, the publication of this kind of data—maps and tables—in professional journals widened the potential discourse on disease events.

Both mapping and printing technologies improved rapidly in the 19th century as the era of mercantilism gave way to industrialism and the rise of the modern city. At the same time, the collection of economic and social data became an increasingly important governmental priority.[19] Newly constituted local and regional boards of health collected disease-related data to formulate responses to health emergencies. Those data were typically shared with regional and national health officials to enable regional or national print datasets. For their part, foreign representatives serving in affected nations would, where possible, obtain and then transmit the resulting reports to their respective governments. By 1831, writers in the British journal *The Lancet* could proudly proclaim more than 1,000 data points in their map of the global incidence of cholera from its first appearance in India in 1818 to its 1831 arrival in Sunderland, a city at the mouth of the River Wear, 10 miles south-east of the city of Newcastle-upon-Tyne (Figure 4).[20]

By the mid-19th century, medical cartography accompanied by elementary health statistics analyzing the mapped data had become commonplace in official reports on disease incidence. Researchers studied not only incidence but also the pathways of disease spread, and, in some cases, the socioeconomic realities contributing to intense pockets of infectious incidence. Edwin Chadwick's map of the location of infectious disease and mortality in the context of socioeconomic advantage and disadvantage in Leeds, UK, is but one example (Figure 5).[21]

The limits of mass printing technologies made the inclusion of colored, or even black and white maps, impossible in the broadsheets and evolving newspapers of the day. That said, by the early 20th century use of disease maps analyzing outbreak and summarizing related data were a principal tool of the then evolving profession of "sanitary science," today's public health.[22]

progression is perhaps best seen in the history of shared, international surveillance reports on influenza. As early as 1948, WHO created a network of international, influenza reportage among member states. Individual reports from different jurisdictions were manually correlated with results into a final report distributed as a print document.

In the 1990s, the 53 nations of its European region began sharing and then aggregating data on yearly incidence.[24] The sheer volume of data accumulated required a digital medium for its organization and distribution. The resulting Global Influenza Surveillance and Response System (GISRS), which issued weekly reports,[25] was the forerunner of today's FluNet, a web-based site for global influenza surveillance and reportage.[26] Its popularization was enabled in the late 1990s by the introduction of web-based browsers capable of accessing the World Wide Web.

Following the 1995 Ebola epidemic in the Democratic Republic of Congo, WHO began developing a more general, digital Globe Outbreak Alert and Response Network for communicable diseases using "systems of electronic communications supported by 151 country offices concentrated in the developing world and the participation of more than 110 existing institutes, laboratories, agencies, and surveillance systems."[27] The SARS pandemic, beginning in 2001, decisively demonstrated to both bureaucrats and researchers "the advantages of rapid electronic communication and new information technologies for emergency response, and the willingness of the international community to form a united front against a common threat."[27]

The results once posted in the map are also available in charts and tables similarly available for general download. Equally accessible to those with computer and modem access is the underlying data.[11] "Being able to track a virus this closely, this carefully, this scientifically in real time is a real positive development for global public health."[28] At every step, the issues of data accumulation, analysis, and presentation slowly shifted from the limited world of officialdom and print toward a more public, digital environment available for general download.

The sheer volume of potential data was too large for rapid manual collection by any individual or single research team. Automatic systems of collection and organization were developed, leading to the current generation of syndromic databases whose dedicated algorithms "scrub" official (CDC, WHO, PAHO, etc.) and unofficial (e.g., news databases, tweets) sources to collect potentially pertinent, geographically
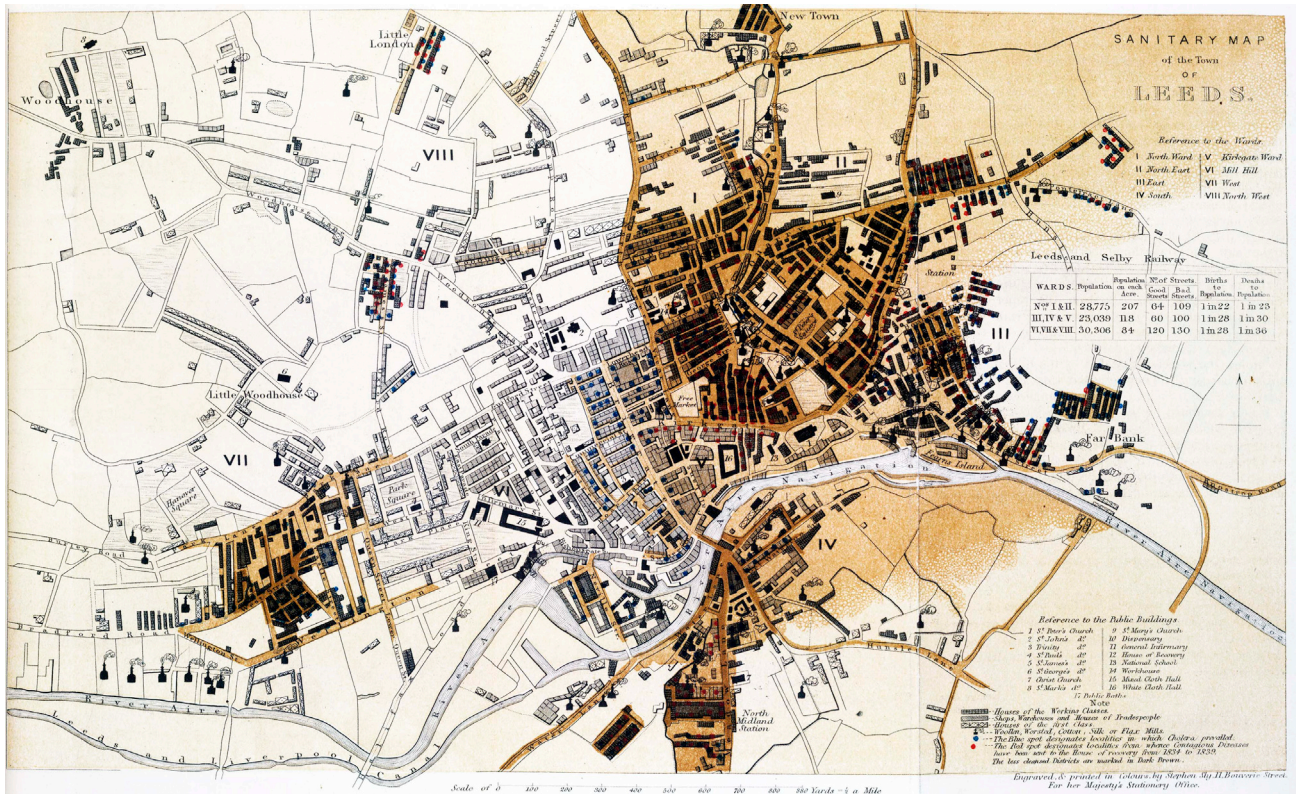
The digital revolution

Into the mid-20th century, as printing technologies improved newspapers became an accepted medium of public information reporting on the work of academics and officials. Mapping increased as an analytic and illustrative tool in both the popular press and in academic studies. Still, that work was limited largely to professional cartographers and statisticians. The use of even elementary statistics was similarly limited to those with both advanced training and access to reams of disease-related print data. Public reportage was based on the eventual publication of professional and governmental reports.

All this began to change in the 1960s with the introduction of mainframe, commercial computers employing machine languages like FORTRAN. At first, data were entered manually on punch cards to create black and white maps printed on dot matrix printers. The results, while crude by contemporary standards, enabled a series of new cartographic techniques. In 1964, G.W. Howe published the first edition of his monumental *National Atlas of Disease Mortality in the United Kingdom* with traditional, hand-drawn maps. Five years later, a second edition introduced computer-generated, disease-specific maps created with SYMAP (Systematic Mapping and Analytic Program).[23]

In Figure 6, a map of arteriosclerosis in Great Britain, familiar county boundaries are transformed into discontinuous, square (urban) and diamond-shaped (rural) symbols sized to reflect a district's resident population. Greater or lesser incidence of arteriosclerosis for each was posted using dense or less-dense hatchings. Others experimented with computerized density gradients for disease incidence using contour lines to show relative infection rates of, for example, schistosomiasis.[17]

It was not until the late 1980s, however, that official data began to be regularly collected in digital rather than print formats. The

Patterns
Perspective

Figure 5. Leeds
The "sanitary map of the town of Leeds" is an example of the way in which 19th century researchers attempted to combine medical cartography and statistics to describe a relationship between disease incidence and socioeconomic differences. Author's collection.

anchored data. The results are stored either as stand-alone, individually accessible databases or as units within multi-subject data caches like The Global Database of Events, Language, and Tone (GDELT).[29] Each reference to a disease "tag" (COVID-19, for example) is collected as a data point with incidence, a date, and location: country, province or state, or city.[30]

The proliferation of these systems has spawned a mini-literature on their potential for biosurveillance[31] as well as the rapid identification and study of epidemic and potentially pandemic events.[32,33] It is tempting to suggest a kind of co-evolution here in which increasing microbial evolution is met by a parallel evolution in data collection and analysis. And, just as epidemic disease occurs at global, national, and regional scales so, too, has the data revolution increasingly documented viral incidence and diffusion across these different scales to describe with precision the rapidity and context of bacterial or viral spread.

The expanding dominance of syndromic, automatic collection systems is not an unequivocal boon. First, democratization of the resulting data is based on the work of a technological class writing program algorithms. Their designs, and thus the data that result, are not necessarily value free but subject to a range of authorial assumptions reflected in the final code. Recent studies have shown, for example, racial biases rampant in supposedly value-free databases used to guide decision making in some US healthcare programs.[34,35] Even where algorithms are

not obviously biased, syndromic databases may carry redundancies and inaccuracies dutifully scrubbed from multiple sources of unequal value.[36]

Geographic information science technologies

Within this progression from print to digital data there is a parallel history of an increasing sophistication in cartography as an analytic medium in its own right. The early 19th century saw the beginnings of this trend.[17] The map was "essentially a statistical argument presented visually, and so was a result of the development of statistics as an important area of knowledge."[19] With the increasing acceptance of digital data collection protocols in the 1980s a new "geographic information science" (GIS) evolved with "hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information."[37] These enabled the presentation of disease events in the context of climatic, economic, and socio-political characteristics of a place or region.

The result has been, at one level, systems "enabling the governmental ordering of the neighborhood, the city, the state, and the planet."[38] This was the "biopolitics" defined by Michel Foucault as a quantification of the "species body, the body imbued with the mechanics of life and serving as the basis of the biological processes: propagation, births and mortality, the level of health, life expectancy, and longevity, with all the conditions that can cause these to vary."[39] For Foucault, this politic was the handmaiden of a "biopower" residing primarily in officialdom's ability to collect
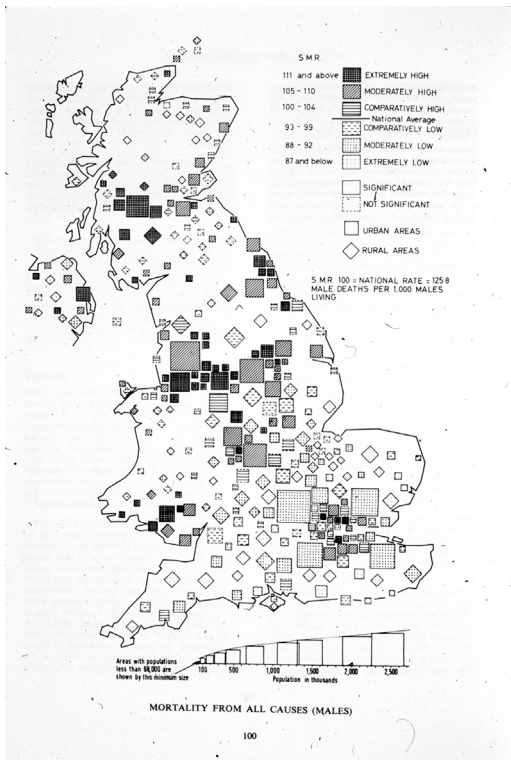
Figure 6. Arteriosclerosis in Great Britain
In the 1960s there were numerous attempts to digitally map disease incidence using dot matrix printers and then new machine languages. Data entered into these programs were not collected digitally but manually. The results were innovative but not broadly imitated. Author's collection.

Figure 7. Early maps by news organizations focused on China and the outbreak in Hubei province as it began to expand through Asia
This early dashboard dot map of COVID-19 presented a simple portrait, without additional charts or data, of disease incidence in China and neighboring countries before global spread to other continents was evident. From The Washington Post. © 2020 The Washington Post. All rights reserved. Used under license.

and then use population statistics to fashion public policies. Today's dashboards transform what had been that official preserve into a common resource, the stuff of daily reports prepared by working broadcast and print journalists.

COVID-19 analysis

The first dashboards presenting COVID-19 data were relatively sparse in both the data presented and the maps that resulted. The illustration in Figure 7 accompanied a January 2020 *Washington Post* story on the early expansion of COVID-19 in China. Its focus was the outbreak's origin site, Wuhan, and surrounding Hubei province. Reports from other Chinese provinces (Guangdong) and cities (Beijing) also were posted as were, importantly, early outbreaks in neighboring countries.

As the pandemic progressed, dashboard maps were increasingly global, with dot maps of viral incidence in international cities (the size of the dot reflecting the size of the population affected) or colored, chloropleth maps of disease intensity in this or that state, province, or country. Popular media not only printed these maps and their accompanying charts or tables but created their own. An April 6, 2030, map in the *New York Times*, for example, imaged the growing incidence of COVID-19 as a set of low hills in smaller cities and huge "spikes" to reflect the size of metropolitan epidemics. Some maps were virtually unintelligible while others
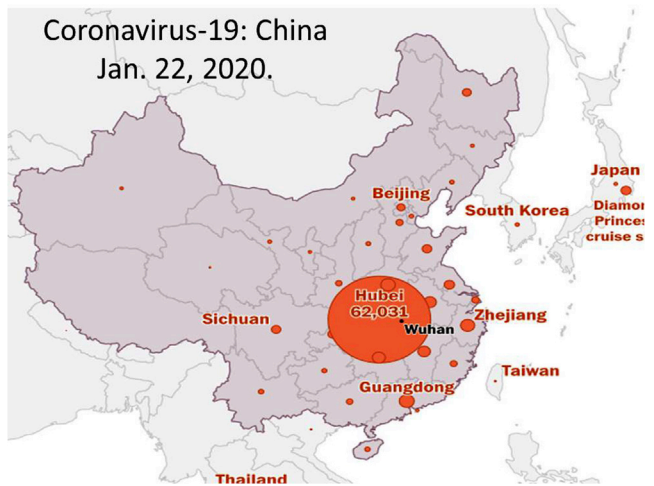
were informative. Figure 8 presents a brilliant image published in the *Washington Post*.[40] Using a projection centered above Wuhan, the original foci of the epidemic, the map describes the density of inter-regional air routes in China and their links to foreign destinations.[41]

Socioeconomic factors

Over months, dashboard data were refined from a simple total number of cases, presented in the early days of the pandemic, to cases per 100,000 persons (or even 10,000 persons). As the pandemic progressed, an increasing set of regional, county-level dashboards were based on available data and that of local agencies.

Besides a general understanding of pandemic dynamics, average readers and viewers were soon drawn into more complex and precise causal studies of local and regional outbreaks. It was apparent that not only did infection rates vary in timing and intensity provincially and nationally, but also within individual cities or counties. In late August 2020, for example, the focus in some jurisdictions was the location of assisted living facilities responsible for more than 40% of all COVID-19-related deaths in the US.[42] Viral outbreaks also were centered in poorer neighborhoods and regions. In Montreal, PQ, for example, a June 11 *CBC News* graphic mapped cases of COVID-19 by local district and set that beside maps of the non-white population and median household income by local district (Figure 9).[43] The maps made clear a correlation between disease intensity, income, and ethnicity.

The resulting "viral disparities" became the focus of a range of articles and reports globally,[44] regionally, *and* locally. These resulted in local investigations and calls for action by citizen groups and organizations. This work went far beyond simply presenting a dashboard. By linking viral incidence to digitally stored, public demographics a new order of engagement emerged independent of the dashboards themselves. Cartographically, this was

Travel Routes: Beijing to the world.
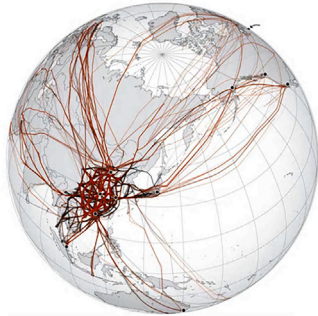
Washington Post, Feb. 21, 2020.

Figure 8. This *Washington Post* map (February 21, 2020) imaginatively describes travel routes from China to the global community
The off-center focus and coloration gave the whole an anatomic look with air routes, such as veins around an eyeball. From The Washington Post. © 2020 The Washington Post. All rights reserved. Used under license.

done in various GIS programs in which spatially grounded datasets could be joined, projected, and then analyzed. In previous epidemics, such studies would have been the preserve of academics or public health officials whose reports would appear months or years after the fact. As the pandemic expanded they were made public as new stories.

An *Atlanta Constitution-Journal* investigation into disease incidence and living conditions at assisted care facilities is an example.[45] Begun with a spreadsheet and map of assisted care facilities in the state, reporters added data on the total number of residents, infection rates, and then COVID19-related deaths at each institution. This was enfolded into a broader analysis using "Census.gov" databases detailing ethnicity, education, and income for the districts in which the nursing homes were located. The resulting complex of attributes showed a correlation between ethnic and socioeconomic attributes and the number of infections and reported deaths.

Nor was work like this restricted to major news organizations and outlets. Reporters at the *Orange County Register* (CA) similarly used incidence data gathered by public officials and public census data to show that COVID-19 hotspots most typically occurred in poorer, densely populated neighborhoods whose residents lived in dense, multi-generation households whose wage earners were employed in precarious low-paying service jobs.[46] Similar work was carried out by various news publications and blogs around the US (for example, in Milwaukee)[47] and in Canada.[48]

DISCUSSION

Public access to digital data stands today as an emerging counter-weight to Michel Foucault's governmental and thus presumably exclusive "biopower" in which control of public data, and its interpretation, was the preserve of officialdom.[49] In addressing the "mechanisms of life" in relation to epidemic occurrence, popular access to incidence data, coupled with socioeconomic data, is not only democratizing but as a result encourages public critiques of governmental responses to epidemic events and the socioeconomic conditions that influence their intensity.

While democratizing the result is not universally democratic. An ability to access the data depends on internet access which is not yet universal. Even with that access, manipulation of the data requires cartographic and statistical programs that, while increasingly available at low cost, are neither free nor intuitive. Nor is there any guarantee that alternate interpretations and critical studies will be broadly disseminated. For example, the "community mapping" movement is grounded in smaller, special interest communities often crafting alternate arguments that result in different maps using public data in different ways. That work typically receives less public (or ministerial) attention than work broadcast or published by the government or in major media outlets like the Canadian Broadcasting Corporation or *The Globe and Mail* (Toronto).

Nor is it clear that the best arguments based on the most inclusive data will be convincing. Even with widespread broadcast and print publication of dashboards, and arguments from them, some simply reject the resulting analysis in favor of alternate theories that may have little factual grounding.
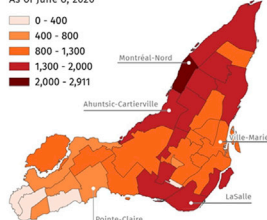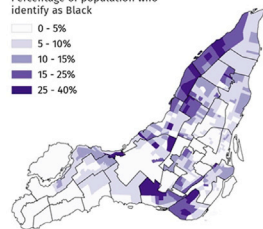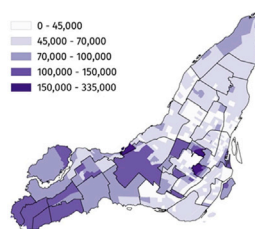
Figure 9. Montreal SES, race, incidence
The relation between relative disease incidence and socioeconomic factors became a subject of stories—with maps, charts, and tables—by the summer of 2020. This example from CBC News, Canada, presents the data in three separate maps for Montreal, PQ.

The wealth of valuable data and resulting popular reports present a kind of existential crisis for academics and professional researchers. If the most revealing analysis appears not in a journal of medical geography or public health but the *Atlanta Constitution-Journal*, *The Toronto Star*, or the *Buffalo News* the question becomes: What is the future of those professionals who, in the past, stood alone as gatekeepers and principal analysts?

My suspicion is that the democratization of data and the broadly public manner of its consideration will not superannuate the epidemiologist, medical geographer, public health expert, or skilled journalist. After all, those crafting the syndromic algorithms, collecting socioeconomic data and analyzing the results almost surely learned their skills in university classrooms. Those who seek to do their own research need the language skills of a reporter to make their conclusions known. That said, one result is likely to be that the relationship between journalist and academic will change from an unequal to a more equal footing.[50] Popular reports using freely available, digital data will provide a baseline of understanding from which more advanced studies may progress.

The experience of COVID-19 and its dashboards as public data sources is an example born of a global emergency. At best, this paper presents a baseline for further and deeper consideration of these digital resources in the future. Another study is needed—and perhaps an atlas—to truly describe both the profusion of these new media and their content. More needs to be done to understand the levels at which the resulting data are engaged (or rejected) by the general public and by researchers in the field. And, too, if these changes are consistent and fundamental their respective use by bureaucratic, commercial, and public actors requires further investigation. Finally, we do not know if this digital revolution will be limited to extreme events like this pandemic or expanded across a range of political and social issues. COVID-19 certainly is not an endpoint either in public health or public information. It is rather a tipping point in the maturation of public access to public data. Ultimately, at least in public health, its importance will be defined by the manner in which the experience with COVID-19 data informs future data collection, analysis, and reportage.

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