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Power and Authority in Disease Maps: Visualizing Medical Cartography Through Yellow Fever Mapping

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Abstract

Medical cartography became an important data visualization tool in the 19th century. In this article, the author argues that early yellow fever maps invoked power and authority over diseased space through their visual conventions and scientific authority as statistical graphics as well as by visually reinforcing underlying Western ideologies about disease, illness, and health. Further, the creation of these maps established a visual precedent for invoking this authority that continues today. As public health continues to move toward a global health perspective in the 21st century, understanding how mapping constructs and shapes knowledge about disease, illness, and health will become increasingly important.

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The origins of data visualization can be traced back to antiquity, when early maps and drawings were created primarily for navigational purposes (see Friendly, 2008; Friendly & Denis, 2006). The statistical graphics that we recognize today evolved more recently, however, after the discovery of probability theory in the mid-17th century and interest grew in gathering a range of data—demographic, economic, social, environmental, and moral (see Beniger & Robyn, 1978; Friendly, 2008; Friendly & Denis, 2006; Funkhouser, 1937). As the collection of this "political arithmetic," as 17th century economist and physician William Petty (cited in Friendly, 2008, p. 505) characterized it, began to proliferate throughout the late 18th and early to mid-19th centuries, so did the creation of visual forms used to display, shape, and interpret this information.

This more recent history of data visualization that began in the 17th century reflects the move toward "visual thinking" (Friendly & Denis, 2006, p. 1) during which the purpose of collecting quantitative information moved from a focus on description to constructing generalizable visual knowledge that could be used to draw inferences and solve problems. In the emerging modern-day fields of public health and epidemiology, early medical cartography became a particularly significant data visualization tool in the first half of the 19th century as officials struggled to control the disease outbreaks that had become increasingly common. Fueled by rapidly growing urban populations, poor sanitation, and limited knowledge of the true causes of disease transmission, illnesses such as cholera and yellow fever spread across the United States and Europe. As these diseases became endemic, early medical cartographers, who were also often physicians, began investigating their causes and produced reports that made both visual (in the form of maps and other statistical graphics) and verbal arguments that attempted to identify causal factors.

English physician John Snow's 1854 map of a cholera outbreak in London's Golden Square district, for instance, illustrates a well-known example of this trend (see Figure 1). The now famous map is often credited with revealing the true cause of the outbreak, the contaminated water from the Broad Street pump, which then led to the quick removal of the pump's handle. In reality, the historical account is more complex (see Brody, Vinten-Johansen, Paneth, & Rip, 1999), and Snow's contributions to public health

Figure 1. Snow's (1855) map of the 1854 outbreak in Golden Square.
Source: Courtesy of the Historical Medical Library of the College of Physicians of Philadelphia.

and epidemiology would not be formally recognized until new attention was called to his work in the 1930s (see Vandenbroucke, Eelkman, & Beukers, 1991). The Broad Street event endures in the "folklore of public health and epidemiology" (Brody, Rip, Vinten-Johansen, Paneth, & Rachman, 2000, p. 64) today, in part, because Snow's story invokes a powerful narrative of scientific progress (McLeod, 2000). We remember Snow because he was right about the pump and, more important, because he was right about cholera. But we also remember Snow because the Broad Street map constructs a powerful visual argument about how disease—in this case, cholera—is situated within a particular time, space, and place.

The notion that maps act rhetorically to advance power relationships has been well theorized in the fields of technical communication (see Barton & Barton, 1993; Propen, 2007, 2012), geography (see Monmonier, 1995), and critical cartography (see Crampton, 2010; Harley, 2009; Pickles, 2004; Wood, 1992), which offers a framework for investigating the ways that maps "link geographic knowledge with power" (Crampton & Krygier, 2006, p. 11) and construct social and cultural knowledge (see Harley, 2002; Monmonier, 1995; Turnbull, 1989; Wood, 1992). At the same time, these relationships have not been well explored within the context of disease mapping.

This article theorizes early medical cartography through this perspective and discusses its implications for contemporary disease mapping as a data visualization tool in the field of public health and epidemiology. Using four historic yellow fever maps created in the United States during the late 18th through the mid-19th centuries as examples, I argue that early disease maps invoked power and authority through their visual conventions and scientific authority as statistical graphics and by visually reinforcing underlying Western values about health, disease, and illness. These trends can still be seen today, which I illustrate by discussing a contemporary yellow fever map that shows areas still at risk for the disease in Africa.

Further, while Western medicine has been criticized for decontextualizing and mechanizing the human experience of disease, I suggest that the ideologies that undergird this perspective were critical in facilitating a population-based understanding of disease prevention, which led, in part, to the emergence of the modern-day disciplines of public health and epidemiology. As public health increasingly moves toward a global health perspective in the 21st century and digital mapping tools such as geographic information systems become a primary methodology for addressing public health problems, understanding how maps construct and shape knowledge about disease, illness, and health will become increasingly important.

Yellow Fever and Early Medical Cartography: Visually Constructing Power and Authority

Today yellow fever is no longer a significant public health concern in most parts of the world. But this disease, along with waterborne illnesses such as cholera, posed a significant threat in the United States and Europe throughout the 19th century. Transmitted through the bite of mosquitoes infected with the yellow fever virus, the disease is believed to have arrived in North America on West African slave ships in the mid-17th century (Rogers, Wilson, Hay, & Graham, 2006; see also Blake, 1968). Throughout the 18th and 19th centuries, epidemics swept major U.S. port cities such as New York and Philadelphia (see Blake, 1968; Foster, Jenkins, & Toogood, 1998; Koch, 2011).

Yellow fever presents a strong opportunity to explore historic as well as contemporary disease mapping from a critical cartography perspective because mapping this disease spans the history of medical cartography. Two of the oldest surviving disease maps were created by Seaman (1798) to document a yellow fever outbreak in the New York harbor area while Pascalis (1819) created a map documenting another outbreak in a neighboring area over 20 years later. In the mid-19th century, Jewell (1853) and Barton (1857) mapped outbreaks near the South Street Wharf area in Philadelphia and in New Orleans, respectively. Finally, as recently as 2011, a map, published on the Centers for Disease Control and Prevention (CDC) website (Jentes et al., 2011), shows at-risk tropical areas in Africa where the disease remains endemic (World Health Organization, 2008).

The first thematic maps are believed to originate in the late 1700s (see Friendly & Denis, 2006; Funkhouser, 1937; Robinson, 1982), following significant advances in the field of cartography throughout the 15th century—specifically, the invention of new printing capabilities and an increasing emphasis on more realistic geographic depictions (see Robinson, 1982). The exact origins of medical cartography, however, are difficult to pinpoint. Several scholars have pointed to the wave of cholera epidemics that began to sweep Europe in the 1830s (Gilbert, 1958; Jarcho, 1970; Robinson, 1982). But Stevenson's (1965) historical work on late 18th-century "spot" maps, which discusses the early yellow fever maps created by Seaman (1798), Pascalis (1819), and Barton (1857), and Koch's (2005) analysis of a 1694 plague map of Bari, Italy (previously identified by Jarcho, 1970), suggest an earlier time frame. Koch (2005) speculated that more disease maps were probably created in the 1600s and early 1700s, but none have survived to the present day (see also Koch, 2011; Robinson, 1982).

In all likelihood, the first disease maps are contemporaneous with the statistical graphics that emerged in the 17th century. The practice of disease mapping, in fact, may have originated in attempts to resolve the ongoing dispute between the two dominant theories of disease transmission at the time, that is, contagion and anticontagion (Stevenson, 1965).

Prior to the discovery of microbiology in the late 19th century, the actual causes of communicable and infectious disease transmission were unknown. Some diseases (e.g., smallpox, scarlet fever, and measles, see Mitman & Numbers, 2003, p. 393) were believed to be contagious. That is, they spread through person-to-person contact. Anticontagionists, however, argued that diseases such as cholera and yellow fever were not contagious and instead spread through miasma (Smith, 1993), essentially exposure to "bad air" (Mitman & Numbers, 2003, p. 394). No one understood exactly how miasma developed. Yet common belief held that the smell of rotting organic matter combined with certain weather conditions (usually heat and humidity) resulted in a "putrid effluvia," as Seaman (1798, p. 331) described it.

After yellow fever arrived in the New World, researchers began to observe that the disease seemed to prosper in warm, humid environments; thus, tracking these conditions became particularly important to those studying the disease (see Koch, 2011). Efforts to identify the specific environmental variables that had prompted an outbreak can be seen in several of the reports that accompanied the historic yellow fever maps discussed in this article. Barton's (1857) report, for instance, includes several detailed tables reporting rainfall, level of humidity, temperature, and barometric pressure. Jewell (1853) noted the direction of the wind several days after the arrival of a ship, the Mandarin, at the South Street Wharf in Philadelphia. The outbreak near this area occurred, Jewell argued, after the ship's cargo was unloaded and "noxious emanations which had been latent in the hold" were "acted upon by . . . heat and moisture . . . [which] poisoned the atmosphere" (p. 12). Such reports sought to establish where the miasma was likely to have originated or could develop in the future (as in Barton's 1857 report) and to identify the exact environmental factors responsible. For instance, an earlier investigation conducted by Barton (1834) also in New Orleans offers the following assessment: "These winds uniformly exasperated the yellow fever, and if they do so, they *can surely tend to produce it*" (p. 7). In Barton's (1857) later report, which he created as a member of a sanitary commission tasked with investigating conditions in the city following another epidemic in New Orleans, his "sanitary map," he explained, shows areas where dirty water and "filth and garbage of all kinds" were accumulating as well as areas with "low, crowded, and filthy tenements," which he claimed "are probably as disastrous in the production of yellow fever" (p. ix).

Similarly, in his second map in his report (see Figure 2), Seaman (1798) discussed polluted areas indicated by *x* and *S* symbols in the dock areas in the lower right-hand corner. He stated, "Without the air of putrid effluvia, they [the citizens of New York] need have no apprehension of a Yellow Fever *spreading* among them" (p. 316).

In fact, many disease maps created throughout the 19th century supported the argument in favor of miasma because contagion, as Barrett (1998) explained, was "not particularly geographic in nature" (p. 767). If a disease spread through contact with an infected person, as contagionists believed, then an epidemic of that disease should follow a pattern of "unending diffusion of cases" (p. 767). Yet many early disease maps, such as those created by Seaman (1798), Pascalis (1819), and Jewell (1853), revealed

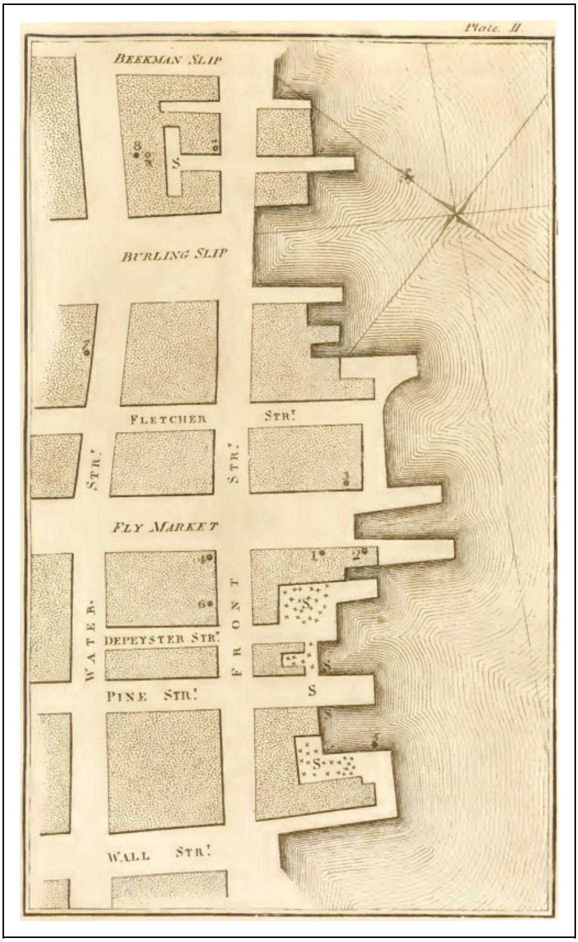

Figure 2. Seaman's (1798) second map (Plate 2).
Source: National Library of Medicine, History of Medicine Division.

patterns of spatial distribution that simply did not visually support contagion but rather seemed to point to environmental factors such as miasma.

These early disease maps, like other statistical graphics, show relationships between and among aggregate data, but they also simultaneously construct temporal and spatial patterns of disease distribution. They showed how yellow fever moved through space and time within a population during an outbreak, visually linking cases with polluted areas and weather conditions to advance a theory of disease causation—usually miasma. In this way, the creation of these maps demonstrates Koch's (2005) observation that maps transform general knowledge into specific information. The creators of these early yellow fever maps assembled information about the conditions surrounding the outbreak—people affected, locations of cases, and polluted areas—into concrete visual representations. Mapping is a form of "abstract thinking," Robinson (1982) explained, "a reduced, substitute space for that of reality" (p. 1), and creating a map, as Koch (2005) stated, "encourages a perspective that is both relational and spatial at once" (p. 2). In explaining how viewers construct meaning from maps, Robinson and Petchenik (1976) suggested that maps link "knowledge and space" (p. 4). Maps depict a select moment in time, fusing abstract information and dynamic, three-dimensional space into flattened, two-dimensional representations that construct a particular version of reality that the map's creator can then use to advance a particular purpose.

The act of creating a map establishes metaphorical control and ownership over the representation of the space shown in the map, transforming the space into a thing—an object that can be studied and subsequently used for some specific purpose, such as actions in the physical world, in terms of navigating the space, making decisions about the space, or engaging in other interactions with the space. Disease maps were created to identify the factors that cause disease in order to effect action such as enacting quarantine measures and sanitary reform, a movement that began in England in the 1830s (see Rosen, 1993, for a history of the sanitary reform movement). For instance, Barton's map, like other sanitary maps created in the early to mid-19th century (see also Koch, 2005; Robinson, 1982), argued in favor of cleaning up areas that might be prone to producing the dreaded disease-causing miasma.

By the mid-19th century, the connection between epidemic disease and poor environmental conditions was clear. Thus, many advocates of sanitary reform, such as Barton, were more interested in identifying areas that posed health risks than in finding the exact causes of specific outbreaks (see Brody et al., 1999; Rosen, 1993). If overall sanitation were improved, then outbreaks of diseases such as cholera and yellow fever could probably be avoided entirely even if weather conditions favorable to miasma developed. Barton's (1857) report demonstrates this view in arguing for the "prevention of moisture and the removal of filth" (p. 208) in areas that he identified on the map (p. ix).

In shaping and defining geographic spaces in ways that allowed early yellow fever researchers such as Barton to argue in favor of sanitary reform, for instance, the creation of these early maps illustrates what Barton and Barton (1993) referred to as "inclusion" and "exclusion" (p. 53), or what Harley (2009) has termed "ideological filtering" (p. 138). That is, the creation of these early maps demonstrates the ways that their creators selected and framed visual information in ways that advanced particular purposes.

Constructing Power and Authority Through Visual Conventions

Early maps demonstrate inclusion and exclusion through their visual conventions—more specifically, through perspective and the placement of visual information. Constructing meaning from maps, like other forms of visual communication, often "seems transparent [only] because we know the [semiotic] code already" (Kress & van Leeuwen, 1996, p. 32) and because visual communication follows particular conventions that readers have come to expect (see Kostelnick & Hassett, 2003). Kress and van Leeuwen (1996) argued that the placement of visual information—top or bottom, left or right, and center or margin, for instance—connotes particular meanings. More specifically, in some interpretive contexts, information that appears at the top is interpreted as "ideal" whereas information that appears at the bottom is interpreted as "real" (pp. 186–187). Information at the center is seen as the "nucleus" whereas information placed around the center is seen as supportive (p. 196). In Western cultures, in particular, the placement of visual information creates a hierarchy, conveying the level of importance of each design element.

Most maps in Western cultures (with the exception of relatively recent digital interfaces that allow users to see a street view), for instance, "look down," assuming an "aerial position of power," as Kimball (2006) characterized it (p. 378). Most maps also place north at the top, a convention that Turnbull (1989) explained is "closely connected with the global rise and economic dominance of northern Europe" (p. 8). The still-used Mercator map, invented in 1569, has been criticized not only for its inaccurate depiction of scale but also for its placement of Europe in the center (see Peters, 1974), which Harley (2009) suggested "must have contributed much to a European sense of superiority" (p. 136).

In addition to perspective, Western maps also rely on metaphoric associations related to size and shading (density). In Western cultures, bigger usually implies better, and larger symbols have historically been used to convey more important information (see also Harley, 2009). The use of

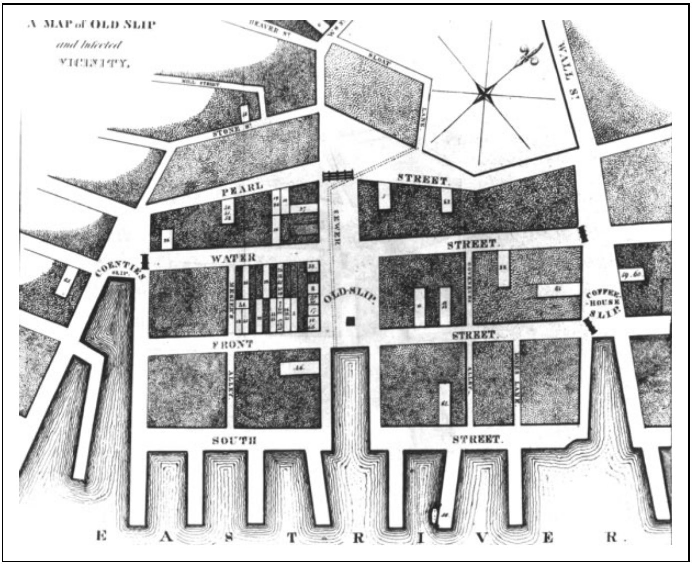

Figure 3. Pascalis's (1819) map of a yellow fever outbreak near the Old Slip area.
Source: National Library of Medicine, History of Medicine Division.

shading to indicate increasing density was established in 1826 (Friendly, 2008); this technique, also used by early cholera maps (Smith, 1993), has now become conventional for showing less or more (density) of a particular variable.

Many of these visual conventions (use of perspective and shading) can be seen in early yellow fever maps. For instance, each map assumes a bird's-eye perspective, looking down on the outbreak. The compass symbol in Figure 2 (Seaman's map) suggests that the top of the map and toward the left represents north whereas the compass symbol in Figure 3 (Pascalis's, 1819 map) indicates that the top right of the map represents north. Symbols in the top right-hand corner of Jewell's (1853) map of the South Street Wharf (see Figure 4) show that north is toward the right and west is toward the top of the map, most likely because the outbreak spread west and north from the dock areas. Jewell (1853) also included illustrations of two ships. The Mandarin is centered at the bottom of the map, emphasizing its importance as the real cause (to use the interpretive framework of Kress & van Leeuwen, 1996). A second ship, the Brig Staets Von Brock, is located near the last case of yellow fever (Jewell, 1853, p. 32) and is shown closer to the

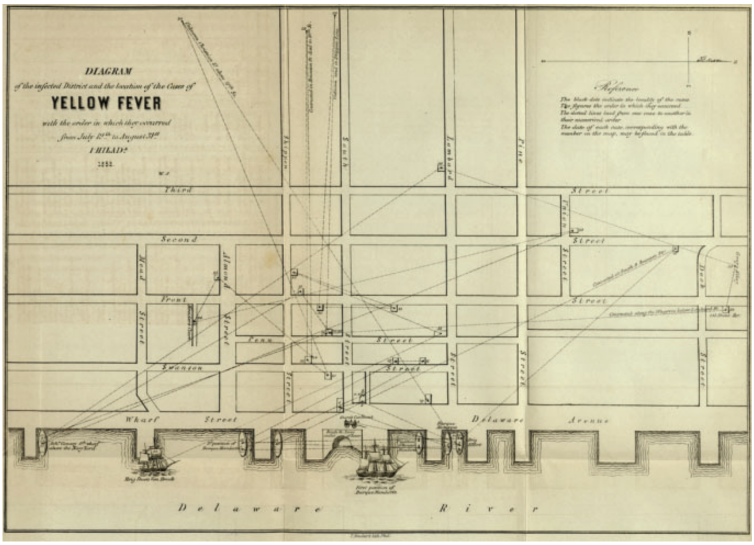

Figure 4. Jewell's (1853) map of a yellow fever outbreak near the South Street Wharf area in Philadelphia. *Source*: Courtesy of the Historical Medical Library of the College of Physicians of Philadelphia.

edge and the bottom of the map, which visually downplays its importance. Jewell clusters most of the cases in the center of the map, emphasizing the nucleus of the outbreak (again drawing on Kress & van Leeuwen, 1996) as yellow fever spread up from the Mandarin and the dock areas it occupied.

Pascalis (1819) too included the docks at the bottom of his map (see Figure 3), which allowed him to place the majority of the cases in the center. This centering visually emphasizes the area where most of the cases occurred—as he put it, "out of 57 cases (the total of them) the enormous proportion of 34 or 35 originated from that single block" (p. 20)—and de-emphasizes the docks and river area. In his report, he described the overall poor sanitary conditions of Old Slip, the location of the outbreak—"This place has always been the common receptacle of the whole filth of the city" (p. 19)—and the specific conditions that may have produced miasma, specifically "heat and moisture, exciting a putrid fermentation in the soil, or in accumulated *putrescible materials* under or about us" (p. 17). Rather than using "spots" or dots to show individual cases, he included rectangular bars and boxes (perhaps to visually represent the houses where cases occurred) with numbers listed inside the bars to show temporal information. From a 21st-century perspective, Pascalis's use of shading is not conventional (the rectangular bars are lighter whereas the city blocks are darker) because this map predates this visual convention. Nonetheless the map demonstrates the convention of using shading to differentiate between visual information.

Conversely, Seaman (1798)—who created two maps of an earlier outbreak also in New York—placed the docks to the right in his representations. He believed that the outbreak originated from concentrated areas of garbage and debris near the docks, as shown in his second map (see Figure 2). Like Jewell he placed these areas near the bottom of the map, perhaps to emphasize the location of the real causes.

The preceding analysis demonstrates that the creators of several early yellow fever maps—Jewell, Pascalis, and Seaman—made visual choices in defining and constructing geographic space that would advance their purposes. Rather than being neutral representations of how yellow fever outbreaks occupied real-world spaces, these maps are fundamentally rhetorical. Ultimately, the purpose of creating any map is to arrange select geographic content into an abstracted visual representation that emphasizes certain features and minimizes others (inclusion and exclusion) in constructing new spatial relationships that advance a particular understanding and interpretation of that space. As Crampton (2010) stated, "Maps *make* reality as much as they represent it" (p. 18). Indeed, these early yellow fever maps are particularly effective in demonstrating this idea because rather than revealing the truth about how yellow fever was actually transmitted, they visually advanced a theory (a hypothesis) of disease causation. Shannon (1981) observed that Seaman and Pascalis accurately concluded that yellow fever was not contagious, but in the absence of scientific knowledge about the disease's etiology, miasma seemed to be the only other logical explanation.

Because the creators of early disease maps were constrained by these limitations, they were also invariably limited in terms of the arguments they could make about disease causation. As Krieger (2011) pointed out, researchers are shaped by the "ideas and beliefs of their time" (p. 27), which further highlights the rhetoricity of these early maps. What is possible to know (or to believe) is controlled by ideology, epistemology, and the limitations of accepted methodologies. That is, scientific knowledge does not emerge from neutral, disinterested, open-ended inquiry; rather, it is shaped by what a particular culture (and researchers within that culture) can know, believe, and do, as well as by what they believe is possible to know, believe, and do, at a particular point in time.

Constructing Power and Authority as Statistical Graphics

Technical communication scholarship has called attention to the rhetoricity of statistical graphics (see Brasseur, 2004; Dragga & Voss, 2001) and scientific communication (see Gross, 1996; Kuhn, 1996). Yet statistical graphics are particularly powerful rhetorical constructions because they are simultaneously both visual and scientific forms of communication. These forms carry the weight of scientific authority within the context of the often-assumed transparency of visuals, which work together to invoke a narrative of scientific progress, promote underlying positivist assumptions, and downplay the ways that these forms work rhetorically to construct quantitative information. As essentially the visual equivalent of scientific data, there is still perhaps no other visual genre, with the exception of photographs and maps, of course, that invokes the notion that visuals are objective and neutral representations quite like statistical graphics.

Historic yellow fever maps visually invoke this scientific authority and presumption of visual neutrality. Seaman's (1798) maps, for instance, did not prove that miasma causes yellow fever. Rather, they worked alongside the mounting evidence outlined in his report as well as his previous research to reveal "the simple result of the foregoing facts and observations." In his report, Seaman definitively concluded "that no Yellow Fever can spread, but by the influence of putrid 'effluvia'" (p. 331). He also alluded to the notion that scientific progress is cumulative and continually evolving, drawing on other possible research and knowledge that might emerge from future investigations:

> If I have succeeded, my end is answered, and my trouble fully compensated; if not, I still gratify myself with the thoughts of having established, with a considerable degree of accuracy, facts, that may be Useful to some more fortunate inquirer. (Seaman, 1798, p. 315)

His final assessment here echoes a familiar appeal to the authority of scientific facts as self-evident. When such facts are carefully weighed and considered in their entirety, a pattern will emerge from research (such as his) that reveals the truth.

Similarly, Pascalis's (1819) map (Figure 3) too draws on scientific authority. He stated that "it has evidently been ascertained, that no case of yellow fever has originated in any part of the city of New-York, except in the spot or vicinity of Old Slip, of which a correct map is subjoined"

(p. 46). His statement appeals to logical reasoning and the authority of the map in establishing an accurate representation of the disease. If yellow fever is contagious, then another infected person somewhere in the city would had to have caused the outbreak, so the contagion would have "diffuse[d] its agency in a more equal and diffusible proportion" (p. 48). The map visually proves the accuracy of his assertion because it is "correct," so some other causal factor must be at work.

Yet while Pascalis's map may have correctly represented cases in the Old Slip area, its coverage of the full geographic reach of the outbreak is not entirely accurate. Koch (2005) explained that Pascalis's map only shows fatal yellow fever cases that occurred near the docks when he could have also shown those that occurred on ships in the nearby harbor; including this information would have strengthened Pascalis's overall argument about the cause of the outbreak but weakened his sanitary reform agenda. By excluding information from his map that did not support his purposes, Pascalis constructed a particular factual reality that maintained a narrative of progress in identifying the epidemic's causes.

Constructing Power and Authority Through Western Ideologies

In addition to using visual conventions and drawing on their scientific authority as statistical graphics, early yellow fever maps also invoked power by visually promoting underlying ideologies of Western medicine, often referred to as the *biomedical* model of medicine. Biomedicine is Western medicine, Segal (2005, p. 23) explained, and it replaced humorism and its holistic approach to health with "the medical body" that emerged with the 19th-century institutionalization of medicine that Foucault theorized (Segal, 2005, p. 26). Biomedicine was solidified in the late 19th century with the discovery of germ theory and is now characterized by four core assumptions outlined by sociologist Elliott Mishler (1981): "(1) the definition of disease as deviation from normal biological functioning; (2) the doctrine of specific etiology; (3) the conception of generic diseases, that is, the universality of a disease taxonomy; and (4) the scientific neutrality of medicine" (p. 3). This last assumption, scientific neutrality, is discussed in the previous section within the context of statistical graphics.

Disease maps visually reinforce Mishler's (1981) first assumption of "disease as deviation from normal biological functioning" by dividing (and marking) the geographic space of an outbreak into binary categories, namely, diseased and not diseased. Because thematic mapping first arose in Europe (see Friendly & Denis, 2006; Funkhouser, 1937; Robinson, 1982), from their inception, disease maps as well as other thematic maps, reflected Western cultural assumptions about space, Trieb (1980) explained, "as something which can be measured, divided, sub-divided and multiplied"—that is, as a concept that can be quantified (p. 5). This division between diseased and not diseased then provides the initial framework for controlling that space.

Indeed, early yellow fever maps visually divide this space. While Seaman's (1798) second map (see Figure 2) marks polluted areas near the docks and uses dots to identify the location of individual cases, Pascalis's (1819) map (see Figure 3) includes mostly rectangular bars with one or more numbers listed inside the bars to show temporal information. In this map, the unshaded streets and rectangular bars create a clear division between diseased and not diseased space when positioned next to the shaded city blocks. In Barton's (1857) map (see Figure 5), created more than 50 years after Seaman's maps, this binary division is even more pronounced. In contrast to Seaman's and Pascalis's maps, which show actual cases, Barton's map highlights areas that could presumably become diseased space. Specifically, his map shows "disturbances of the soil" (thin black lines) and "Nuisances," areas such as "cemeteries, Slaughter houses ... Open basins and unfilled lots" (thick black lines), as explained on the map. Unlike Pascalis, Barton uses shading in ways that are immediately understandable to 21st-century viewers—areas at risk for spreading miasma are clearly identifiable through the now-established visual convention of greater density equaling more disease (and potential disease).

Mishler's (1981) second assumption, "the doctrine of specific etiology," is the notion that the specific cause of a disease or illness can be clearly identified. From a 21st-century perspective, this notion seems obviously useful and necessary. To effectively treat an illness, physicians must accurately diagnose the specific condition that caused it. In contrast to humorism, which proposed that health was defined by a balance between the four bodily *humors*—blood, phlegm, black bile, and yellow bile—specific etiology clearly supports a biomedical model of disease and health. Humorism also held that illness was attributed to an imbalance in humors; thus, treating illness involved correcting this internal imbalance. From a humoral perspective, then, attempting to identify specific disease markers outside the context of the relationships between the humors would not have advanced disease prevention because disease was believed to be caused by internal factors.

Disease maps visually reinforce the biomedical model through specific etiology by mapping single variables of interest—cases of a particular

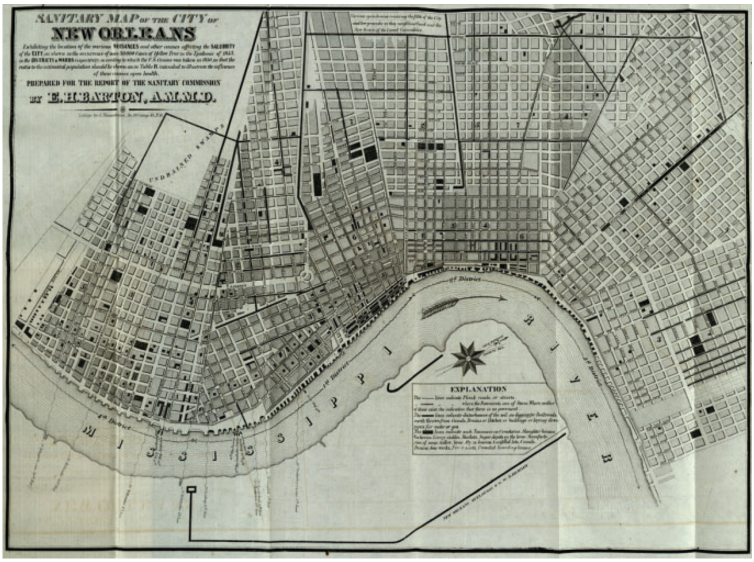

Figure 5. Barton's (1857) sanitary map of New Orleans. *Source*: Courtesy of the Historical Medical Library of the College of Physicians of Philadelphia.

disease or illness, for instance—in a particular geographic region. Specific etiology can be seen in the oldest surviving disease maps such as the 1694 Bari plague map:

> Embedded in the map is a tight argument linking the history of plague's previous occurrences (the basis for containment), the limits of medical science (no treatment but a general etiology), and the social structure of the greater community (civil, military, medical and religious). (Koch, 2005, p. 23)

Early yellow fever maps too reflect specific etiology. The creation of these maps promotes the idea that disease can be described and understood through the temporal (e.g., indicated by numbering cases, as in Figures 2 and 3) and spatial progression of each outbreak in its respective geographic locations. Koch (2005) observed that Pascalis's (1819) map argued for "cause and effect relationships" based on "simple proximity" (p. 37); certainly Seaman's (1798, see Figure 2) and Jewell's (1853, see Figure 4) maps too rely on this visual strategy. Shannon (1981) explained that Seaman intended his first map (not shown) "to be a demonstration of cause and effect" (p. 224) through his visual representations of the spatial relationships between the distribution of the disease and what Seaman determined to be the causal factors. Visually, these early maps reinforce the idea that if users of the map could better understand how a disease occupies and moves through space, place, and time, then they could also more effectively understand the underlying causal factors.

Historic yellow fever maps also demonstrate Mishler's (1981) third assumption, "the universality of a disease taxonomy," which refers to the idea that "disease symptoms and processes are expected to be the same in different historical periods and in different cultures and societies" (p. 9). In early yellow fever maps, disease and illness become static rather than dynamic entities that change as an outbreak moves through space and time. Koch (2011) observed that Seaman "assumed all yellow fever outbreaks were the same disease, and further, he [Seaman] implied that yellow fever everywhere (Barbados, Boston, Philadelphia, New Orleans, and on) was the same" (p. 87).

Embedded within this assumption of universality are two other assumptions: predictability and prevention. If all outbreaks of a particular disease are the same, that is, they follow a similar temporal (and spatial) progression of symptomatology and outcomes, then knowing about the characteristics of an outbreak that occurred in the past can be used to predict (and subsequently prevent) future outbreaks. Barton's (1857) sanitary map demonstrates this idea by identifying areas where the miasma that caused yellow fever might develop in the future. Pinpointing these locations allowed Barton as well as other users of the map to enact metaphorical as well as real-world control over the space by seeing it as something that could be understood, managed, and ultimately fixed. Kimball (2006) made a similar point in his treatment of the visual rhetoric of Charles Booth's poverty maps, suggesting that, in part, Booth's maps communicate the idea that they represent "a fixable real London" (p. 361). In promoting the notion that physical space can be controlled in this way, disease maps also advance a narrative of scientific progress. If the spatial and temporal distribution of disease can be understood, better containment methods can be developed, which will ideally result in fewer outbreaks.

Constructing Power and Authority in Contemporary Yellow Fever Mapping

The controlling metaphor of Western medicine is perhaps, as Segal (2005) put it, "the body is a machine," attended to in terms of "working and

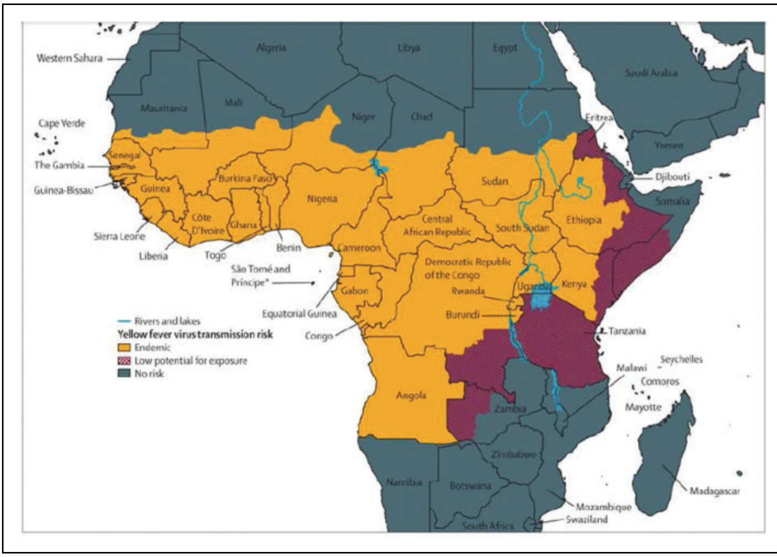

Figure 6. Areas at risk for yellow fever in Africa (Jentes et al, 2011).

nonworking parts" (p. 121). But the controlling metaphor of modern-day epidemiology, with its emphasis on managing epidemic disease in populations, is containment, and containment is achieved by enacting real-world control over diseased space. Historic yellow fever maps enacted this control metaphorically through their visual choices, by drawing on their scientific authority as statistical graphics and by visually invoking Western ideologies about disease, illness, and health. Today these strategies remain largely unchanged, which can still be seen in a yellow fever map (Figure 6) showing areas at risk for the disease in Africa.

Much like early yellow fever maps, this contemporary map uses perspective to assume metaphorical control over the space it represents by looking down on at-risk and not at-risk areas through an all-knowing point of view. The most important information—at-risk countries—is also placed in the center of the map, visually calling attention to these places.

Color and shading too are significant visual features. The map uses yellow to communicate a literal semiotic message (yellow shading equals yellow fever) as well as a metaphoric message—the warm color yellow visually emphasizes the at-risk areas in contrast to the gray not at-risk areas. While color is not used in the historic yellow fever maps discussed earlier (possibly due to technological limitations), some early cholera maps such as Rothenburg's 1836 map of an outbreak in Hamburg (see Koch, 2011, pp. 130–131) and Shapter's 1832 map of an outbreak in Exeter (see Koch, 2011, pp. 157–159), used red to show increasing density and "the greater or lesser strength of the epidemic," as Rothenburg put it (cited in Robinson, 1982, p. 171), establishing a historic precedent for using color to communicate the density of diseased space.

Using shading to signify increasing quantity is now a conventional feature of most disease maps, which can be seen in many historic yellow fever maps, such as Barton's (1857) sanitary map as well as the cholera maps mentioned previously. Yet because the number of reported cases for yellow fever over the past 50 years is extremely low (see World Health Organization, 2014a), these contemporary maps use the opposite visual strategy—that is, lighter density indicates at-risk areas; darker density indicates not at-risk areas. The contrast between these light and dark areas also creates a visual binary between at-risk areas and not at-risk areas, with the darker areas signifying spaces that have been contained and the lighter areas signifying areas that still need to be contained.

Contemporary maps also advance underlying Western assumptions and ideologies about disease and illness through their use of color. For instance, the yellow shading (signifying yellow fever) in the map shown in Figure 6 marks diseased space as different from the "neutral" dark-gray space, visually reinforcing the idea that the yellow, at-risk space is "deviation" from the normal. Further, the visual representation of each of these two spaces (yellow and dark gray) is uniform, suggesting "a universal disease (and not diseased) taxonomy" (Mishler, 1981, p. 3)—that is, all at-risk and all not at-risk areas are the same.

This contemporary map too advances a narrative of scientific progress, which can be seen by considering the increasing geographic range of the yellow fever maps discussed throughout this article. The earliest maps created by Seaman (1798) and Pascalis (1819) show just a few city blocks. Thirty years after Pascalis's map, Jewell's (1853) map expands geographic coverage to a neighborhood (the South Street Wharf area in Philadelphia, see Figure 4). Shortly thereafter, Barton's (1857) map shows the entire city of New Orleans (see Figure 5). The contemporary map shown in Figure 6 encompasses the entire continent of Africa. This brief historic comparison demonstrates that as geographic coverage of yellow fever has expanded, the density of diseased space has also correspondingly decreased.

Indeed, after the invention of the yellow fever vaccine in the 1930s and subsequent mass vaccination efforts (see Rogers et al., 2006; World Health

Organization, 2014b), the disease is no longer the major public health concern in many parts of the world that it was in the 19th century. Yet the disease remains endemic in 44 African and South American countries (World Health Organization, 2008). At the same time, because the spread of this disease has been largely contained, contemporary maps no longer show cases (i.e., actual diseased space) because there are so few. Rather, they show areas at risk for becoming diseased space, thus further advancing an overall narrative of scientific progress by encompassing increasingly larger areas, demonstrating global containment.

The Biomedical Model and Implications for Disease Mapping in the 21st Century

Today public health is global health, and researchers at the local, state, national, and international level routinely coordinate disease prevention and health promotion efforts across large geographic areas. Within this context, disease mapping continues to be a powerful data visualization tool, and new technologies over the past few decades such as geographic information systems have allowed researchers to create increasingly sophisticated visual representations (see also Lawson & Kleinman, 2005). Thus, understanding the ways in which these representations visually construct knowledge about how disease is situated in geographic space has significant implications for contemporary public health decisions.

The earliest surviving disease maps (see Figures 2 and 3) established visual strategies for enacting metaphorical control over diseased space in ways that promote Western ideologies about medicine that can still be seen in contemporary maps (see Figure 6). Further, these ideologies often frame how Western cultures conceive of disease, illness, and health in the 21st century. By positioning disease and illness as *other*, as a deviation, as Mishler (1981, p. 3) put it, from normal human experience, Western medicine works to advance the notion that disease and illness can be managed, controlled, and more important, conquered. Indeed it is difficult not to use the language of conquest when describing disease and illness in Western cultures in the 21st century because this perspective is also reinforced through language in the form of war metaphors (see Segal, 2005).

Yet many cultures see disease and illness differently, and some read and use maps in ways that differ dramatically from those in Western cultures (see Turnbull's 1989 discussion of aboriginal maps). Thus, if global public health practices and decisions are shaped only by the ideologies that underlie Western medicine, we may miss opportunities to see other problem-solving approaches as well as benefit from non-Western perspectives.

Segal (2005) explained that Western medicine emerged in the 16th and 17th centuries after a shift occurred in medical practice from attending to the "body as a whole" (p. 24), which characterized humoral theory, to attending to the "medical body" (p. 26). This move from the "diseased person" to the "disease community" (p. 27), as Segal put it, has been critiqued by Foucault (1973) as leading to the institutionalization and mechanization of Western medicine. Indeed, the perspective advanced by Western medicine can reduce disease, illness, and even health to disembodied things that exist outside of bodily experiences. Many diseases are caused by external agents—viruses and bacteria, for instance—but the physical state of being sick or healthy is embodied. The ideologies that underlie Western medicine, however, can work to downplay and mask the notion that illness is a lived bodily experience.

This discussion has highlighted several limitations of Western medicine. Yet the ideologies that tend to underlie Western medicine have also offered a way of thinking about disease, illness, and health that facilitated the move toward our modern-day public health perspective with its emphasis on disease prevention and health promotion in populations. The history of public health can be traced back to antiquity (see Rosen, 1993), but public health was only formally recognized as a discipline in the mid-19th century (Krieger, 2011), during a time when the evolution of contemporary statistical graphics had entered a "golden age," as Friendly (2008) described it.

Patients have individual experiences with sickness and health, but epidemics affect populations. And attending to an epidemic requires adopting the broader perspective that Western medicine facilitates. Western medicine allows researchers to see epidemics as occurring within populations and to see disease and illness as measurable and quantifiable—that is, as information that can be used to draw generalizable conclusions, which can then lead to informed public health decisions.

The data visualization techniques used in the early yellow fever maps illustrate this shift from an individual to a group-based perspective. Seaman (1798, see Figure 2) and Pascalis (1819, see Figure 3), for instance, each include a single dot and a number on their maps representing individual cases (patients). Each number also correlates with a short description of each patient's symptoms in the body of the report and often the time frame for the development of symptoms and the progression of the illness. Thus, the more detailed qualitative information in the report is separated from the less detailed and quantifiable information shown in the map. Similarly, Jewell (1853) included detailed descriptive information. But unlike Seaman and Pascalis, he used two data visualization techniques that further quantify the information about this particular outbreak: his map, which includes cases and numbers, and a table next to the map, which visually aggregates much of his descriptive information.

From a 21st-century perspective, much of the descriptive patient information in these reports probably seems unnecessary. But this level of detail probably served at least two purposes. First, without definitively knowing how yellow fever was actually spread or having the scientific knowledge to accurately diagnose the disease, these descriptions may have been necessary to persuade readers that the epidemic had indeed been caused by yellow fever and not another illness with similar symptomology. Second, considering the ways in which these three maps (see Figures 2, 3, and 4) attempt to group quantitative and qualitative information both textually and graphically reveals the transition to an increasingly abstracted representation of quantifiable information. Once researchers began to think about controlling disease from an epidemiological perspective—that is, in terms of how disease affects populations and not just individual patients—they could then use this quantitative information to develop specific theories of disease etiology. These theories could then be used to formulate hypotheses about disease spread and ultimately used to prevent future outbreaks.

This shift in thinking facilitated by Western medicine toward a population-based perspective may seem to reject the validity of patients' individual lived bodily experiences. But instead it offers a consolidated version of individualized experience, allowing researchers to understand disease, illness, and health in ways that they would not, indeed could not, have otherwise been able to understand. More specifically, the very notion that epidemic disease (or any disease) might be contained would simply not have been possible without this shift in perspective. The earliest disease maps show this change in thinking, which continues to shape how we conceive of disease, illness, and even health today.

The goal of critical cartography and modern-day geographic information systems, Crampton (2010) explained, "is not to over-turn this [scientific] way of knowing ... but to ask how it has come to be so powerful ... to ask what the implications are of this knowledge and whether or not alternative ways of knowing are possible" (pp. 39–40). Further, he suggested that "one way to challenge [these] orders of knowledge is by putting them into historical perspective" (p. 17). By conducting a selected history of yellow fever mapping, this article seeks to do just that—more specifically, to illustrate the ways in which historic disease maps established a visual precedent for invoking metaphorical control over diseased space, the ways in which the ideologies of Western medicine reinforced this control, and the ways in which these maps shaped the visual conventions of disease mapping that are still in practice today.

Mapmaking, Jacob (1996) explained, is about creating "possibilities":

> Every map displays a specific world; so does it display the world as it is, as it was, as it will be, as it could be, or as it should be? Each of these possibilities implies a specific view of the map and specific intellectual operations. (p. 195)

Disease maps show a snapshot of a particular epidemic in space and time at a particular point in the past. But while these maps document the previous state of an epidemic, they are not really about understanding the past. Disease maps are created to better understand the future. These data visualizations tell us about what happened, but more important, they tell us about what might happen—the world as it might be or could be (to use Jacob's wording). They tell us what is possible to know and believe about the future, which in turn allows us to have some sense of power, authority, and ultimately control over that future.

Authors' Note

Figure 6 reprinted from *Lancet Infectious Diseases*, 11, Jentes, E. S., Poumerol, G., Gershman, M. D., Hill, D. R., Lemarchand, J., Lewis, R. F., Staples, J. E., Tomori, O., Wilder-Smith, A., & Monath, T. P., for the informal WHO Working Group on Geographic Risk for Yellow Fever. The revised global yellow fever risk map and recommendations for vaccination, 2010: consensus of the Informal WHO Working Group on Geographic Risk for Yellow Fever, 622–32, (2011), with permission from Elsevier.

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