

How Maps Work

Representation, Visualization, and Design

Alan M. MacEachren

To Fran

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www.guilford.com

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Paperback edition 2004

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Printed in the United States of America

This book is printed on acid-free paper

Last digit is print number: 9 8 7 6 5 4 3 2

Library of Congress Cataloging-in-Publication Data

MacEachren, Alan M., 1952-

How maps work: representation, visualization, and design / Alan
M. MacEachren.

p. cm.

Includes bibliographical references and index.

ISBN 0-89862-589-0 (hc.) ISBN 1-57230-040-X (pbk.)

1. Cartography. I. Title.

GA105.3.M32 1995

526—dc20

94-31138

CIP

CHAPTER ONE

Taking a *Scientific* Approach to Improving Map Representation and Design

Cartography is about representation. This statement may seem obvious, but it has been overlooked in our search for organizing principles for the field. Rather than restricting research in cartography to maps that present well-defined messages (and suggesting a single, map-engineering approach to improving the transmission of these messages, as the communication approach did), attention to maps as spatial representation expands the field. Exploring maps as representation forges important links between cartography and a variety of cognate fields concerned with this topic in its various facets (including geographical information systems [GIS] and remote sensing, as well as art, cognitive science, sociology, cognitive and environmental psychology, semiotics, and even the history and philosophy of science). This view of cartography does not discount the importance of communication-oriented research. Some maps do, in fact, serve primarily as vehicles for communicating specific messages. What taking a representational perspective on cartography does do, however, is place this research in a broader context. In doing so, it allows us to better recognize the limits that a communication perspective has as a driving force for the field as a whole.

To promote understanding of the implications that follow from the above contentions, I will begin by taking a brief historical look at the cartographic research of the past four decades. This research had a well-defined direction for much of this time, but during the past decade it be-

came clear that research cartographers, as well as practitioners, were becoming disillusioned with the field's direction. As a result, a number of critiques and suggestions for potential redirection have been put forth. It is within this context of change that the present book, with the perspective identified above, has evolved.

Two developments of the past four decades played crucial roles in establishing a research agenda for the study of map symbolization and design. The first was Arthur H. Robinson's dissertation (published as *The Look of Maps* in 1952), with its call for objective research, and the second was the adoption in the 1970s of a paradigm of cartography as communication science. I begin, therefore, with a brief overview of these events followed by some recent perspectives on the promise versus the limits of a "scientific" approach to cartographic symbolization, and a proposal for an alternative to "communication" as the basis for this scientific approach.

TOWARD FUNCTIONAL MAPS

World War II was crucial in shaping the direction of cartography as a discipline (and a craft).¹ As the result of the war experience of several U.S. geographers, particularly Robinson and his role as a principal player in government cartographic efforts supporting the military, the emphasis of the field shifted from production efficiency and graphic design toward map "functionality."

Beginning with essays from his dissertation, Robinson (1952) pointed out some limits to approaching map symbolization and design from a purely artistic viewpoint, as he suggested was the guiding perspective at the time. Maps, like buildings that are designed primarily for artistic impact, are often not functional (e.g., the 1970s New York subway map won awards for *design* but resulted in a number of lost graduate students when an informal experiment was performed to judge its functionality [Allis, 1979]), and the Renaissance Center in Detroit produced a dramatic change in the city's skyline, but even professional geographers could not keep track of where they were during the 1975 Association of American Geographers annual meeting.

Robinson (1952) argued that treating maps as art can lead to "arbitrary and capricious" decisions. He saw only two alternatives: either standardize everything so that no confusion can result about the meaning of symbols, or study and analyze characteristics of perception as they apply to maps so that symbolization and design decisions can be based on "objective" rules. Although a few suggestions emanated from the international cartographic community concerning standard symbol sets to be used on thematic maps (Ratajski, 1971), that option was not considered

seriously by many cartographers, and clearly was not advocated by Robinson (1973). Most academic cartographers took up the second option of formulating "objective" rules.

Robinson's dissertation, then, signaled the beginning of a more objective approach to map symbolization and design based on testing the effectiveness of alternatives, an approach that followed the positivist model of physical science. In his dissertation, Robinson cited several aspects of cartographic method for which he felt more objective guidelines were required (e.g., lettering, color, and map design). He also suggested that this objective look at cartographic methods should begin by considering the limitations of human perception. One goal he proposed was identification of the "least practical differences" in map symbols (e.g., the smallest difference in lettering size that would be noticeable to most readers). This goal was naturally linked by others to psychophysical research in psychology. Psychologists had focused on measuring "just noticeable differences" as a step toward deriving "laws" to "explain" human responses to various stimuli. Fechner's Law, for example, had suggested that just noticeable differences exhibit a logarithmic relationship to actual differences in the magnitude of stimuli, and in 1957 Stevens countered with his "power law." Following from these laws, we would predict that least noticeable type-size differences on a map will increase with increasing lettering size according to a logarithmic or power function, respectively.

CARTOGRAPHY AS GRAPHIC COMMUNICATION

The second dramatic occurrence of the past four decades, in relation to how we address questions of symbolization and design, was the development and elaboration of the concept of cartography as graphic communication. It is this perspective on the cartographic enterprise that is behind much of the empirical research stimulated by Robinson's dissertation four decades ago.

The view of cartography as a communication process has been depicted graphically by many authors. While details of these depictions vary, all models share a basic structure with an information source tapped by a cartographer who determines what (and how) to depict, a map as the midpoint of the process, and a map user who "reads" the map and develops some understanding of it by relating the map information to prior knowledge (Figure 1.1).

Although Robinson did not propose the communication model for cartography, he pointed the direction by arguing for "functional design" and for objective evaluation of map effectiveness as the mechanism to



FIGURE 1.1. A schematic depiction of cartography as a process of information communication.

achieve it. In *The Look of Maps* (1952, p. 15) he made the following comment: “If we then make the obvious assumption that the content of a map is appropriate to its purpose, there yet remains the equally significant evaluation of the visual methods employed to convey that content.” In this statement we find the idea that maps have a predefined purpose (rather than the map user having an information need that available maps may or may not meet), and that the goal is to convey (or communicate) the content selected to meet this purpose. We also find the attitude that map content is something that does not have to be questioned, a view that has been disparaged of late. Robinson went on to argue that: “Most scientific cartography is concerned with the dissemination of spatial knowledge” (p. 17). Again, *knowledge* that already exists and that the cartographer has access to is to be *disseminated* through the map, rather than *constructed* by the analyst who uses the map.

Models of cartographic communication did not actually appear until the late 1960s. The initial one was an extremely complicated flow diagram created by Christopher Board (1967). The depiction of cartography as a communication system having the greatest initial impact on cartography, however, was one put forward by a Czechoslovakian cartographer, Koláčný (1969). This model was developed approximately 15 years after Robinson’s dissertation. Considering its nature will help us to understand changes in the approach taken to map design and symbolization that succeeded Robinson’s initial call to action.

Koláčný’s and other graphic depictions of cartography as a communication science reflect contemplation by diverse cartographers over a number of years concerning how to improve maps and how easily and accurately maps can be interpreted. Communication came to be viewed as the primary function of cartography and the map was considered the vehicle for that communication.

Due to the communication paradigm, the purview of cartography expanded to encompass more than mapmaking. It was approached as a *process* of communicating spatial information that had inputs, transmission, and reception of information, and that therefore could be analyzed as a system. From this point of view, authors identified numerous obstacles or filters that information must pass through on its route from reality

through the cartographer to the map, and then through the map to the map user. On the cartographer's side of the system, these filters include objectives, knowledge and experience, abilities and attitudes, external considerations such as client demands, as well as the abstraction processes by which information is put into map form (e.g., projection, simplification, generalization, classification, symbolization, etc.). For map use, the following factors were identified as filters: the perceptual and spatial abilities of readers, understanding of the symbol system (e.g., training or ability to understand the legend), goals, attitudes, viewing time, intelligence, prior knowledge, and preconceptions (Figure 1.2). According to communication theory, each of these variables can act to inhibit information transmission, resulting in information loss or communication errors.

Treating cartography as a formal communication system implies that we can improve map communication if we can reduce the filtering or loss of information at various points in the system. An improvement any-

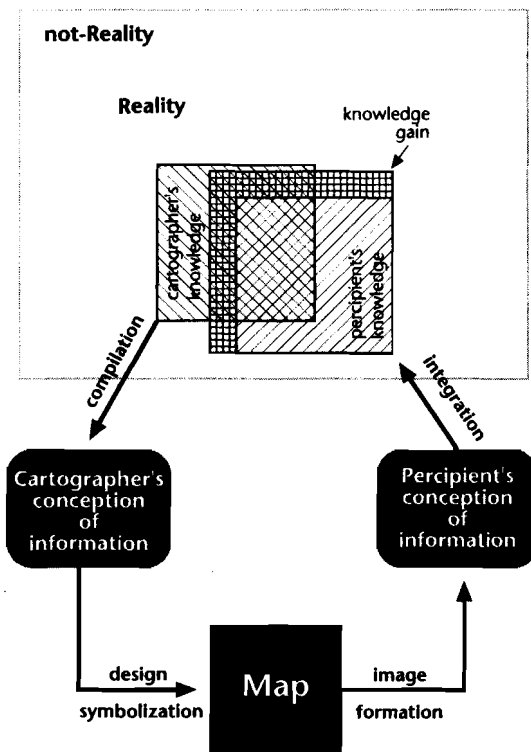


FIGURE 1.2. My own 1979 view of cartography as a process of graphic communication. After MacEachren (1979, Fig. 1.3, pp. 10–11).

where in the system should have a positive effect, and an information loss should be impossible to overcome. Most efforts to study cartographic communication have been directed to the middle stages in the system: the cartographer's transformation of selected information into the map and the initial extraction of information from the map by the user. Little attention has been directed to how decisions are made about what should and should not be mapped (a primary concern of the postmodern approach to cartography, discussed below) or to the influence of prior knowledge (map use goals, mental models, schemata, etc.) on what is noticed, how map information is evaluated, or what is retained.

Throughout this book, we will see the consequences of the widespread acceptance of the communication model as a research paradigm. Among them are a concern with the map user, the use of empirical research to investigate the impact of symbolization and design choices, and a belief that objectively derived guidelines can be established for map symbolization and design. Although these and other perspectives inherent in the communication paradigm continue to be accepted by most cartographers, the basic paradigm of cartography as communication science has been attacked on several grounds and few cartographers now accept it in its literal sense.

Among the objections raised are (1) a realization that viewing cartography as communication science omits many ways people use maps and that the particular experimental approach initially selected to evaluate maps as communication vehicles was a barren one; (2) a concern that any (positivist) scientific approach to study and improvement of maps will, by definition, ignore the important contributions of art in the cartographic process; and (3) a philosophical perspective, voiced by an increasing number of scholars, that does not accept the concept of maps as "objective" representations of reality and therefore discounts the idea that objective research is possible.² Each of these points will be touched on briefly below to set the stage for the approach offered here to studying how maps work.

OBJECTIONS TO SCOPE AND METHOD

One of the mistakes made by those who adopted the communication paradigm (and I was one of "those") was to place severe restrictions on Robinson's call for research directed toward functional maps. Maps, in relation to the communication paradigm, were judged on a functional basis, but the definition of function was restricted to communicating some predetermined message. Clearly only a small subset of maps are produced to "communicate" a particular message. Topographic maps, maps that depict

location of events, and travel maps have a function, but no predetermined message (except perhaps in the rhetorical sense, as Wood and Fels, 1986, have pointed out for state highway maps). Even many thematic maps (e.g., geologic or soils maps, a textbook map of world GNP, etc.) often have no explicit predetermined message (but as Yapa, 1992, points out, the GNP map may have implicit messages). A student, for example, may be asked to use a map of world GNP to compare the wealth of continents, to pick out individual countries with a specified GNP, to study the relationships between latitude and GNP or between GNP and agricultural production, and so on. It is inappropriate to consider the information obtained from this kind of map use as a message that the cartographer was trying to "communicate." In this example, the information extracted by the student is determined by the questions that a teacher poses (and from the meaning and significance assigned to GNP). Such meaning often cannot be anticipated by the cartographer.

The spread of technology for both geographic information and analysis and scientific visualization fosters map use early in the research sequence. Following Tukey's (1977) lead, DiBiase (1990) points out that scientific research progresses through at least four stages: exploration, confirmation, synthesis, and presentation. In the early exploratory stages of a research project, an analyst might create a map to investigate some spatially distributed phenomena. Here, again, there is no predetermined message. The goal of map use is to stimulate a hypothesis rather than to communicate a message. Information is instead "constructed" by the user, from the spatial representation of the world provided by the cartographer.

In addition to ignoring maps that do not have a predetermined message, a second failing of the communication paradigm was its strong link to behavioral psychology. This approach to psychology sought "laws" that relate behavioral responses to stimuli available to our senses. The approach dominated experimental psychology in the United States for several decades but was being supplanted within that discipline just at the time cartography decided to borrow from it. Behaviorists treated humans as black boxes that respond to stimuli rather than as information-processing systems that build knowledge from available input (a view held by many current researchers in cognitive psychology and a basic premise of cognitive science). Along with an assumption that the cartographer's role was to communicate, a behavioral perspective led to an assumption that we could devise rules for manipulating symbols to ensure a desired response. Once these "laws" were worked out, the theory contended, *optimal* maps could be constructed, with "optimal" defined as producing a user response that was as close as possible to the intended response.

During the 1960s and 1970s, when cartographers were embracing the communication model and a behavioral approach to empirical re-

search, psychology was undergoing a revolution in its perspective on what to study and how to study it. Psychologists began to realize that stimulus-response laws do not *explain* human perception or behavior (any more than the gravity models used by geographers can *explain* spatial interaction). While the ability to predict is helpful, both in relation to map symbol perception and intracity trade, by itself it does not provide a basis for dealing with significant changes to the system (e.g., new symbol systems created due to technological advances, or a change in the importance of geographic distance due to similar technological developments). In psychology, a cognitive approach developed in which the focus shifted from predicting behavior to explaining how information is processed.

Although there were calls for cartography to consider cognitive aspects of map reading as early as the mid-1970s (e.g., Petcherik, 1975), it is only recently that cartographers have begun to appreciate what this shift in approach means. Much of the "cognitive" research done by cartographers thus far has retained a neobehaviorist approach of measuring subject reactions without trying to infer either cognitive processes or to draw upon cognitive theory. The approach is similar to that still followed by human factors engineers and might be thought of as *map engineering*. A map engineering approach can solve particular narrow problems (e.g., determining parameters of map interfaces on helicopter display panels), but it is unlikely to result in generalizable theory.³

Rather than treating the cartographer and the map as conduits through which information is filtered, it makes more sense to study the perceptual and cognitive processes involved in both map "reading" and spatial information processing to determine constraints and features of the "information-processing device" (i.e., humans) so that symbolization and design can be adapted to it. One of my principal arguments in Part I of this book is that we can facilitate map use by developing models of human-map interaction and human spatial cognition, and through these models identify and more completely understand the most important variables of map symbolization and design.

ART AND SCIENCE

The communication paradigm for cartography (in spite of its dominance in North American cartography during the 1970s and 1980s) is viewed by many as quite sterile. Indeed, when taken to its extreme it is. Some authors have gone so far as to try describing cartography using the formal mathematical/electrical engineering approach of information theory as it was developed to explain the loss of signal quality over lines of electronic communication (Shannon and Weaver, 1949). Attempts have been

made to measure map information in terms of information “primitives” that you count at the beginning and end of the communication process. The difference in these totals was considered to be a measure of information loss and the proportion a measure of adequacy of transmission. This approach was doomed to failure, if for no other reason than that the user can combine map information with previous knowledge to produce conclusions that were not part of the initial *map message*.

Information theory and related attempts to treat cartography as a relatively well-behaved physical system have caused some cartographers (e.g., Keates, 1984) to warn us that adopting a scientific approach leads to devaluing the art in cartography.⁴ Keates, in discussing the imitative, emotive, expressionistic, and communicative functions of art, makes a rather convincing case that maps do contain artistic qualities that are difficult or impossible to account for through any “scientific” assessment (e.g., Imhof’s [1965/1982] terrain shading is surely “imitative,” *The War Atlas* clearly is “emotive,” and the contrasting styles that we have come to associate with maps from the National Geographic Society, the Central Intelligence Agency, *Time* magazine, and other prominent map producers are clearly “expressionistic”). That maps, like (other?) art, can be “communicative” is probably an acceptable idea to all cartographers. Even in the case of this communicative function of maps, however, the communication model leads us to measure the communication of individual *bits* of information rather than to assess the overall intellectual import of the map and its potential to convey many meanings at multiple levels of analysis.

A new view of the role of art and science in cartography is clearly needed. It is probably a mistake to view maps as objects that contain varied amounts of scientific or artistic content for which we must determine an appropriate balance (as both Keates, 1984, and Robinson, 1952, seem to, with Keates arguing for more art and Robinson for more science). Instead, it makes more sense to consider complementary *artistic and scientific approaches* to studying and improving maps, both of which can be applied to any given cartographic problem. The artistic approach is intuitive and holistic, achieving improvements through experience supplemented by *critical examination* (where critical examination implies expert appraisal of the results of our cartographic decision-making efforts). It draws on science in using perspective, understanding of human vision, color theory, and so on.⁵ The scientific approach (emphasized in Part I of this book) is more inductive and often reductionist, breaking the problem into manageable pieces with the assumption that the total picture (in the form of a general theory) will become clear by systematically examining each individual part of the process.⁶ A scientific approach draws on art in developing initial hypotheses about light, shading, color, type, and more.

DECONSTRUCTING THE DISCIPLINE

In addition to the concern that a scientific approach to the study of map symbolization and design might lead to the elimination of art from cartography, concern has been raised about other dangers of viewing cartography as an objective activity and evaluating it using the objective, positivist, reductionistic approach of physical science. Borrowing from postmodern thinking, several authors, most notably Wood and Fels (1986), Harley (1988, 1989), and Wood (1992), have pointed to the inherent subjectivity in, and rhetorical content of, maps. Wood and Fels (1986), for example, in their detailed analysis of the seemingly benign state highway map of North Carolina, find subtle propaganda in the presence of the state insect (a busy bee) and blatant bigotry in the choice of photographs to adorn the back of the map.

This perspective suggests that maps are as much a reflection of (or metaphor for) the culture that produces them as they are a representation of a section of the earth or activities upon it. Harley (1989, p. 15), for example, argues that cartographers have created an "epistemological myth" that cartographic method reflects the "cumulative progress of an objective science always producing better delineations of reality."

The contention of these authors seems to be that cartography is neither objective nor a science, and that no amount of research can result in "better" maps because there is no objective way to define "better." Cartography, it is argued, is more akin to literature than to astronomy or geophysics. The appropriate analytical methods, then, should be modeled after literary criticism rather than after experimental methods used in the "hard" sciences. This perspective would direct our attention to philosophy and social theory rather than to psychology, human factors, linguistics, education, or cognitive science for approaches by which map symbolization and design can be assessed. Even artistic appraisal might be viewed as irrelevant or inappropriate to the task of assessing the sociocultural consequences of maps as the product of cartography. The directions pointed by these authors are refreshing, but their apparent insistence on a wholesale replacement of one limiting approach to cartography with another is not.

While the postmodern assessment of cartography has certainly generated a lively debate (see commentaries on Harley's "Deconstructing the Map," in *Cartographica*, 26 (2), 1989), and has reminded cartographers of the social implications of the products they produce, it does not—and by design cannot—provide answers to any fundamental questions about how we should select symbolization or design strategies. What it does provide is a way to assess how these selection decisions impact those individuals, groups, or societies whose environment is represented by the map.

If we accept the premise that maps can “work” (i.e., that they are a useful way of obtaining spatial information), we have an obligation to facilitate their use as information sources. The fact that we cannot eliminate the cultural baggage inherent in any human artifact does not give us a license to ignore the practical consequences of our decisions in designing that artifact. The realization that architecture contains similar cultural baggage, for example, does not reduce the importance of work such as Lynch’s (1960) on the image of the city (designed to obtain knowledge by which city planning and building design can be used to make experiencing a city more meaningful or memorable) or ergonomic studies (designed to make working in a building safer, less tedious, or more pleasant). Similarly, research that makes maps used by air traffic controllers or pilots less prone to misinterpretation would probably be valued by anyone who travels by air, perhaps even a “postmodernist.” On the other hand, the fact that maps do seem to work does not absolve us of responsibility to consider the kind of work they do, whether explicitly or implicitly, openly or surreptitiously. What is needed, I believe, is a more balanced perspective on cartographic research that attempts to merge the perceptual, cognitive, and semiotic issues of maps as functional devices for portraying space and the sociocultural issues of how these portrayals might facilitate, guide, control, or stifle social interaction. Although this book is largely about how maps work to achieve their explicit goals, attention is also paid to how they work to achieve their implicit goals. Specifically, questions concerning maps as multifaceted representations and as tools of rhetorical discourse along with the social processes by which maps and map symbols acquire their meaning are considered.

TAKING A FRESH APPROACH TO SYMBOLIZATION AND DESIGN RESEARCH

There are three perspectives currently taken toward scientific research on map symbolization and design stimulated by the communication paradigm. One is that a scientific approach to cartography is impractical or irrelevant, either (as noted above) because cartography is an art rather than a science or because the rhetorical content of maps is more important than the *information* they contain (if they are admitted to contain any). At the other extreme is a belief that the communication paradigm is the most promising approach to achieving cartography’s ultimate goal of more functional maps, but that a combination of sloppy research, poor selection of initial problems to pursue, misdirected emphasis, wrong methods, and the relative youth of the approach has led to somewhat disappointing results thus far (e.g., Olson, 1983; Dobson, 1985; Medyckyj-

Scott and Board, 1991). The third perspective, and the one adopted here, accepts cartography's function as creating interpretable graphic summaries of spatial information (i.e., representations) and the goal of producing more consistently functional maps, but judges the communication paradigm to be a much too constraining model for the discipline (although it has a function in addressing presentational uses of thematic maps or in evaluating the interpretability of individual symbols or symbol types).

My position is that there is no single correct scientific, or nonscientific, approach to how maps work. As David Marr (1985, pp. 110–111), a noted vision scientist, has asserted, to understand any complex system we must “contemplate different kinds of explanation at different levels of description that are linked, at least in principle, into a cohesive whole, even if linking the levels in complete detail is impractical.” The representational approach to maps advocated here is not intended as a call for a single new perspective on cartography to replace another single approach. The intent is to illustrate the importance of understanding representation as a general concept if we are to understand maps. I am contending that the concept of representation is fundamental to all approaches that we might take to cartography.

The map is examined here, then, not as a communication vehicle, but as one of many potential representations of phenomena in space that a user may draw upon as a source of information or an aid to decision making and behavior in space. Emphasis is placed on how the map “represents” in both a lexical and a semiotic sense (see below) and on how vision and cognition represent that representation in forms that allow the map viewer access to meaning. The map user's interaction with the map is viewed as a complex information-processing problem in which a series of neurological then cognitive representations of what is seen are built and these representations are interrogated using schemata (mental representations) that provide a context (or set the limits) within which the conceptual picture derived from the map can be understood.

An integrated view of spatial representation considered at multiple levels provides a major organizing principle for this book. A typology of levels at which representation can be addressed proposed by Howard (1980) has been influential in my parsing of cartographic representation. Howard's typology distinguishes among three perspectives on the study of symbols—the lexical, the functional, and the cognitive—and leads to correspondingly different (but complementary) approaches to the concept of “theory of representation.” He deliberately avoids speaking of “a theory” or “the theory” because of the multiplicity of theories that become possible when we realize the scope of the concept of representation.

The *lexical* approach to representation might be considered the level

of meaning in its broadest sense. This approach deals with how symbols achieve their meaning and how we learn to use particular forms of symbolization. Considered are levels of meaning (e.g., specific and general, literal and metaphorical), along with the etymology of symbol meaning and any ethnographic variation that may exist. Among the questions to be considered under a lexical approach to representation, Howard (1980, p. 504) includes "questions of style and interpretation in art or of the nature of artistic, scientific, historical, or religious understanding." Aspects of work by "lexicographers, art critics, cultural anthropologists, epistemologists, and historians" fall within the bounds that Howard delineates for this approach. In the context of cartographic representation, then, the lexical approach corresponds to calls by Harley (1988), Wood (1992), and others to consider both the implicit meaning and the power inherent in maps as well as their explicit meaning—in Harley's (1989) terms, to "deconstruct the map."

Howard labeled the second approach to representation the *functional*. This perspective corresponds "to the broader colloquial view of symbolism as anything that can carry meaning" (Howard, 1980, p. 504). This approach can be embraced under the concept of semiotics: "The logical analysis or plotting of specific differences and kinships among linguistic, logico-mathematical, pictorial, diagrammatic, gestural, musical, and other sorts of symbol systems construed as different ways of using one thing to refer to another." The basic question here is "what are the relations that sustain a particular symbolic function and its contribution to meaning?" (Howard, 1980, p. 504). Drawing on Goodman (1976, p. 143—rather than 144ff. as cited), Howard (1980, p. 504) argues that these relations "form a system consisting of a symbol scheme (the items or inscriptions used to symbolize) correlated with a field of reference." Rather than exploring what symbols mean (as in the lexical approach), the issue becomes "what does it mean to be a symbol and how do they variously provide their meaning?" When we take a functional approach to representation, it allows us to recognize that "different ways of presenting information on a surface can imply different ways of relating to those marks and inscriptions" (Howard, 1980, p. 506). An aspect of this idea that will be considered below is that differences among various forms of visual-information presentations go beyond differences in their surface appearance. More fundamental are the different sets of rules for construction and interpretation (i.e., mental categories and knowledge schemata) that have developed and are understood by users of these depictions.

While lexical and functional approaches to representation look primarily at cultural practices, social processes, scientific practices, and so on, for clues to the meaning of symbols and to the development and application of symbol systems, the *cognitive* approach looks to the individ-

ual. At the level of the individual, the issue becomes identification and understanding of “psychological, cultural, or communication processes required or most frequently involved in the acquisition and mature use of many sorts of symbols in thought and action” (Howard, 1980, p. 506). Among the questions that Howard (1980, p. 506) suggests as typical of this perspective are: “How do symbols of different kinds mediate thought and perception?” and “How does information (on some proper analysis of that puzzling notion) admit of multiple symbolic manifestations and which ones are more economical for certain educational purposes or levels of learning?” The cognitive approach, according to Howard, is “concerned with facts and hypotheses about the acquisition and use of symbols in virtually every aspect of life.”

To understand how maps work, I believe we should follow Howard's lead and attempt to understand *representation* at many levels (Figure 1.3). How humans represent information mentally determines how groups and societies can develop a consensus about letting symbols (in the broadest sense of the word) stand for objects, relationships, events, and the like, in the “real” world. When the communication paradigm considered representation, it did so in the limited sense of focusing on how cartographers represent the environment with map symbols. In relation to map users, the only questions that seemed relevant following the communication system logic were those related to how users interpret the cartographic representations. If we allow that perception is a representation (e.g., visual perception is the representation of visual scenes before our eyes) and that cognition involves higher levels of representation (of objects, relationships, processes, etc.), then we see that map symbols are not the only representations that should be of concern to cartography. At the other extreme (from individual mental processes) Harley (1989), Wood (1992), and others have made it clear that representation at a social level



FIGURE 1.3. The multiple levels of map representation.

is also an important factor in map understanding. It is not only the map user who mentally represents map information nor only the map author—cartographer who imbues a map with meaning, both explicit and implicit, it is the society and culture within which map author—cartographer and map user coexist that provide that meaning. Society gives meaning (at multiple levels) to the symbols that the cartographer uses to assign meaning (also at multiple levels). How cartographers reach consensus about what should be represented and the meaning of particular symbol types (or even individual symbols), and about the ways in which the cartographer's social context influences these decisions, are issues relevant to a representational approach to cartography. Attention to these issues should complement, not compete with, attention to the visual and cognitive representations derived from the resulting maps.

When we consider Howard's typology of approaches to representation in relation to maps, it becomes apparent that his first two approaches deal with the public realm of how maps are imbued with meaning, from an epistemological—philosophical—sociological—historical perspective in the case of the lexical approach, and from a logical—categorical perspective in the case of his functional approach. In contrast, the third approach deals with the private realm of the individual and how the individual *sees* and *interprets* individual symbols and maps. This public—private distinction is reflected in the first two sections of this book (Figure 1.4). A representational view of cartography, therefore, suggests two primary levels of analysis: the private/perceptual—cognitive (where attention is directed to how human vision and cognition represent concepts about the world and the contents of a visually displayed map, i.e., how meaning is derived from maps) and the public/social (where attention is directed to the ways in which symbols and maps represent, i.e., how maps are imbued with meaning). The private focus is particularly concerned with the processes of vision as a hypothesis about what is seen and the



FIGURE 1.4. The public and private issues of maps as representations.

role of conceptual categories and knowledge schemata in assigning meaning to the representations derived by vision. The public focus is concerned with developing logical systems for creating meaningful representations and understanding in a broader context how symbols acquire meaning at multiple levels.

ORGANIZATION OF THIS BOOK

The book is divided into three main sections that address distinct issues of how maps work.⁷ The organizing structure for the first two sections of the book is derived from the categorization of approaches to theory of representation described above. The third section applies these approaches to understanding how maps are used in an increasingly critical map application area: geographic visualization.

In presenting the multilevel approach to spatial representation proposed here, the logical place to begin is with the individual. Both social (i.e., public) issues of the mix of explicit and implicit meaning in map symbols and whole maps and personal (i.e., private) issues of how a particular map user interprets a particular map are dependent upon how human perception and cognition represent, and give meaning to, space. I begin by considering how vision and cognition work together as a process that acts upon and transforms representations of sensory input, making use of both unconscious reactions (some innate and some developed with practice) together with mental categories and schemata as the keys to interpreting these representations. From this base (presented in Part I), I go on (in Part II) to consider semiological issues at the functional level of cartographers trying to create logical abstractions of the environment, and the social issues at the lexical level of how symbols acquire their multiple levels of meaning and how map representations are used in social interaction. Understanding of cartographic representation at these three levels, then, allows consideration of how maps are used in geographic visualization, the topic of Part III.

Part I, *How Meaning Is Derived from Maps*, begins with an overview of information-processing approaches to vision and visual cognition and their potential application to the study of cartographic representation. Human-map interaction is considered to have a set of components related to the levels of processing required. These range from largely perceptual processes (e.g., detecting point symbols on the background of a complex highway map, discriminating between colors on a vegetation map, identifying one region as figure on another that is ground) to inferential processes that require substantial contributions from prior knowledge and experience (e.g., visualizing the shape of terrain from a contour depic-

tion, planning a travel route across town, or developing a hypothesis about the impact of temperature on crop damage due to a particular insect). Chapter 2 provides a structure for the two subsequent chapters in Part I, "How Maps Are Seen" and "How Maps Are Understood." The first of these presents a sketch of current understanding of the eye-brain system and the limitations that this hardware may put on what we are able to see. Next, I consider issues of perceptual organization of the visual scene by early (largely preattentive) processes and their implications for "seeing" map symbols and sorting figure from ground. This is followed by some observations about how cartographic research on symbol discrimination, ordering, and estimation can be related to this information-processing approach. The chapter concludes with a section on the methods by which we can trick vision into seeing depth in two-dimensional maps. The final chapter of Part I looks at subsequent cognitive processing of information that vision provides and considers the interaction between preattentive visual processing of maps and the knowledge structures used to mentally organize both general knowledge and knowledge of maps. Recent research on mental category systems and attempts by both psychologists and cartographers to explore the notion of knowledge/problem-solving schemata are considered.

Part II, *How Maps Are Imbued with Meaning*, focuses on the public aspects of representation theory: the functional and the lexical. Both are examined from a semiotic perspective. The section opens with a primer on semiotics for cartography, Chapter 5. This primer is necessary as a way to cut through the daunting morass of semiotic terminology. With the base provided by this synopsis of key semiotic concepts, Chapter 6 is devoted to functional aspects of a semiotic approach to cartographic representation. A framework is presented that underlies a developing rule base of cartographic guidelines for matching both individual symbols and map types to their referents. Potential directions for research dealing with symbolization and design rules are considered. In the section's final chapter, lexical perspectives are drawn on in an effort to explain how map users interpret individual symbols, symbol groups, and entire maps, and how categories inherent in cartographic decisions about symbol-referent relationships dictate a particular view on the reality represented. Both denotative and connotative meaning in maps are addressed.

Throughout the book, I take the approach that maps and, by implication, map symbolization and design, should be evaluated not by how much information they communicate how quickly, but by how well they suit a particular task. With this perspective in mind, Part III, *How Maps Are Used: Applications in Geographic Visualization*, focuses on a key problem domain attracting the increasing attention of cartographers. This part combines the lexical and semiotic perspectives on how maps repre-

sent with emphasis on visual–cognitive processes in human–map interaction. Three chapters address prompts to visual thinking, the search for relationships in data, and truth in geographic visualization. The goal of this combined approach is to understand, at various levels, how cartographic decisions about representation influence thinking, problem solving, and decision making that is facilitated by the resulting maps. The topics of noticing unexpected patterns and pattern comparison are discussed in relation to a model for cartographic visualization. The role of both social and cognitive processes in developing knowledge schemata with which map information is processed is considered. Concepts and perspectives from cognitive, environmental, and developmental psychology, as well as from cognitive science, computer-assisted instruction, sociology, and the history and philosophy of science, serve as a framework for understanding how spatial knowledge can be acquired from maps and how maps function in spatial exploration and analysis contexts. Particular attention is given to the role of interactive/dynamic maps in scientific exploration and exploratory spatial data analysis (ESDA).

In the Postscript, I offer a view toward the future that anchors the theory of cartographic representation in the broader context of theory for spatial representation. This approach builds upon the previous chapters to argue for a multilevel, multiperspective approach to maps and map use that recognizes cartography as a field concerned with representation in all its respects.

NOTES

1. An interesting perspective on cartography as a craft is provided by Meddykyj-Scott and Board (1991). They describe the limits to formalizing methods and procedures inherent in a craft-based field and discuss cognitive cartographic research as a complementary approach to deriving operational map design guidelines.

2. Objective is used here to mean “free from personal prejudice, unbiased.”

3. Map engineering is defined here as an approach to cartographic design that involves formulating and applying precise rules for decision making. These rules are derived from a combination of the application of scientific principles with iterative refinement through empirical testing. This approach contrasts with a graphic-design-oriented approach to map design. The latter tends to be more holistic, less rule-bound, and focused on aesthetic as well as functional goals.

4. Art is considered here to be more than simply achieving a pleasing appearance. The term is used in its broader sense of grappling with emotions, prompting subjective responses, contemplating “aesthetics” (the branch of philosophy that deals with the principles and effects of beauty), along with concerns for the production of pleasing designs.

5. The artistic approach, as envisaged here, is more systematic in application than the “cartography as craft” approach that Medyckyj-Scott and Board (1991) suggest that cartography has followed.

6. Unless otherwise noted, “science” or “scientific” should be taken to mean following the rubric of logical positivism, thus following methods that involve systematic progress through four stages: observation, theory development, test of theory empirically, and modification of theory in response to results (Harvey, 1969).

7. A brief Postscript summarizes the concepts derived and offers suggestions on where the broader theoretical approach to maps and map use delineated here might lead.