1

SCENARIO

A surgeon enters the bright, even light of an operating room where the patient, prepared for surgery, occupies a table surrounded by the expected array of monitors, respirators, and sterilized tools. But rather than taking his usual place near the patient, the surgeon seats himself at a nearby console where an assistant places over his head a helmet that completely covers his eyes and most of his face. The helmet is plugged into a computer and the doctor grasps two wands shaped to resemble microsurgical scalpels. He signals to a technician at a computer terminal that he is ready: a delicate surgical procedure on one of the patient's eyes is about to begin.[1]

What is happening here? Without ever physically touching the patient, nor even seeing him directly, the doctor is directing a delicate procedure inside the eye itself. The "helmet" he wears is a head-mounted display (HMD) that positions before his own eyes two small color television monitors connected to a stereo imaging device. What the doctor "sees" is a real-time, stereoscopic image of the movement and position of his microsurgical tools (FIGURE 1 / PLATE 1 and FIGURE 2 / PLATE 2). Moving his head changes the position of the miniature camera so that the doctor seems to be inside the eye itself, able to see at close range the movements and effects of the scalpel's actions.

Those movements are controlled by a sophisticated robot, which responds to the surgeon's manipulation of the scalpel-like wand held in each hand, but executed with a greater precision and stability than the doctor could ever perform by himself. The computer driving the robot automatically reduces his movements by a factor of 100, and it removes nearly all the physiological tremor of his hands. It also continuously monitors the surgeon's actions by comparing them to the structure of a mathematically defined virtual eye stored within its data banks, so that if he should try to proceed too quickly among delicate tissues of the actual eye, the computer will impede or correct the gesture. Sensors within the scalpel mechanism register the amount of resistance produced by its

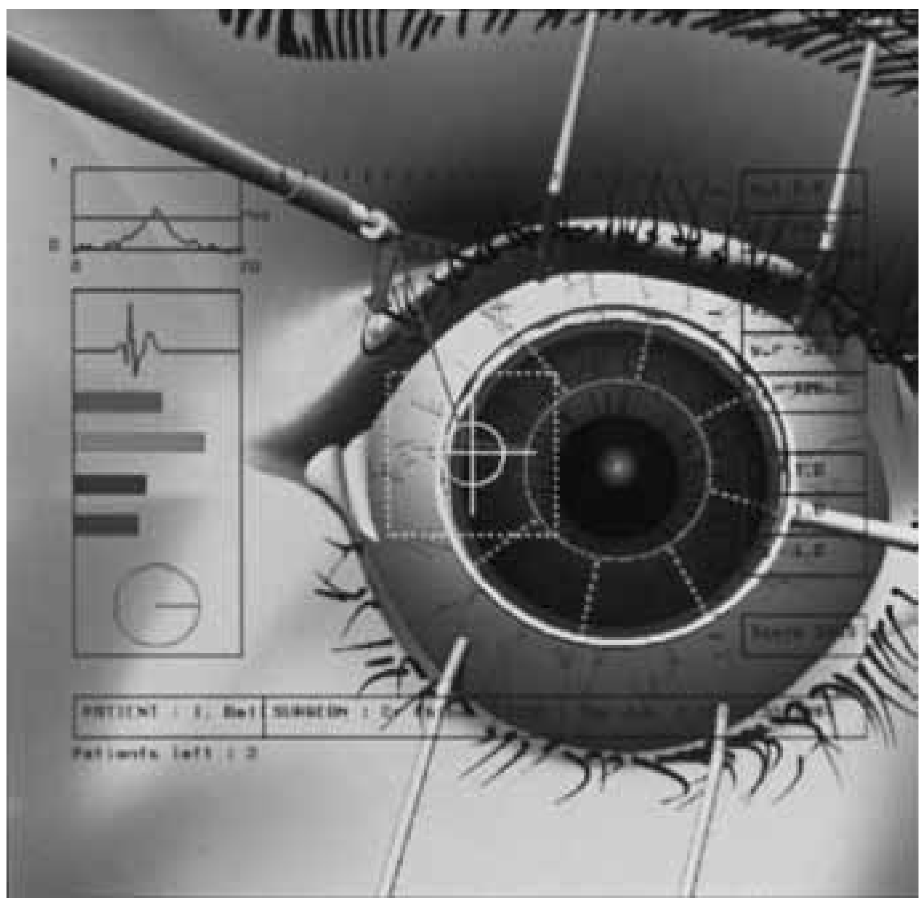

FIGURE 1

"Surgical virtual environment showing virtual surgical instruments, 3-D guidance information, surgeon's tremor power spectrum (top left) and patient's vital signs (left-hand side)." Computer-driven interface from Ian W. Hunter et al., "Ophthalmic Microsurgical Robot and Associated Virtual Environment," *Computers in Biology and Medicine*, vol. 25 (1995). © 1995, with permission from Elsevier.

cutting action and pass the data to the controlling computer, where it is magnified by a factor of 100 and sent to the wands held by the doctor: in this way, the surgeon "feels" the effect of his actions within the patient's eyeball.

In a comparison probably inspired by the layered meanings of the German word *Operateur* [surgeon/projectionist], Walter Benjamin drew an analogy between the work of a surgeon and that of a cameraman. "The surgeon," he wrote, "greatly diminishes the distance between himself and the patient by penetrating into the patient's body . . . at the decisive moment [he] abstains from facing the patient man to man; rather, it is through the operation that he penetrates into him." Benjamin is describing a familiar scenario, an early version of which is pictured in Denis Diderot and Jean Le Rond d'Alembert's *Encyclopedia* (FIGURE 3).

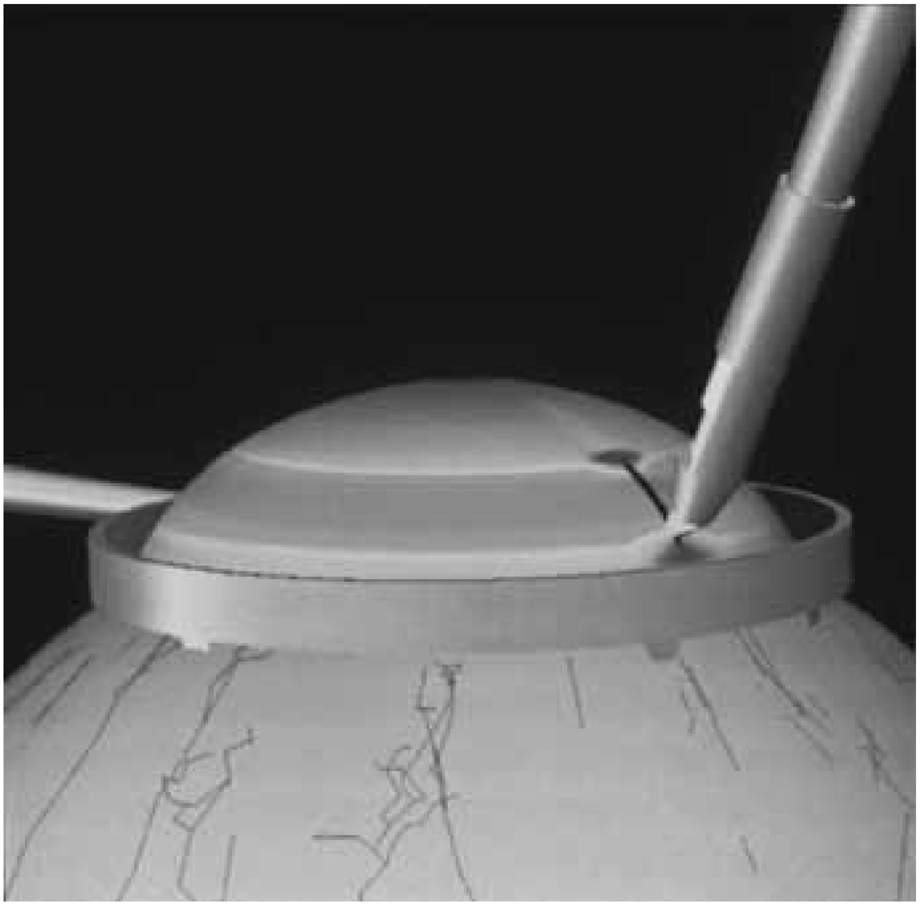

FIGURE 2
"Stress contours calculated on an incised human cornea during a radial keratotomy simulation." Computer-driven interface from Ian W. Hunter et al., "Ophthalmic Microsurgical Robot and Associated Virtual Environment," *Computers in Biology and Medicine*, vol. 25 (1995). © 1995, with permission from Elsevier.

FIGURE 3
"Chirurgie," pl. XXIV. Engraving by Robert Bénard after a design by Louis-Jacques Goussier for Diderot and d'Alembert, *Recueil des Planches*, vol. 3. Courtesy Department of Special Collections, Stanford University Libraries. Photo: Marrinan.

He goes on to say that a cameraman's relationship to the world—like a surgeon's instrumentalized relationship to his patient—is both depersonalized by the cinematic apparatus and "penetrates deeply into its web."[2] What Benjamin could not imagine in 1936 was that advances in microrobotics, electronic imaging, and computing power would transform his metaphor into reality: our ophthalmologist, who neither touches his patient nor sees him directly, is literally a surgeon-cameraman, completely immersed in a world of electronically produced images yet guiding a scalpel through the living tissue of his patient's eye.

The machinery of a modern operating room seems to challenge many of the everyday, commonsense notions that Benjamin took as givens: the integrity of a physical body; its opacity to others; and a rather uncomplicated relationship between what John Locke called "the primary qualities of things, which are discovered by our senses" and our complex ideas of "corporeal substances" that derive from sensible secondary qualities.[3] Indeed, some predictions of what an operating room of the future will be like include scenarios where entire procedures are performed by computer-controlled robots, attached to advanced imaging devices (such as MRI machines) and working with digitally stored models of the patient (obtained from CAT scanners), whose motions are guided by artificial intelligence programs.[4] For the moment, the physical limitations of robot mechanisms, the lack of adequate mathematical definitions of complex tissues (needed to program a robot), the massive computational demands such systems would place on computer processors, and the high costs of research and development keep such radical scenarios on the distant horizon of medical technology.[5] Commercially available surgical robots, such as the da Vinci, have been approved for laparoscopic, minimally invasive surgery under the guidance of an attending physician, but completely autonomous robots have yet to be developed.[6]

Alongside these practical reasons related to surgical safety and affordability, surgeons worry that they would no longer directly control the situation. Sophisticated computer-guided robots require their own specialist operators, which means that surgeons must pass commands to technicians rather than working directly on the physical body of the patient.[7] As one medical team has written, doctors generally prefer to have a robot pre-programmed for a procedure under active control of the surgeon, because in this case "from both the surgeon's and the patient's point of view, the robot is merely a 'tool'. It is evident that the surgeon carries out the operation and not the robot."[8] This suggests a lingering suspicion about the reliability of transferring data directly from electronic sensors to robotic actors, and implies that both sides of the surgical experience prefer an expert human to inhabit—or at least physically monitor—the circuit of information and action. There seems to be a reluctance to accept penetration of our bodies by a fully autonomous "apparatus" (Benjamin's term) of medical technology, regardless of its sophistication.

We open this book with an almost science-fiction account of modern medicine because it stages the experience of virtual reality in a markedly graphic manner, by placing a physical body under an actual scalpel guided through a fictive space of computer simulation. Underlying this unusual meeting of surgeon and patient, mediated almost exclusively by mechanical sensors, digital sampling, and algorithmic instruction sets, is an implicit confidence in the information delivered to the surgeon, in his ability to form a clear and accurate idea of the physical corrections to be made to the affected eye. Anyone would hope the surgeon has an accurate picture of the patient's condition so that the operation might be successful. Yet this raises a simple but profound question: is the helmet's stream of real-time data a description of the eye?

Proponents of a copy theory of representation would probably say "no." The paradox is that advocates of a non-mimetic theory of description, such as Nelson Goodman, would be hard-pressed to answer "yes." Goodman distinguishes description from depiction on the grounds that the former is syntactically "articulated" rather than "dense." By this he means that the components of descriptions are disjointed and measurably discontinuous from one another, whereas those of depictions appear indivisible—even though they may be infinitely subdivided to achieve higher resolution. The digitized sampling of data and its numeric displays in the surgeon's helmet surely qualify as articulate systems, while the real-time video image he views simultaneously provides a visual spectrum every bit as "dense" as would a conventional depiction.[9]

What is unusual about the surgery example is the convergence of dissimilar data—a kind of willful grafting of Goodman's two syntactic schemes—in which both the surgeon and the patient have placed their trust. This trust does not develop because they are convinced that one sees the visual organ more completely in the helmet than with the naked eye, but because—for the highly specialized encounter of surgery—this is the most functional way of seeing it. The surgeon cares little if the patient has green or blue eyes, for example, and the helmet display ignores those qualities, yet it reports with great accuracy every minute change in the scalpel's position. So we will answer with a term employed by Goodman, but not used in his sense, that the digital data-stream is not a description of the eye but a *diagram*. A diagram is a proliferation of manifestly selective packets of dissimilar data correlated in an explicitly process-oriented array that has some of the attributes of a representation but is situated in the world like an object. Diagrams are closer in kind to a Jackson Pollock than to a Rembrandt.

Diagrams have existed for centuries. Our ambition is neither to write that long history nor to devise an all-inclusive, trans-historical definition.[10] Nevertheless, we may enumerate some of their formal characteristics: they tend to be reductive renderings, usually executed as drawings, using few if any colors; they are generally supplemented with notations keyed to explanatory captions, with parts correlated by means of a geometric notational system. The *Oxford English Dictionary*'s (*OED*) etymology of the word is somewhat broader, indicating that musical notations and written registers were part of its early usage. By the mid-nineteenth century, the *OED* reports that "diagram" was being used to "represent symbolically the course or results of any action or process, or the variations that characterize it." This emerging ability to concretize process forms the center of our book. The modern history of the word masks something implicit about the nature of diagrams that can be recovered by recalling the Greek use of *diagramma* in mathematical proofs. "The perceived diagram does not exhaust the geometrical object," writes Reviel Netz. "This object is partly defined by the text. . . . But the properties of the perceived diagram form a true subset of the real properties of the mathematical object. This is why diagrams are good to think with."[11] It is significant that d'Alembert's short entry for "Diagramme" in the *Encyclopedia* elides the ancient and modern meanings: "It is a figure or construction of lines intended to explain or to demonstrate an assertion."[12]

Between the early seventeenth century and the middle of the nineteenth century, diagrams were increasingly adapted to represent complex processes uncovered by scientific investigations or instantiated by mechanical inventions. Was this an accident? We argue that the hybrid visual attributes of diagrams facilitate their migration to these complex tasks of representation. The proliferation of discrete packets of dissimilar data, which characterizes diagrams, allows them to be apprehended in series or, paradoxically, from several vantage points. Their disunified field of presentation—ruptured by shifts in scale, focus, or resolution—provokes seriated cognitive processes demanding an active correlation of information. Our general approach in this book is to emphasize this potential for process—both cognitive process and historical process—implicit in the types of visual configurations usually called diagrams. Our earlier and later citations from the *OED* frame the eighteenth-century point of departure for this book—and the publication of Diderot and d'Alembert's *Encyclopedia*. The diagrammatic premises of their approach to visualizing knowledge are explored in Chapter 2.

Our view of Diderot and d'Alembert's intellectual project in the *Encyclopedia* is intertwined with our process-oriented concept of diagram, and more akin to the analysis of Jean Starobinski than that of Michel Foucault. For Foucault, the *Encyclopedia* is a table—an array for nearly unfettered inspection. For Starobinski, it is an arena of knowledge rife with internal discontinuities barely concealed by its "imposing facade, baroque in style and markedly stoic," behind which "spreads the completely modern activity of discontinuous appropriation that is quick to forget the outmoded constraints of organic unity."[13] Starobinski suggests that the arbitrary alphabetic order of the *Encyclopedia* actually sows disorder by breaking with the closed loop of knowledge implicit in the form's history. Especially germane to Starobinski's account is his attention to the complex system of cross-references that work against the alphabetic arrangement and produce a secondary order—a proliferation of readings instituted by the cross-references but animated by the reader/user's individual penchant to know. In the words of Annie Becq, at the heart of the *Encyclopedia* lies a paradox "that values continuity while recognizing in fact that discontinuity is necessary."[14] This same paradox structures and animates what we call diagram.

We emphasize the *Encyclopedia*'s proliferation of knowledge rather than focusing upon its disciplinary compartmentalization. We take our cue from the inclusionary mood of a familiar passage in Diderot's *Prospectus*:

That is what we had to explain to the public about the arts and sciences. The section on the industrial arts required no less detail and no less care. Never, perhaps, have so many difficulties been brought together with so few means of vanquishing them. Too much has been written about the sciences. Less has been written about most of the liberal arts. Almost nothing has been written about the industrial arts.[15]

Diderot's ambition was to produce not only the great "interlinking of the sciences" that constitutes an encyclopedia, but also a catalogue of the bewildering diversity and density of activities that comprise human life.[16] To make it possible for readers to find their way through this labyrinth, the authors adopted the alphabetic ordering of a dictionary which, as many writers have noted, established a tension between encyclopedic closure and a serialized accumulation of knowledge.[17] Diderot himself was aware of the problem:

If one raises the objection that the alphabetical order will ruin the coherence of our system of human knowledge, we will reply: since that coherence depends less on the arrangement of topics than on their interconnections, nothing can destroy it; we will be careful to clarify it by the ordering of subjects within each article and by the accuracy and frequency of cross-references.[18]

What Diderot describes here, notably in his attention to "interconnections" and the "frequency of the cross-references," is a process of learning and discovery that cuts across the dictionary order in complex and unpredictable ways. The aim of this process—which we take to be the essence of diagram—was:

to point out the indirect and direct links amongst natural creatures that have interested mankind; to demonstrate that the intertwining of both roots and branches makes it impossible to know well a few parts of this whole without going up or down many others.[19]

The implication here, as Starobinski and Herbert Dieckmann suggest, is not that knowledge for Diderot entails absolute inclusiveness, but rather emerges from a process of *enchaînement* [linking] guided by cross-references; that is, from the user's active exercise of relational judgment.

Most critical readings of the *Encyclopedia* align its mode of presentation with a rationalist enterprise of analytic subdivision in which large and complex subjects are broken down—or fragmented—into small units of study. Our view, informed by Diderot's understanding of the relationship of parts to whole, is not to treat the entries or illustrations as fragments of an idealized entity, but as a proliferation of independent elements that, when interconnected, produce knowledge of the whole. The distinction is worth making, for it asks whether the *Encyclopedia* is written from the vantage point of absolute knowledge able to disassemble complex objects at will (Foucault's table) or is a collection of working objects—devised ad hoc in the manner of *bricolage*—that evoke the world's density from a finite number of material soundings.[20]

Working objects are both the tools and products of research processes that in practice correlate familiar oppositions: word and image; representation and the real world; physical mechanics of vision and its processing in the mind; or Goodman's articulate and dense syntactic systems.[21] Here, too, we recover the place of diagrams in Greek mathematical reasoning in which, according to Netz, "the diagram is not a representation of something else; it is the thing itself."[22] Diagrams are things to work with. By framing our concept of diagram as a flexible tool of research, we link it to Diderot's idea that the *Encyclopedia* makes knowledge visible by its system of correlations [rapports] rather than its arrangement of materials. The *Encyclopedia* fails as a compendium, but establishes the matrix of diagrammatic knowledge.[23]

The *Encyclopedia* seemed a new organization and presentation of knowledge. And so it is. At the same time, the authors reached freely into the encyclopedias, dictionaries, manuals, and compendia of imagery that formed the modern tradition within which they lived intellectually. They were inspired by Francis Bacon and guided by figures like Pierre Bayle, Antoine Furetière, John Harris, and, above all, Ephraim Chambers, whose two-volume *Cyclopaedia* of 1728 they intended initially to translate.[24] Diderot and d'Alembert acknowledged their debt to Chambers's vision of an encyclopedia as "the chain by which one can descend without interruption from the first principles of an art or science all the way down to its remotest consequences . . . back up to its first principles."[25] They recognized the cross-references as his great innovation, although they believed he had failed to exploit fully their potential. They also note that Chambers "had read books but he scarcely saw any artisans," so that his work does not contain "many things that one learns only in the workshops." In an *Encyclopedia*, they argue, these omissions break the "enchainement and [are] harmful to both the form and the substance" of the work.[26] A telling phrase in Diderot's *Prospectus* about their intellectual debt to Chambers was deliberately deleted from the published version of the *Preliminary Discourse*: "the general arrangement is the only point in common between our work and his."[27] By contrast, Diderot and d'Alembert distinguished their project from the *Cyclopaedia* by the sheer scale of their ambitions: against Chambers' two-volume work they propose multiple folio volumes of text that would eventually number seventeen. From this immense increase of scale followed the need for multiple authorship, and with this a multiplicity of diverse perspectives that ultimately were to be adjudicated through the judgment of readers following cross-references. Full implementation of the technique of cross-references both implied and enabled the increase of scale that characterizes the *Encyclopedia*.

More to our purposes, Diderot and d'Alembert explicitly imagined their system of cross-references to be extended to the huge reserve of visual material proposed for the plates. They fully subscribed to the notion that a picture is worth a thousand words:

> But the general lack of experience, both in writing about the arts and in reading things written about them, makes it difficult to explain these things in an intelligible manner. From that problem is born the need for figures. One could demonstrate by a thousand examples that a simple dictionary of definitions, however well it is done, cannot omit illustrations without falling into obscure or vague descriptions; how much more compelling for us, then, was the need for this aid! A glance at the object or at its picture tells more about it than a page of text.[28]

Their original plan was to include no fewer than 600 plates in two volumes.[29] The final product was vastly more visual: 2,569 plates distributed over eleven volumes whose scope and diversity dwarfed the 30 plates of Chambers's *Cyclopaedia*.[30] Equally significant is the imagined role of this storehouse of imagery in the everyday use of the *Encyclopedia*. Diderot and d'Alembert do not propose to illustrate every detail of a machine or every step of a process, but "have restricted them to the important movements of the worker and to only those phases of the operation that are very easy to portray and very difficult to explain."[31] They admit that an experienced artisan will probably not discover much that is new in the plates, except for some novel points of view and some observations that only become apparent after years of work. A studious reader, by contrast, will find "what he would have learned by watching an artisan operate." Moreover, each plate will be linked to an explanation "with references to the places in the rest of the Dictionary relating to each figure."[32] Here is the process of discovery through correlation imagined by D'Alembert and Diderot:

> The reader opens a volume of the plates; he sees a machine that whets his curiosity; it is, for example, a powder mill or a paper mill, a sugar mill or a silk mill, etc. Opposite it he will read: figure 50, 51, or 60, etc., powder mill, sugar mill, paper mill, silk mill, etc. Following that he will find a succinct explanation of these machines with references to the articles "Powder," "Paper," "Silk," etc.[33]

There can be no more eloquent description of correlation among image, dictionary definitions, and textual explications than this scenario of an ideal user actually working with the materials of the *Encyclopedia*. Our claim is not that the *Encyclopedia* invents specific formal devices, but by foregrounding the process of discovery, and encouraging its operation, the volumes set new standards for the cognitive activity of readers able to glean from the editors' selection of plates "knowledge of the other circumstances which one does not see."[34]

The need to correlate dense and articulate systems became pressing at the historical conjuncture when they no longer could be indexed to a fixed and stable world. The *Encyclopedia*'s article on description brings this issue to the fore. Where Gotthold Ephraim Lessing and others stepped forward to debunk the system of *ut pictura poesis* that postulates an identity between word and image, the authors of the *Encyclopedia* devised a system of correlation that adopted the linear order of a dictionary but cross-cut and doubled back upon that linearity with diagram-like gestures of attention that link texts, plates, and legends in a process predicted by the *Prospectus*.[35] Our example of eye surgery suggests that

Goodman's distinction between articulate systems and dense systems no longer accounts for the complex correlations of computer-generated environments, but we do not want our point to rest solely upon contemporary advances in high-speed calculation. Rather, this book sketches from the time of the *Encyclopedia* a genealogy of visual correlation as a form of knowledge—a process aided and abetted by advances in mathematics as much as optics—that constitutes what we call the culture of diagram.

What kind of observer animates this process? What is the physical role and ontological status of this observer? What kind of observer is a surgeon who wears a head-mounted display while performing a delicate procedure? Clearly, the surgeon is not a creature alienated from his body by the scepticism of Descartes, for his gestures become scalpel cuts upon another person. Although enmeshed in machinery, the surgeon replicates neither Locke's isolation from the world in the camera obscura of understanding nor Jonathan Crary's disempowered subject of technological manipulation. Facing a complex of real-time visual displays and the digital readout of instruments, the surgeon deploys an active process of cognition that cuts across Peter Galison's distinction between picturing (image) and counting (logic). What the surgeon sees is not a mirror-like rendering of the eye. In fact, questions about visual reality or visual truth are obviated by the faith that both surgeon and patient bring to the operation. Why is this? Because the system works. Our surgeon, above all, is a user and a practitioner whose métier surely would have fascinated Diderot.

Users and métiers return us to the physical world of people and things and to the endless exchanges among them in everyday life. Things do not privilege a single vantage point, but are viewed or handled or manipulated in many different ways. People and animals—even some machines—can focus perceptual attention: objects cannot. To focus attention implies a capacity to shape the way others see the world and, by extension, the potential to shape collective views of the world by convention and education. Pictorial representation in Europe since the Renaissance is a history of possessing the world and objects in it by presenting them again (re-presenting) under controlled conditions that specify visual focus, resolution, and spatial context, among other variables. Systems of perspective—be they Alberti's one-point construct, the distance-point method attributed by Svetlana Alpers to Dutch artists, or alternatives discussed by James Elkins—are, in our account, ways of formalizing relationships in the world. Moreover, all are diagrammatic. This shared diagrammatic basis is more trenchant than one system's positioning of a physical viewer at the center (Alberti), or another's erasure of that viewer to foster the illusion that things describe themselves (Alpers). Historically, as Samuel Edgerton shows, diagrams based on Alberti's model quickly dominated others in Renaissance Italy because his *costruzione legittima* gave "depicted scenes a sense of harmony with natural law, thereby underscoring man's moral responsibility within God's geometrically ordered universe." According to Peter de Bolla, this model continued to dominate eighteenth-century practice as a means of controlling the growing awareness of contingency attached to physical acts of viewing and the social spaces of spectating—cracks in the structure opened by the imagination. But all such perspective diagrams are functionally identical in their attempts to fill the spatial voids among people or things with an orderly intelligibility.[36]

Some diagrams are simply representational—things, processes, even people splayed open to view (FIGURE 4)—and that may or may not situate an implicit observer as spectator. Certain kinds of diagrams—from Alberti's *costruzione legittima* to Foucault's reading of Jeremy Bentham's panopticon—do dictate a dominant point of view. The diagrams that interest us, however, differ from these hierarchical models because they are situated in the world like objects: they foster many potential points of view, from several different angles, with a mixed sense of scale that implies nearness alongside distance. Scientific practice, and the perfection of instruments like the telescope and microscope, required specialized diagrams functionally more useful than perspective. Data-recording instruments might shrink the need for visual representation to a minimum, yet recorded changes in barometric pressure still must be correlated with the visual experience of cloud formations if we hope to present an adequate description of the weather. Today, meteorologists constantly refer to satellite photographs to supplement the numerical data of their instruments.

The last half of eighteenth century, as we show, witnessed a kind of warfare among systems of diagram for explanatory power. The nature of this combat becomes clear in the columns of the *Encyclopedia* article on

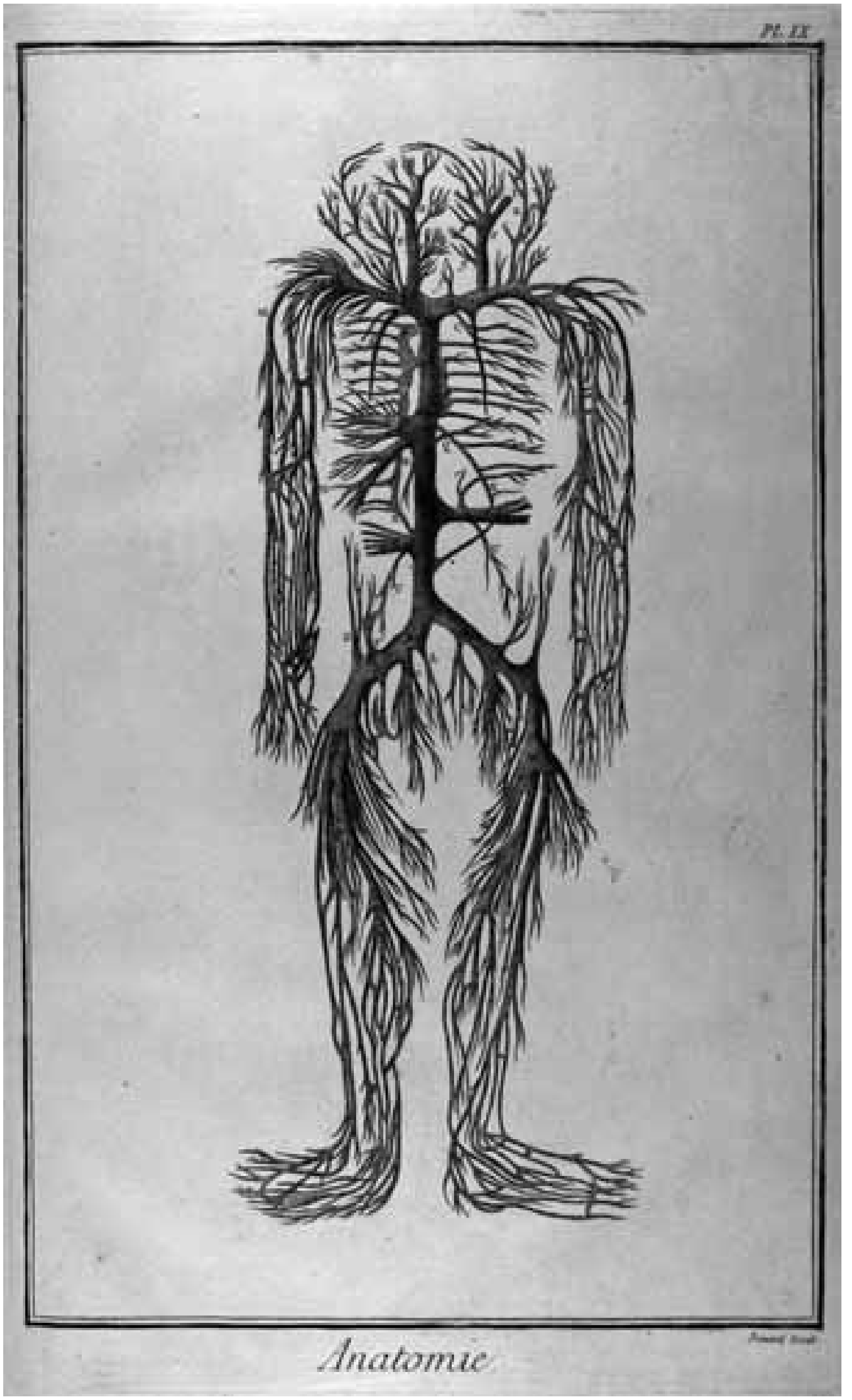

FIGURE 4

"Anatomie," pl. IX. Engraving by Robert Bénard for Diderot and d'Alembert, *Recueil des Planches*, vol. 1. Courtesy Department of Special Collections, Stanford University Libraries. Photo: Marrinan.

description of 1754, discussed fully in Chapter 3. The article was written by four authors who posit four distinct points of view; in effect, four diagrams for describing things and their relationships to one another.[37] Louis-Jean-Marie Daubenton calls for differential analyses based on the complexity of the object under study. Edmé-François Mallet steadfastly adheres to the unities of time and place consonant with rhetoric's legislation of emotional control. Louis de Jaucourt counters with a model that privileges the emotional response (the secret emotion) that might be elicited within a viewer and escapes all such legislation. Finally, Jean Le Rond d'Alembert registers a parallel debate among contemporary mathematicians: on the surface, he endorses the accepted description of curves as figures drawn literally with the instruments of geometry, yet a cross-reference to the long article on "curves" indexes his own fascination with the prospect of purely computational descriptions using the calculus. Twenty years later, in his supplement to the original article, Jean-François Marmontel revisits the efficacy of one-point perspective by invoking the emotional impact of staged performances, which he calls *tableaux*, that unfold within a theatrical space rigorously organized by lines of sight. Marmontel's rewrite, and its context of contemporary theater and painting, is the focus of Chapter 4.

The incommensurability of these separate analyses betrays a fundamental tension within the *Encyclopedia*'s concept of description. The article performs an historical snapshot of the emerging culture of diagram that crystallizes domains of knowledge and maps the areas where descriptive representation reaches its disciplinary limits. The *Encyclopedia*'s innovation lay in the ambition to bridge those limits, in both its texts and plates, with a new emphasis upon a correlation [rapport] of data. Its ability to achieve this goal was limited to the media resources of print culture. Barbara Stafford recognizes Diderot's "concrete habit of putting all sensory and intellectual domains in imaginative and dialogical communication with one another," yet she insists upon a "trivialization, denigration, and phantomization of images" that led to their "theoretical marginalization."[38] Although Stafford acknowledges the complexity and nascent modernity of the *Encyclopedia*'s visual arrays, she underscores the "hygienic severity and emotional restraint" of their settings as arenas for "a choreography of tidy gestures."[39] This austere version of the science of the *philosophes*, which Stafford contrasts to the sensuous variety and tantalizing magic effects of popular pseudo-science demonstrations, diverges from our reading of the plates as richly textured pictorial and diagrammatic objects.[40] The plates materialize the sensuous feel of engraved printing while mapping correlations among people, places, and things to produce a fulsome, extra-optical understanding of the practices, métiers, and products of contemporary life.

In our view, the intellectual project of the *Encyclopedia* is not ensnared in the word–image opposition that preoccupied so many mid-eighteenth-century thinkers, memorably summarized by Lessing. We believe it transcends what Stafford calls a "continuing pictorial impotence" in the face of a "linguistic hegemony."[41] The *Encyclopedia* sidesteps a simple word–image dualism by invoking the power of mathematics to open a conceptual space for correlations neither rooted in direct experience nor verifiable by the senses. This conceptual opening, which is crucial to our account, is mentioned only briefly in d'Alembert's contribution to the article on description. He gestures to a future mathematics of transcendental curves—objects of knowledge not occurring in nature—that might allow non-visual correlations among experiential phenomena. The post-d'Alembert history of mathematics as a tool of description is one of increasing attention to and reliance upon non-experiential modes of understanding: models of correlation extrapolated from verifiable data are replaced, albeit with intense disagreement among scientists, by predictive models based on probabilities. Such procedures challenge fundamentally the mechanistic and causal view of the world that prevailed in Newton's wake. Predictive models, in turn, laid the groundwork for quantum mechanics and the study of phenomena that are visible—if at all—for only a few millionths of a second in specialized viewing chambers. Although existing at the limits of visibility, the reality of such phenomena can be apprehended only by mathematical formulas. The unfolding of the culture of diagram, as discussed in Chapter 5, hinges upon the emergence of mathematics as the single most powerful tool for the correlation of dissimilar forms of data.

Correlation is a search for relationships among variables, and its success is measured when a convergence of data is recognized. Such a convergence might be actual, as when pressing a doorbell brings your friend to a third-floor window and elicits a cry of salutation. It might be graphical, as when the curve of measured humidity crosses the plot of ambient temperature. It might be purely mathematical, as when several equations intersect to define a set of shared variables, or practical, as when an architect uses a CAD program to define the possible undulations of a load-bearing wall. Today, correlations can also be virtual, as when computer-driven systems of imaging, data collection, and mathematically drawn vectors plot digitally a non-existent space to create the experience of flying an airplane or performing eye surgery.

High speed mathematical correlations in real time are the motors of virtual reality environments, and they underpin our surgeon's voyage to the center of his patient's eye. Importantly, the surgeon does not master the situation—the computer forbids any false move—but rather exercises a métier from within a fully integrated diagrammatic matrix. The surgeon's ability to correlate the complex flow of data appearing in the headset depends upon his active participation in a process that suspends human will to the extent that it is driven by instruments. Immersion in a virtual environment is not a form of advanced perspective domination—not the ultimate mimetic representation—but simply the performance of an assigned role within a complex convergence of words, images, numerical data, and synthesized touch. We might say that virtual environments take seriously the objectness of diagram by producing an experience that cannot be reduced to a single point of view—in the high-speed correlations of virtual reality, Diderot's *rapports* become homologous with the world itself.[42]