1 Mapping and mapmaking

Mapping is a way of thinking about abstract things in a graphic and practical way. In this book, the things thought about are the nature and diffusion of diseases, the ways viruses and bacteria spread through a neighborhood or around the world. The abstractions these maps consider are the ecologies advancing or impeding viral and bacterial introduction to human communities. The idea is not simply to use mapping descriptively to represent statistics to describe so many cases here or so many deaths there. That is important, but in itself insufficient. The real objective is to understand the *relation* between viral or bacterial communities, their human hosts, and the environment that inhibits or encourages their relationship. Typically, the hope is that by identifying elements of that relation, and then interfering with them, the intrusion of dangerous bacteria or viruses can be controlled and limited, if not eliminated.

The task seems increasingly urgent these days. In the late 1960s, U.S. health officials promised that "plagues will be banished forever from Earth" (Lederberg 2003). Why not? It was assumed that vaccination programs, the availability of effective antibiotics, and a generally improving standard of

living had freed the developed world from the scourge of epidemic and pandemic killers. It was also assumed that other, poorer nations might be similarly advanced in only a matter of time. As officials declared victory over epidemic disease, however, the agents of those diseases were evolving in response to the changes then being made in society and in medical science. Today, we are in a new period of bacterial and viral evolution, the result of which has been a host of new diseases. These include AIDS/HIV, bovine spongiform encephalopathy (BSE, or mad cow disease), hantavirus pulmonary syndrome, Legionnaires' disease, Lyme disease, severe acute respiratory syndrome (SARS), West Nile virus, and the new antibiotic-resistant strains of diseases like tuberculosis and syphilis.

"Although these occurrences may appear inexplicable, rarely if ever do emerging infections appear without reason" (Morse 1999). Understanding those reasons has been a primary goal of medical mapping at least since the early nineteenth century. Even earlier, medical mapping was used to consider if not the nature of this or that disease, then both its patterns of diffusion and the methods by which it might be inhibited. Mapping was an approach employed both by the officials charged with responding to this or that disease incursion and the medical personnel who struggled to treat those afflicted. By contemporary standards, the techniques of mapping and mapmaking were as crude and limited as the science they presented. But that does not mean they were ineffective. Then as well as now, mapping served and serves the science of its day. The maps that result are traces of that science, evidence of both the brilliance and the limits of the medical thinking that informs and is informed by the mapping.

The emerging diseases of our age occur at a time when new techniques of mapping promise the potential of a better understanding of specific states of health, illness, and the conditions that promote one or the other. Geographic information systems (GIS)—computer not paper-based—share with traditional mapping an approach that is graphic and cartographic as well as statistical. Their power resides not only in the clarity of their presentation, but also in the manner in which the mapping process encourages our thinking about the relations between microscopic agents, human host populations, and the factors that encourage or inhibit their mutual relations. In this, mapping stands not independent of but in association with the other tools of epidemiology and public health that assist in our understanding of both the nature of human disease *in situ* and the potential for its containment.

The history of medical mapping is the history of an ecological perspective on the emergence and containment of states of disease because "mapping" refers to a way of thinking that is inherently ecological. It assigns relations between elements of one or more abstract sets in a manner that permits all to be considered together. In that assignment, mapping assumes at least one of the sets thus joined has a spatial component that provides a locational anchor (spatial coordinates) that is geographically descriptive. Regardless of whether a physical map results, the cognitive process of map thinking encourages a perspective that is relational and spatial at once. Mapmaking, on the other hand, refers to the process by which map thinking is transformed into a concrete two-dimensional artifact, a map (Wood 1993b).

Mapping is like story telling (Wood 2002; Kaiser, Wood, and Abramms 2005). Mapmaking is like story writing, indeed like publishing: it transforms the narrative into a form that can be reproduced and then shared. While distinct, the two are related. There is no mapmaking without map thinking. Map thinking inevitably invites a concrete result—a map artifact broadly sketched on paper, carefully drawn by hand or developed on a computer using a GIS program. How maps are made affects the mapping, transforming the way we understand the relation between the sets mapped. Methods of production and distribution together affect the conceptual process (what can we do and how can it be distributed?) that shapes the final artifact. Together, these related processes (thinking, mapping, making, and distributing) determine not only the map artifact, but also the process of map thinking, the way we first define and then address a particular problem in the context of a specific theoretical perspective.

Speaking, writing, publishing: each affects the other in myriad ways that uniquely contribute to the evolving story each attempts to tell. Mapping, mapmaking, and map publishing are similarly interdependent. But the root in mapping lies map *thinking*, the process through which elements of experience are abstracted, identified, joined, and then transformed into a common narrative.

Destinies

"In health care, destiny is geography" (*Dartmouth Atlas of Health Care* 1998, 21). Because both pathogen and host interact within an environment, understanding their relation means understanding the environment. This is first and foremost a geographic exercise in which elements encouraging or inhibiting the host/pathogen relation are located in place, in space at one or another scale. Both disease and its inverse, general health, are the result of a *pas de deux* danced in place by host and pathogen to a complex beat of local, regional, and global environmental elements. But it is also true that "overall disease burden is primarily a function of demography" (Gibson et al. 2002), the characteristics of human communities and the environments in which they exist. But demography is no less geographic, occurring in place and at various scales. And so, in thinking about health and disease we have to think simultaneously about demographic and geographic characteristics of host *and* pathogenic communities at various scales of interdependence, encouraging or inhibiting specific relations.

The challenge of mapping the complexities of an illness or the conditions promoting health is that both demand enormous specificity in the search for a general perspective. Each incidence must be carefully located, each factor precisely assigned. The greater the incidence of occurrence, the more potent the resulting map. For example, little can be said of two isolated incidences such as that of Isabella de Gracias, 19, or Mei Tang-Mu, 26, who each gave birth to a premature infant of 880 grams and 856 grams, respectively, at Women's and Children's Hospital in Vancouver, Canada, on June 16, 2003.[1] Certainly it is important to the families themselves, including the mothers, but as stated the incidents are disconnected, isolated factoids outside any meaningful context. That the first lived at 250 East

Hastings and the second nearby at 300 East Pender reveals only that both lived within a kilometer of each other in the downtown east side area of Vancouver. However, mapping all Vancouver's premature births by maternal residence may show that in 2003 women from the downtown east side were 24 percent more likely to have premature or low-weight births than were those from any other neighborhood in the greater Vancouver regional district.

The first question immediately becomes what contributes to the localized likelihood of premature and low-weight births? A number of factors have been identified, including the age of the woman, general health status, income, nutritional factors, number of prior births, likelihood of drug abuse, and the degree of prenatal medical care. Many of these correlate with income. In general, the poorer the mother, the less likely she is to have good nutrition, good healthcare, and so on. A quick look at income data by census tract identifies the Vancouver downtown east side, an area with a high proportion of immigrant and First Nations peoples, as among the poorest in Canada. Where women are relatively recent immigrants from developing countries, other data suggests that another level of risk is introduced.

In this way, we build from the specific to the general. Seeking means to address the problem, programs can be tailored to increase the likelihood of prenatal care for those individuals whose pregnancies are, by profile, most at risk. Maps invite locational responses (a clinic, a prenatal program) to locational problems (too many premature births in a neighborhood). Discussions of what services need to be offered, and where, become the concrete response to a general issue discovered in an aggregation of specific events (premature births in specific environments and their relation to variables—income and nutrition) at one or more scales of address.

The second, less frequently asked question is what is this phenomenon related to? To what extent may rate of low-birth-weight infants be an indicator of a more general context of illness, one of several health outcomes of socioeconomic or spatial factors? Here we find that in the United States at least the incidence of low-birth-weight infants correlates with incidence of tuberculosis (a disease of poverty), of HIV/AIDS, and of crime (Wallace, Huang, Gould, and Wallace 1997). All are outcomes of the environments we create and then impose upon those who live in areas that are socioeconomically deficient (Wallace and Wallace 1997).

Just as important, these urban zones of illness and crime are not contained, but in their turn become reservoirs by which disease radiates through the greater urban area. "Time incidence in the central city determines the incidence in the surrounding counties, as modulated by the area density of the community pattern" (Wallace and Wallace 1997, 1, 343). In building the maps of low-birth-weight infants and the socioeconomic characteristics that promote them (demographics, healthcare service levels, income, social service, and so on), we map not just a single problem but the context of a host of problems whose determinants are shared (Holling 1992; and Wallace et al. 1995). In this process, we

also map reservoirs of ill health that affect not simply contained neighborhoods or specific populations, but the greater population as well.

This is the way mapping approaches the world. It thinks about classes of discrete events (people with diarrhea, respiratory distress, hernias, etc.) in the context of potentially relevant data (location, income, exposure to pathogen, etc.) in an attempt to demonstrate or disprove a causal relation. When events are aggregated at specific scales (neighborhood, city, state, nation, etc.) and in association with related classes of data (income, nutrition, family size, etc.), a graphically demonstrable conclusion matures that suggests potentially fruitful activities. At every step there is a balance between individual events within a class of occurrence and the context that enables or inhibits them. It is in the ecology, in understanding the relation of shared events (low-weight births) and their enablers (income, nutrition, etc.) that the hard thinking of mapping occurs.

Paradoxically, perhaps, mapping results as much from what is left out as what is included. "For a map to be readable, and useful, certain—in fact most—information needs to be excluded" (Heersink 2001, 136). The world is too full, the potential associations too numerous, to cover everything. From the start one therefore focuses, cuts, and defines the problem, then distills its elements in a way that permits what is left to be mapped. The question is always what elements are necessary to describe the determinants of this or that condition. How will these selections best describe the problem we have to consider?

These decisions are reflected in every map, each decision based on the intent of the mapper and the technologies available to the mapmaker. The intent of the mapper, who may or may not be the mapmaker, is crucial to the map that results. This should not be a surprise. All research reflects the intent of the researcher, who chooses to consider a limited set of data and then to present it in a particular fashion. Whether the data is argued in statistics, graphs, charts, or text, the nature of the task is always about the self-conscious selection and arrangement of data in the context of a hypothesis or theory.

Because maps are presumed to be representative of an objective world, however, the nature of that exclusion in service of a theory is sometimes obscured. It is therefore important to be clear that what the map is for determines everything that goes into it and all that is excluded from it. The mapped result typically will be a distillation of observed relations, not a representation; at least not in the way "representation" is typically used (Ingold 2000; Wood 1993a).[2] This is true because mapping is always the embodiment of a thesis, not a simple representation of an objective reality independent of that thesis. Medical mapping typically proposes a causal relation between selected fragments of a spatial ecology, not the ecology itself. Still, we often say a map is "a representation" (Robinson and Petchenik 1986), a two-dimensional picture of something happening in the four dimensions of our existence. This is how most people are taught to think of maps, just as they are taught to think of science as objective and, therefore, value free. It is this very objectivity, this representational ability, that some insist raises contemporary geographical information systems (GIS) mapping to the level of a "science"

(Schurmann 1999). But science is more complex than that (for example, see Lewontin 1992) and so is the process of mapping. So, too, are the maps that result.[3]

Mapping and mapmaking do not permit us to see the world in an objective fashion. Instead, they let us study interpretations of selected aspects of a spatially grounded, interrelated process. These interpretations are distilled in the abstractions we fashion as mappers, mapmakers, and as scientists. Mapping does not "provide the ability to imagine the world from 'outside'" (Hall 2003, 158), a necessity for the "objectivity" some cartographers promise. Rather, mapping puts us *inside* the world in a way that considers its constitutive relations. Nor do mapping or mapmaking "produce space" (Lefebvre 1974) in some magical way. Rather, they permit us to organize spatial events at scales that best articulate an understanding of the phenomena chosen for study. The outcome is an interpretation of the relation of things, of spatial relations between selected aspects of a dynamic ecology. The maps that result are neither the world nor an objective record of our worldly experience, but a means whereby we come to understand aspects of it. Maps embody the mapping, which is a way of making sense of health and disease in populations in the world. It is as simple and as hard as that.

Propositions

The authority of mapping resides in its relational perspective. Its power is derived from its grounded approach in which location is a principal attribute of the characterizing of events. It is as well a graphical way of thinking, in intention if not in fact, whose constituent propositions take the simple bidirectional form: "This is there" and "there is this" (Wood 2003). Mapping invites associations based on this bidirectionality: If these deaths (this) are clustered around that well (there), then that well (there) is central to these deaths (this).[4]

It is this equivalence that assures mapping presents the articulation of a relation or of relationships whose individual elements are necessarily spatial, transposed into locations (x,y) on the plane of the map. Isabella de Gracias and Mei Tang-Mu live at addresses whose coordinates locate their homes in proximity to each other in downtown east side Vancouver. The women are related locationally (geographically) by their proximity. They are related as well by their membership in the set of mothers who gave birth to low-weight babies. So, too, are other mothers living in Vancouver who gave birth to premature children in 2002 and who may be geographically related to de Gracias and Tang-Mu. When their home addresses relate them all, one to another, making of their individual experiences a range of experience, the "there" of mothers of low-birth-weight babies in the downtown east side blossoms categorically and geographically in the mapping.

The neighborhood they share is described both geographically and by attributes (physical and social) that may be contributing factors to their membership in the class of mothers of low-birth-weight babies. "There," the characteristics of the area, contribute to "this" problem that occurs within an area whose characteristics are known. The streets on which de Gracias, Tang-Mu, and the others

live share common sources of water and power, a similar density of habitation, and a broadly similar general socioeconomic profile. Those qualities are part of the broader domain (the downtown east side) to which a specific range of events (premature birth of low-weight babies) is joined in an attempt to uncover causative relations. Range and domain are the "this" and "that" which are mutually defining.

What results is a "structural coupling" (Maturana and Varela 1992, 76–77) in which a history of recurrent interactions leads to a structural congruence between two or more parts of a system whose relations are identified through the process.[5] Mapping fuses the elements of these couplings in a mutually defining relationship, distills the relations within the structure, thereby reducing the mass of potentially relevant data in the search for pertinent associations. Perversely, the process embeds temporality and motility in a map that seems atemporal and motionless (Beck and Wood 1976, 214–215). In a map we may see the homes of women who gave birth to low-weight babies as if the locations were eternal, unmoving. But the women come from elsewhere, and the homes in which they now live are a base from which they travel in the greater community. Home is also a place they will leave, moving on to other apartments or homes (and perhaps other cities) across their life span. In the mapped aggregation of a time, that of these births, we ignore these facts and instead present a fiction of constancy, of a "this" and "there" that is frozen in time, as if nobody ever moved anywhere at all.

Similarly, while the map is a plane in which movement can only be suggested, motility, like time, is embedded as well. One may chart the progress of a disease around a nation or around the world in a map: West Nile virus was here in 1999, there in 2000, and moved on to that place in 2001. The travels of an individual are noted through different symbols representing movement along a mapped route. But the whole is itself out-of-time, a distillation of movement to be read as a whole in one glance. We take both the temporal and motile synchronicity for granted only at our peril. It is integral to the map's power and an element that contributes much to the map's utility in medical sciences.

When the process works, the result is transforming. The medical histories of Isabella de Gracias, Mei Tang-Mu, and fifty other women are distilled to a single class of events occurring within a specific time frame. That class is located within a domain (Vancouver's downtown east side) of city streets that is understood through a set of attributes (income, housing density, etc.) that may or may not help us understand the problem of low-weight births in that neighborhood. Mapped together, the range (this) and domain (there) are transformed into a single argument that relates the attributes of one to the characteristics of the other. The result is a testable proposition relating high incidence of low-birth-weight babies to characteristics of the downtown east side that simultaneously is defined as an area whose characteristics promote the risk of low-birth-weight infants. In other words, this is there, and there is this.

"There no longer can be any doubt that maps are propositions, that every map is an argument, and that maps shape our 'realities' in the same way those realities are influenced by conventional text" (Churchill and Slarsky 2004, 13). By arguing a relation of low-birth-weight babies and the downtown

east side, one proposes a relation, at another level, between socioeconomic characteristics of the area as factors contributing to the incidence of occurrence in that area. If the maps shape our reality through the testing of relational propositions in this process of structural coupling, they do so only within a broader frame of the assumptions and suppositions of medical theories explaining disease and differing states of health. That is, propositions occur only within a theory of health and disease, which determine each proposition to be argued or the policy to be considered in addressing a disease outbreak.

Histories

The relation between theory and scientific proposition is generally accepted in medical history and sociology, but often ignored by those considering medical mapping. Those who promote mapping as a tool of discovery say that historically "mapping made scientific discovery available to all" (Jenkins 2001). They argue that the map's ability to analyze and articulate locational data in an easily comprehensible fashion facilitated a more popular understanding of complex issues of disease and health. But the importance of mapping to the process of scientific thinking, and especially medical thinking, is less commonly considered. The very accessibility of maps, some argue, came at the price of the statistical rigor that is the hallmark of contemporary medical science. Because of this, many assume the *real* thinking, the hard thinking about health and disease is not done by mapping but through statistical manipulation. Map*making* is just a way to display statistical interpretation of the relation between a pathogen and a host.

Nothing could be further from the truth. From their coterminous beginnings, medical mapping and medical statistics have always shared a common intellectual base. While many today think of mapping as no more than a way to illustrate statistical conclusions, the truth is that "the interplay between figures [maps] and texts is critical to the understanding of [scientific] papers. Each needs the other to tell the story" (Cockerill 2003, A2–3). Mapping and statistics both use graphic presentations: the map, the table, and the graph. Both seek to create categories of meaning from the sets of data they consider. Each in its own way proposes a relation between those sets and then tests the validity of that proposition. Statisticians may analyze mapped relations just as mappers may present statistical relations. Either way, the real question has always been *what* data is to be correlated and *how* they relate to elements that may encourage or discourage this or that phenomenon.

Medical mapping and medical statistics are both a part of the story of the slow progression of medical science and its struggle to understand the nature of disease and its presence within this or that society. Both developed not apart from, but within, the context of a broader medical science and the society that supported its attempt to confront the realities of endemic and epidemic disease. Mapping, statistics, and the sciences that they support grew not separate from, but as part of, the great transformation of a Hippocratic and Galenic medical tradition to one that defined states of disease and health in relatively modern terms.[6] One can't seek to understand the one without understanding the others.

The result is richer than the existing literature suggests and richer, too, than I expected when this project began in 2002. I then assumed, as does much of the literature, that medical mapping was a mid-nineteenth century phenomenon that arose almost spontaneously in the work of an adventurous, brilliant researcher or two. But genius is rarely fostered in a vacuum. The advances of nineteenth century medical mapping were real, but their reality was the continuation of a history that preceded them and prepared their way. Mapping did not arise full-blown in the nineteenth century any more than did bacteriology or virology in the twentieth century.

In struggling to understand the course of medical mapping through the range of maps that trace its history, the importance of mapping and printing technology is underscored. The history of medical mapping is the story not simply of medical progress but of progress in map*making* as well. Just as clinical medicine progressed through the introduction of specific instruments (the microscope, sphygmomanometer, stethoscope, thermometer, etc.), mapping developed through evolving technologies of production and distribution. Etched plates became copperplates that became lithographs. Hand presses became mechanized, their speed improved, and new printing technologies became ever-more capable of reproducing detailed graphics, first in black and white and then in color. More complex maps were produced and, just as important, could be shared.

Evolving computer technologies have permitted ever-more complex mapping and ever-more robust statistics not "out of time" but in time, within the history this book describes. They are twinned from the start, and the current "revolution" in Web-based data facilitating computer-based mapping is no more (but surely no less) than a next step in the conjoined evolution of mapping and statistics in service of medical knowledge.

But the real subject of this volume is not technological but conceptual. Its focus is the type of thinking that mapping promotes, and the ways of thinking that mapping brings to the study of disease. Because this book is about mapping as a way of thinking rather than simply a way of presenting, its lessons are generally rather than specifically applicable. Disease and health are my passion, my interest, and mapping is an approach I use in my work. But map *thinking* is a self-consciously intellectual approach to a startling congress of problems. To the extent this book serves its immediate subject, it offers a more general model informative to those whose interest may involve the potential of mapping in other areas. For this reason, the book is neither a simple primer in medical cartography nor an introduction to the epidemiology of infectious disease. It is for people in the health sciences interested in mapping and map thinking, and for those expert in maps and mapmaking interested in the study of health and disease.

The goal, therefore, is (there is no better way of saying this) to map the struggle to understand health and disease ecologies from the late 1600s to the present. Chapter by chapter a range of mapped events (plague, yellow fever, cholera, typhus, etc.) is considered within the concrete, interlocking domains of their occurrence. These are variously defined, study by study, as clinical, economic, geographic,

scientific, and social. The general intellectual environment in which the resulting distillation occurred was the medical science of the day, a science that maps both presented and contributed to. What results is an understanding of disease and health as ecological outcomes in which we are always active and complicit.

While this promises to be a study of the cartographies of health *and* disease, the majority of its maps are disease-related. The reason is that for most of the last three hundred years the vast majority of maps made in service of medical knowledge have been of epidemic or pandemic conditions that were a signal threat to the lives and health of thousands, and in some cases millions of people. Indeed, where it has been considered as an independent state, health has historically been defined as the absence of chronic or acute disease. Thus, the promotion of health has typically been seen as the absence of conditions that create this or that disease, not a state whose own properties could be easily and independently defined.

Special attention is given here, as it is in most medical mapping textbooks, to the mapping of one disease: cholera. For a variety of reasons, this was the most frequently mapped scourge of the nineteenth century, the modeling of which became the paradigm for other, later disease studies. The central figure in this period was Dr. John Snow, whose mapping of cholera in 1854 London is typically described as the Archimedian point of medical mapping, and not coincidentally, of epidemiology and public health (Vinten-Johansen et al. 2003, 392–399). It is the point after which nothing was the same, a fulcrum balancing a medical prehistory (the old way) with what came afterward (our way). Seminal as it was, however, Snow's work was only an event within a series of events, a point on a timeline that preceded him and continued into our time. Because so much has been written about Snow and the epidemics he studied, the chapters on Snow serve to organize a great deal of the story of our knowing as told through maps of disease and health. The importance of his studies lies not in his maps alone but more precisely in the manner he mapped—conceptually and graphically—a typography of disease that was graphic, concrete, comprehensible, and scientific.

Previous authors have typically ordered their studies of mapping and historical mapping either cartographically or "thematically" (Robinson 1982). Cartographic maps locate the incidence of disease (or the locus of its vectors) with dot-like symbols (points), in networks of incidence and diffusion (lines), or within areas of administrative jurisdiction (polygons). Others have assumed a map's subject would serve a taxonomy clearly placing it in a single thematic category (maps of diffusion, location, jurisdiction, resource, etc.). These categories are too limiting and artificial, saying more about the researcher than the subject at hand.

Because maps are ecological and relational, most share a range of cartographic symbol sets: points, lines, and aereal markers. For example, the incidence of low-weight births (points) occur among people who live on streets (lines) they traverse daily across neighborhoods with socioeconomic profiles (polygons). To separate these elements is to sunder the relevant relations, the very tale the map seeks

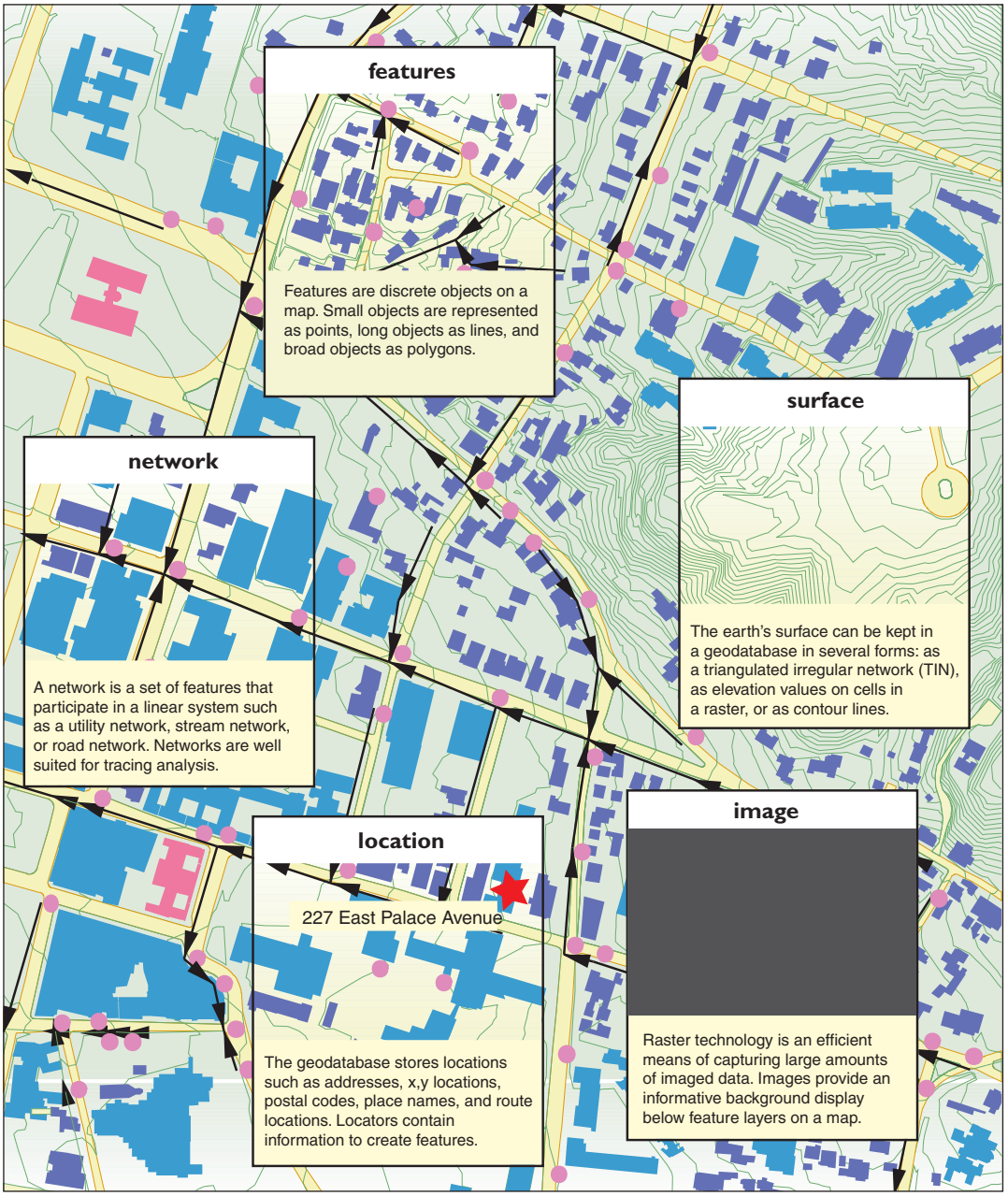

Figure 1.1 A taxonomy of mapped elements within a complex map environment. All work together to create a single argument, a proposition relating elements fused within an environment of connecting pathways that are cohesive and dynamic.

Source: Courtesy of the city of Santa Fe, New Mexico.

to tell. It is in the conjunction of locational feature, dynamic network, and general neighborhood that a map does all its work. To argue one to the exclusion of all others does no justice to the mapmaker's thinking or the resulting map itself.

It is not that symbolization and the specific content that symbols organize are not important. They are. So, too, is the general idea embedded in a thematic category, one that declares a researcher's specific topical concern. But symbolization and categorical choices are strategies of our knowing, not the knowing itself. The importance of medical mapping resides in the medicine being mapped, the relations being argued, and the thinking about states of disease and health the mapped result distills. And so this book is organized instead as a history ordered by the chronology of the slow advance of the medicine that individual maps served. This greater chronology asserts its own order upon the subject of both technologies of map distribution and production as well as the arguments individual maps present. And that, perhaps, is this project's most important lesson: mapping is important because it advances knowing. It is the science, and the way maps serve it, which should be our focus as new diseases and new health problems are confronted.

End notes

1. Isabella de Gracias and Mei Tang-Mu are fictitious examples used here for illustrative purposes. But the issue of low-birth-weight infants and the relation between economic status, age, parental history, etc., to the incidence of low-weight births is a real problem and one much discussed in the medical literature. And, of course, issues of socioeconomic disadvantage in Vancouver's downtown east side are similarly subjects of topical discussion and concern in Vancouver and its health provider organizations.

2. Against the traditional insistence by cartographers and geographers that mapping is representative is the work of the new or critical geographers (Lemann 2001), who in the 1990s were busy rewriting the history of mapping as a socially interpretative process. Details on the debate over mapping as a socially constructed rather than objectively representative process are best found in Tim Ingold (2000, 223–235) and in various writings in Denis Wood's oeuvre over the last fifteen years.

3. Whether mapping—whatever the technology—is a discipline, a tool, or a science depends, of course, on how one distinguishes science from other modes of knowing. For the flavor of the literature see, for example, Schurmann (1999); Wright, Goodchild, and Proctor (1997); Goodchild (1994); and Pickles (1997).

4. The idea of this equivalence and the propositional nature of mapping generally is based on work by Denis Wood (2003), especially work in collaboration with John Fels. Wood made available drafts of papers that advance their thesis but which at the time of this writing remained in review and not in press.

5. Maturana and Varela define history through an exploration of this process of structural coupling. Wood (2004a, 64–65) uses their phrase and more generally their approach to describe the manner and degree people are related in and through a shared environment—historical and modern—at every level.

6. This is a history told and retold by historians of science and of medicine. Those seeking popular, nontechnical, introductory texts in this area are referred to Porter's *The Greatest Benefit to Mankind* (1998) and Nuland's *Doctors: The Biography of Medicine* (1989).