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Mapping Disease Patterns

For as long as disease patterns have been mapped there has been skepticism over the value of the pictures which are drawn. For instance, a map of the geography of the 1832 influenza epidemic in Glasgow (Scotland) was produced by the inmates of a lunatic asylum, mainly to occupy their time [1]. Later, in the nineteenth century, the value of mapping disease patterns was recognized as specific epidemiologic breakthroughs were attributed to the insight gained from mapping. Often cited is a map of the distribution of deaths from the 1848 cholera epidemic in London (England) which, so the tale goes, inspired the removal of the handle of the water pump at the center of a cluster of dots on the map, resulting in the curtailing of the epidemic [12].

Maps of diseases are like news pictures of crowd trouble. Viewers should always ask themselves what is not being shown in the map while looking at what is there. In particular, look around the edge of the map. Ask why it ends where it does. For instance, maps of diseases are often centered on the point the author thinks is most important. Figure 1 shows the central section of John Snow's map of deaths from cholera in Soho. Note how the eye is drawn to the pump in the center, particularly by the very high number of deaths at the intersection of Cambridge and Broad Streets. Had Snow drawn his map of all of London he would have discovered a greater density of deaths just south of the river Thames, as shown in Figure 2. This concentration would have changed location again had Snow had recourse to an isodemographic base map, as shown in Figure 3. As our picture of a disease pans out, as we include more cases and as we change the way we view the picture, the patterns on our maps show change too.

Disease mapping has been most strongly influenced by the history of diseases. Figure 4 shows the prevalence of 12 major causes of death in England and Wales since the publication of Snow's map of cholera. Infectious diseases now account for a tiny fraction of deaths in developed countries (which can afford most disease mapping and research). It is causes of death which are not declining, such as suicide, and those which are rising in importance, such as cancers, which increasingly interest researchers. For these causes of illness and death the analysis of point patterns around particular sites is

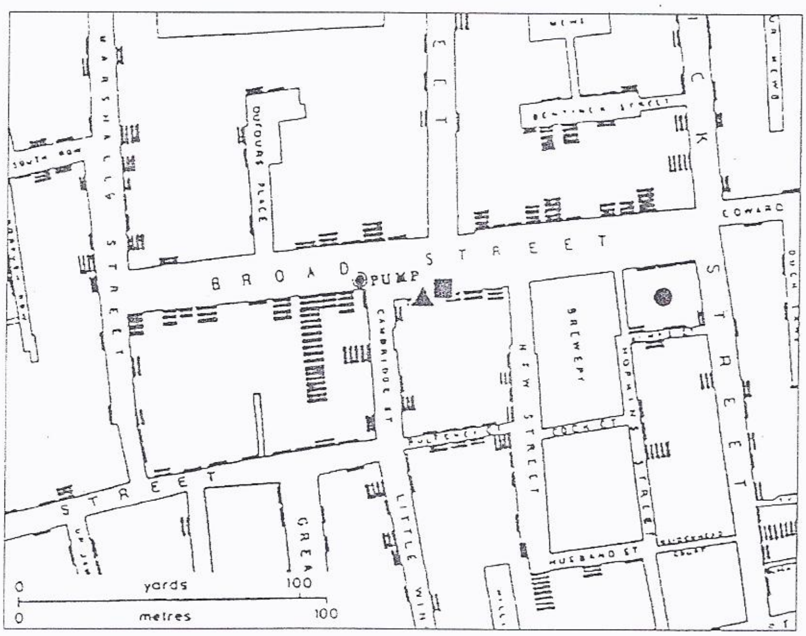

Figure 1 John Snow's map of cholera deaths in Soho, London, 1854 – taken from Cliff & Haggett [1, Figure 1.15D]

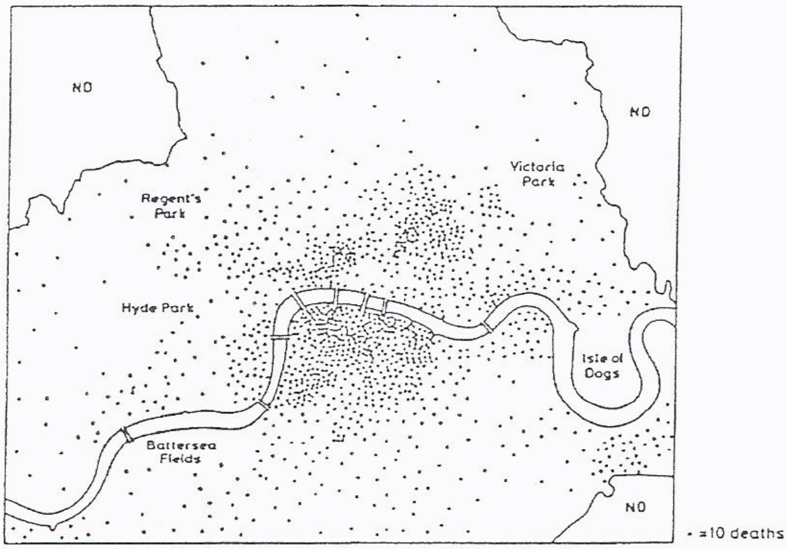

Figure 2 Cholera deaths in London in 1849 – taken from Cliff & Haggett [1, Figure 1.3B]

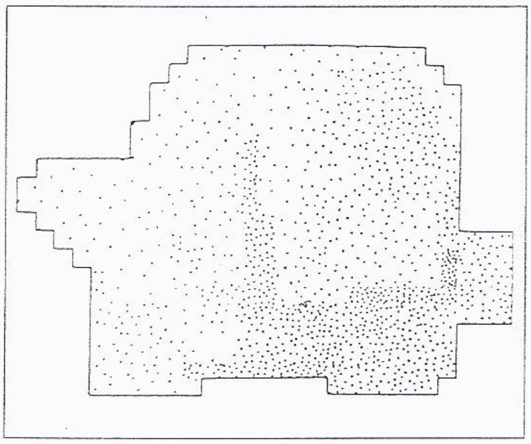

Figure 3 Figure 2 on a population cartogram – taken from Cliff & Haggett [1, Figure 1.18D]

still a major issue, but the patterns are usually far less clearly spatially defined than were outbreaks of cholera. More importantly, it is increasingly being accepted that more abstract factors, such as social inequality, can lie behind particular patterns of disease, and these require more abstract mappings for their study.

There are many different ways of mapping disease but here there is only space to explore one alternative. The alternatives include traditional choropleth mapping, where areas on a map are shaded according to statistics about the population. Most common in epidemiology is the mapping of areas colored by their BAS091- standardized mortality ratios (*see* **Standardization Methods**). Another common form of mapping is to map points or the incidences of disease, and often color is also used here to highlight different types of disease. Various different point symbols can be used in mapping, particularly common is the use of proportional circles which are colored or segmented to highlight different features of a disease. The size of the circles is often made proportional to the population at risk of contracting a disease, at which point this type of cartography begins to merge into isodemographic mapping [4, 5].

Diseases occur across a population as much as across land. That is not to say that geographic distributions are not important, but that we should take account of the distribution of the population at risk to a particular disease, or cause, before mapping its pattern. One way in which this can be done is to use a map projection which draws every area in proportion to the number of people at risk living in that

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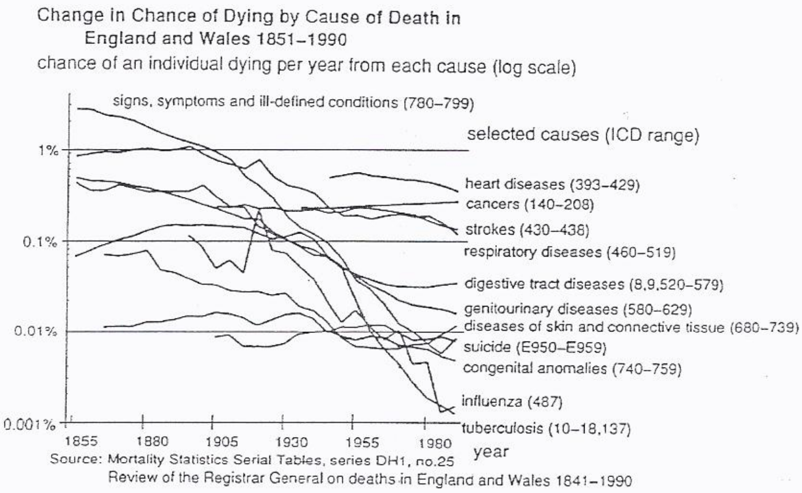


Figure 4 Cause of death 1855–1990 – taken from Dorling [3, Figure 5.21]

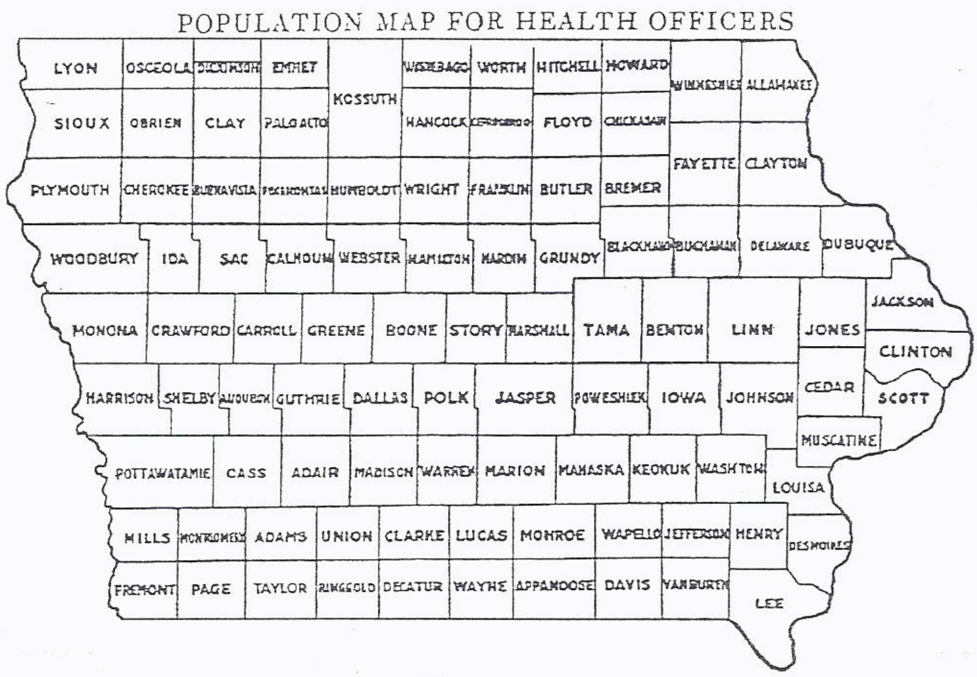
area – hence the term isodemographic ("equal people"). Isodemographic maps, more commonly called cartograms, are used for many purposes, mostly obviously in mapping the geography of elections. However, their most established use has been in disease mapping. Figure 5 shows one of the earliest examples of a cartogram designed for epidemiologic purposes [15, p. 1023]. Figure 5(a) is the conventional map of the counties of Iowa State, and Figure 5(b) is an equal population cartogram upon which colored pins were placed to show the locations of reportable diseases. The square in the middle of the cartogram is Des Moines city in Polk County.

The designer of the Iowa cartogram was a doctor working in the state department of health. Many researchers have been struck by the idea that they could learn more about disease through mapping it in unconventional ways. The first cartogram of London was an "epidemiologic map" produced by a doctor working for the then London County Council Department of Public Health [14]. The cartogram (Figure 6) contained crosses drawn in the borough rectangles to show the incidence of polio during the 1947 epidemic. Because the rectangles were each drawn with the same height, their widths are proportional to population as well as their areas. The borough with the highest rate of polio and hence the tallest column of crosses in the Figure was Shoreditch. Almost exactly 100 years separates the two London epidemics, which were first drawn on a map and cartogram, respectively. Cartograms showing distributions within countries came later.

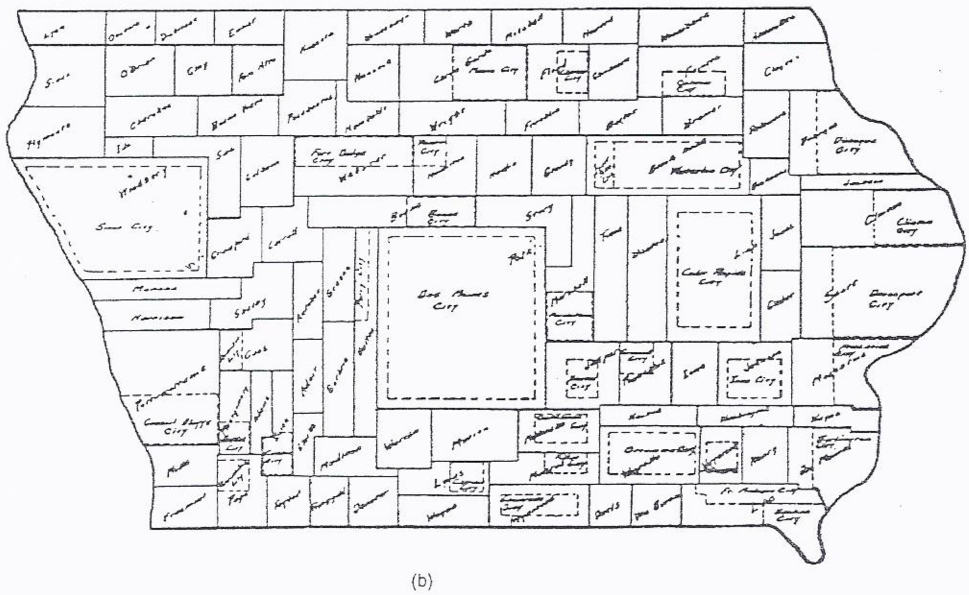
A claim was made to have produced the first cartograms showing national disease distributions only a decade after the crude cartogram of London was first drawn [6]. The nation was Scotland, and a separate cartogram was constructed by hand for each of eight age–sex groups. Figure 7 shows the cartogram being used to study the 1959–1963 mortality of women in Scotland aged 45–54. The author of this cartogram concluded that a national series of cartograms should be produced for each age–sex group for use in epidemiologic studies in Britain. This was never done, and it is debatable whether such an exact mapping base is needed in most studies. A single isodemographic base map of the whole population will usually suffice to uncover all but the most subtle of patterns.

A National Atlas of Disease Mortality in the UK was published in 1963 under the auspices of the Royal Geographical Society; the atlas contained no cartograms. However, a revised edition was published a few years later which made copious use of a "demographic base map" [7]. It is interesting to note that, when the revised edition was being prepared, the president of the Society was Dudley Stamp, who believed that "The fundamental tool for the geographical analysis is undoubtedly the map or, perhaps more correctly, the cartogram" [13, p. 135]. In the cartogram which was used in the revised national atlas (Figure 8), squares were used to represent urban

4 Mapping Disease Patterns



(a)



(b)

Figure 5 The use of cold vaccine in Iowa County Area, 1926 – taken from Wallace [15, p. 1023]

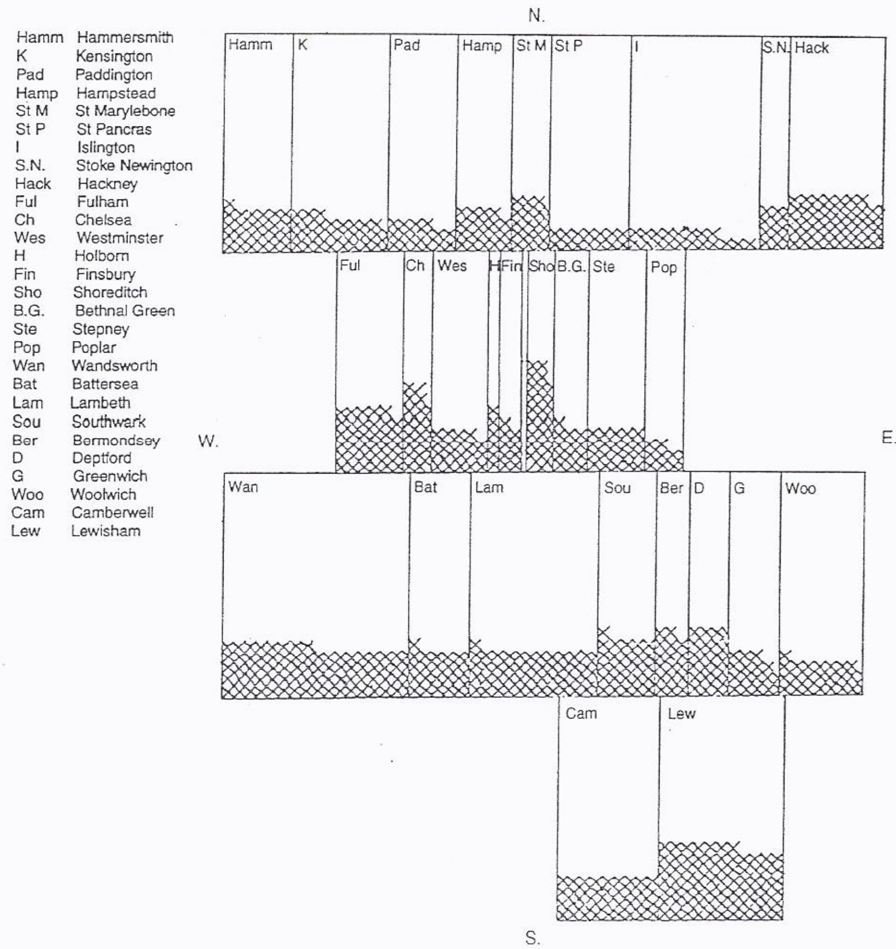


Figure 6 London borough cartogram showing 1947 poliomyelitis notifications – taken from Taylor [14, p. 201]

areas, while diamonds were used to show statistics for rural districts. No attempt was made to maintain contiguity, but a stylized coastline was placed around the symbols, which were all drawn with their areas in proportion to the populations at risk from the disease being shown on each particular cartogram.

In the *National Atlas of Disease Mortality in the United Kingdom*, Howe used a national cartogram to display the distribution of standardized mortality between 1959 and 1963 from separate as well as all causes of death for both men and women. High rates were seen in northern districts and some Inner London boroughs (including Shoreditch, which is also highlighted on one of the earliest cartograms of London; see above). Extremely high rates in central Scotland were particularly noticeable, as were the low rates in districts which surround London. At the extremes the average man living in Salford was 50% more likely to die each year than his counterpart in Bournemouth [7]. Both these areas are shrunk on a "normal" map. The pattern for women was very similar to that for men although, in general, it was less pronounced. However, women did have the highest mortality rate of any area on the map in rural Dunbartonshire, where they were more than twice as likely to die each year than were women nationally (allowing for local age structure). The cartogram highlights this area, but also puts it in the perspective of the populations at risk from the high mortality rates for women in and around the Glasgow

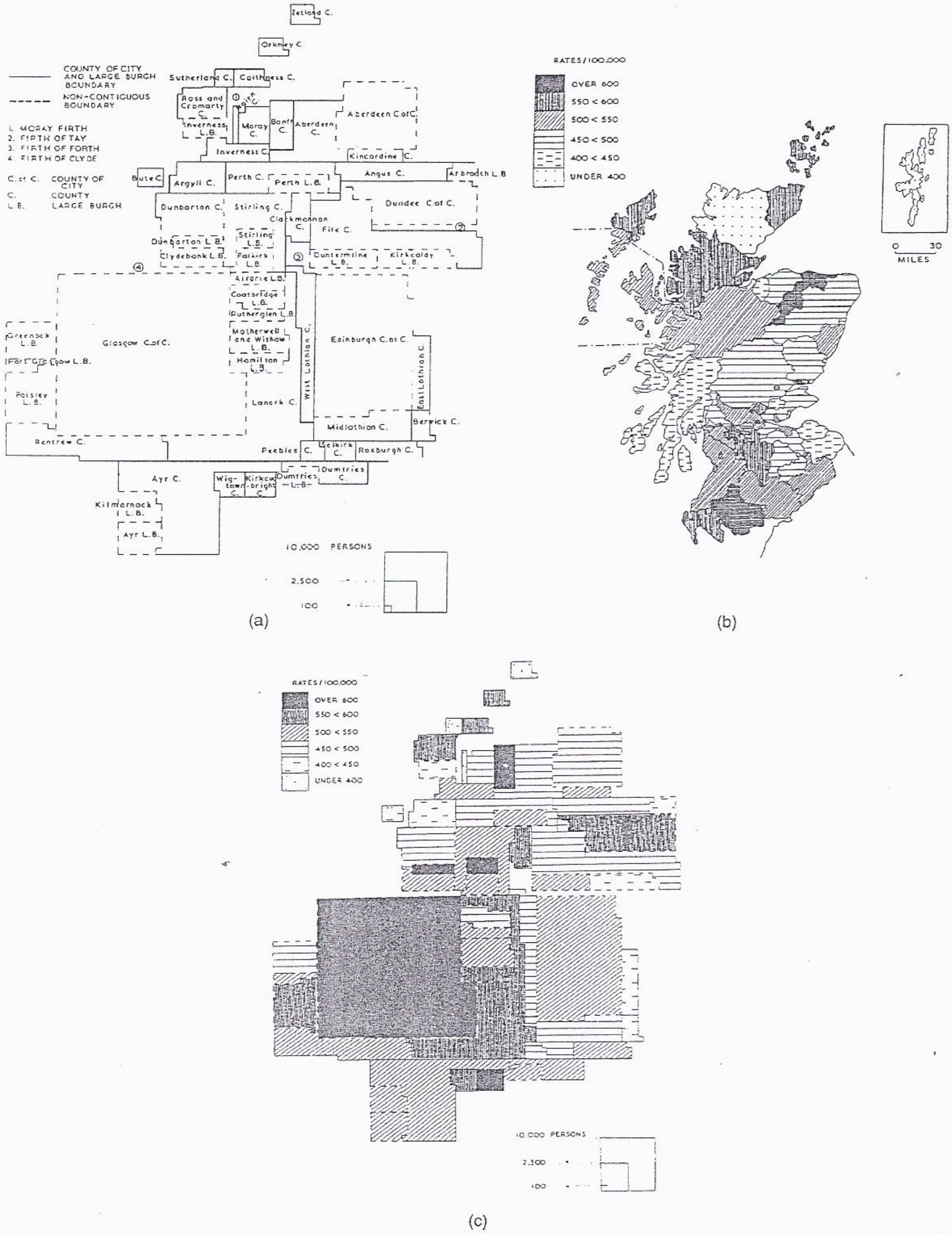


Figure 7 Cartogram and map of Scottish health districts – taken from Forster [6]. (a) Cartogram of females aged 45–54 in 1961 by Scottish health districts; (b) map of 1959–63 mortality rates of females aged 45–54 by district; (c) 1959–63 mortality rates of females aged 45–54 shown in (a)

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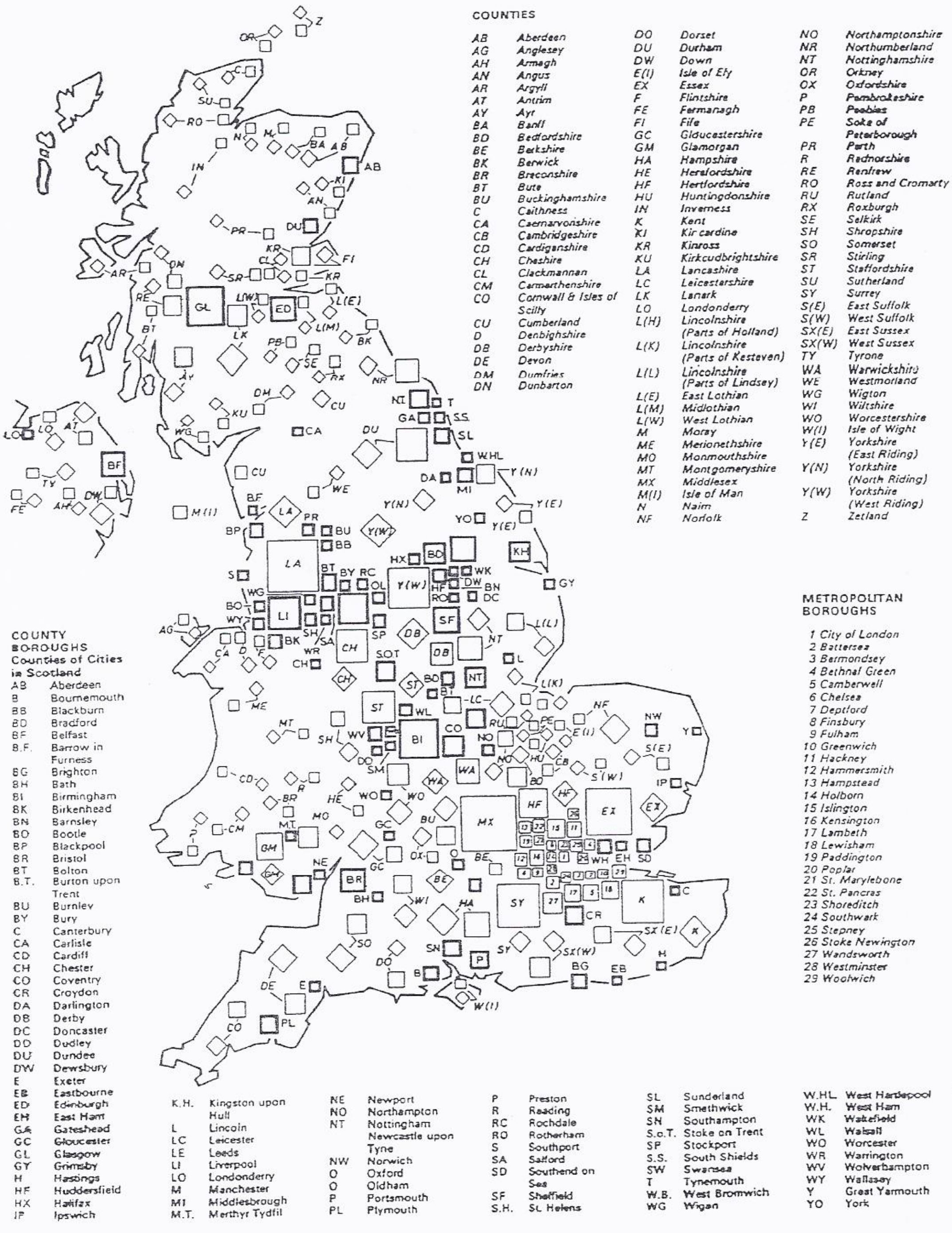


Figure 8 Cartogram of districts of disease mapping in the UK – taken from Howe [7]

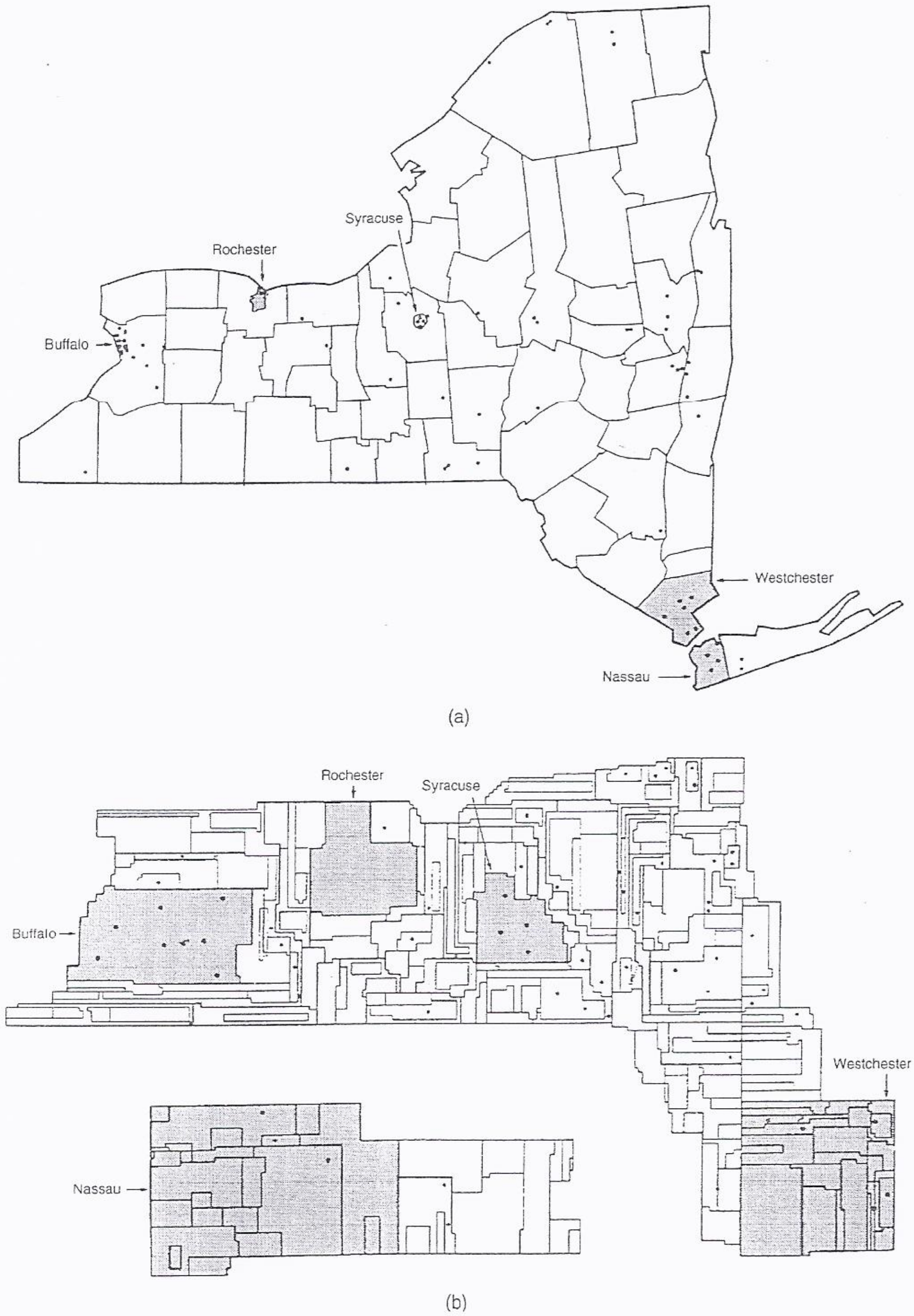
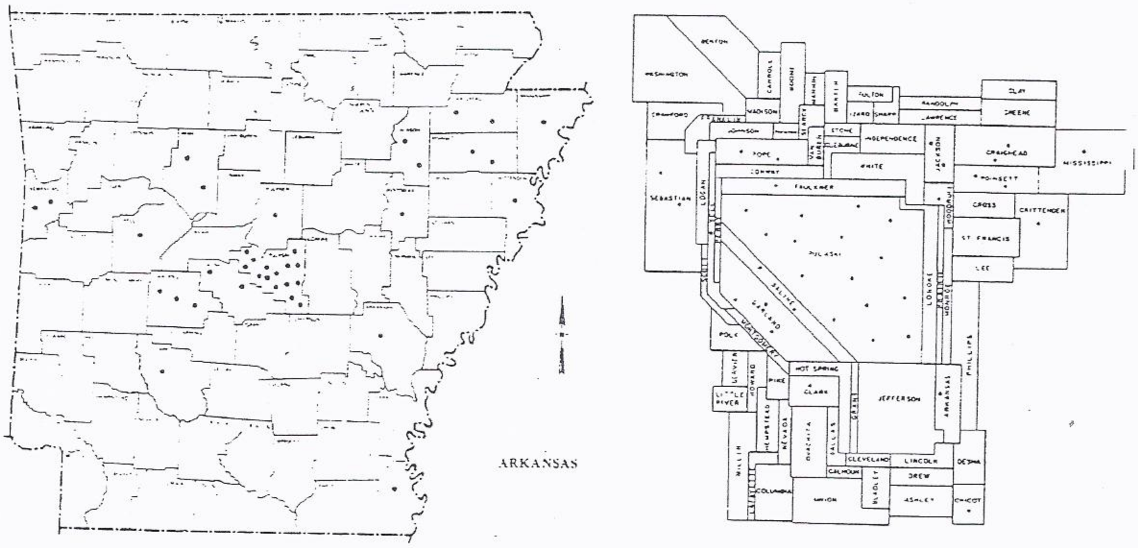


Figure 9 Wilm's tumour cases on (a) map and (b) cartogram in New York State - taken from Levison & Haddon [8]



(a) (b)

Figure 10 Salmonella Newport cases on (a) map and (b) cartogram in Arkansas State – taken from Dean [2]

area. Questions for investigation are immediately generated by comparing the maps in Howe's atlases with those produced by Forster for a decade earlier (see Figure 7).

Isodemographic mapping is also used to study the prevalence of disease – individual cases of a disease or death which together might possibly be connected. Figure 9 shows the distribution of cases of Wilm's tumor, a childhood cancer, identified in New York State between 1958 and 1962, drawn upon an equal land area map. Apparent clusters of cases have been marked on the map [8]. In the second diagram in Figure 9, the same cases are drawn upon an equal population cartogram and the apparent clusters can be seen to have been quite evenly dispersed across the population. The same process has been used in Figure 10 to illustrate how cases of Salmonella food poisoning occurring in Arkansas in 1974 were not unduly clustered in Pulaski county [2].

In recent years researchers have turned their attention to trying to develop cartograms upon which actual, rather than illusory, clusters of disease can
BAC063- be identified (*see* **Clustering**). The major problem with using population cartograms to identify clusters of disease is that the choice of which areas are closest to which on a cartogram can be quite arbitrary. For instance, if the same set of incidences of one particular disease were plotted on three different cartograms, then different parts of the country may appear to have dense clusters of cases depending on which cartogram was chosen. This would be true regardless of whether the clusters were to be identified by eye or by statistical procedures; the different base maps would result in different patterns emerging. The proposition that there is no single "true answer" as to whether a disease is clustered does not go down too well in some circles. Because of this problem a group of researchers at Berkeley developed a computer algorithm for identifying incidences of disease [9]. The algorithm was used to produce the cartogram in Figure 11 of San Francisco county, upon which apparent clusters of disease were shown to be false [11]. However, application of the method to another California county did provide evidence of some clustering of high cancer rates near oil refineries [10].

Mapping of disease patterns is becoming increasingly common due to the proliferation of computer mapping. However, many of these programs were designed to produce general maps of any subject and are often most appropriate to show land use or the distribution of points in physical space. Over most of the course of the last century, doctors, public health

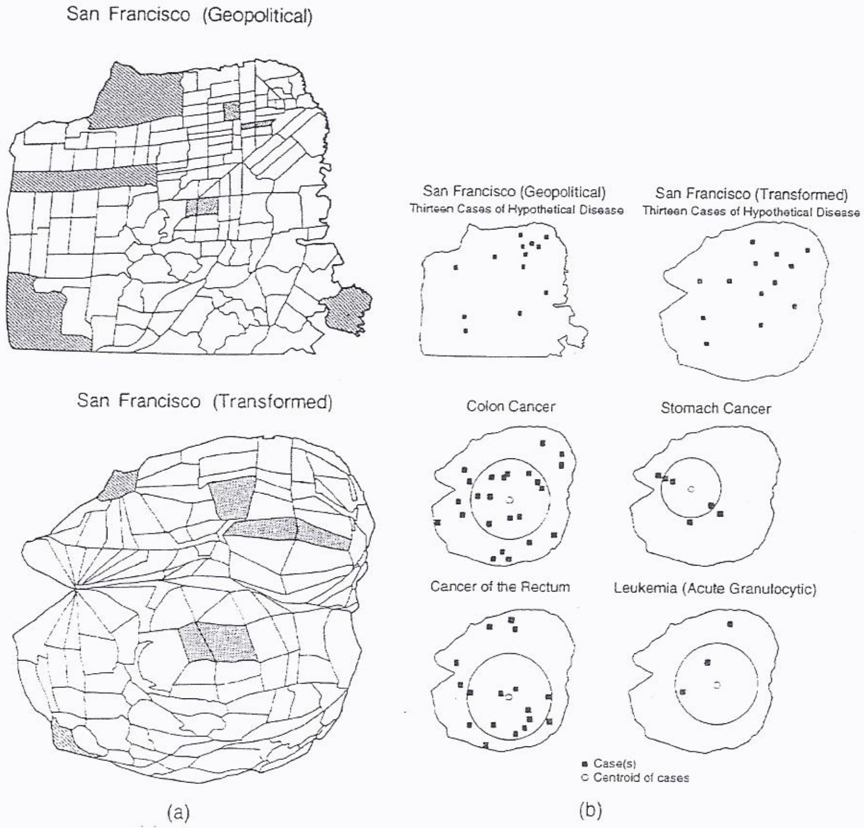


Figure 11 San Francisco map (a) for 1980 census, and cartogram (b) of hypothetical and actual diseases – taken from Selvin et al. [11]

officials, and researchers have discovered and rediscovered that traditional maps often do not provide the most appropriate projection to look for patterns of disease. Here, a few alternatives have been shown of just one different form of disease mapping to try to explain why it involves more than just sticking pins in paper.

Acknowledgments

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BAG032-BAG032M (*See also* **Geographic Patterns of Disease; Geographical Analysis**)

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