

# 6

## CROSSINGS

Our archaeology of diagram has sketched the contours of a long process by which instruments and tools of analysis expanded the horizons of knowledge beyond the range of the human sensorium. The dominant mode of visualization, established since the Renaissance, placed an object in space under the gaze of a precisely positioned observer. The *Encyclopedia* registers how much description already was fragmented by the mid-eighteenth century, in part because new instruments could see farther, in more detail, or with a finer grain than human beings, and generated data sets demanding new formulas of presentation. We have read the plates of the *Encyclopedia* as concerted efforts to materialize these new configurations, albeit within the technical limits of the printed page. The salient quality of the plates, in our account, is their surprising, sometimes shocking use of visual arrays: the relative scales, vantage points, and shifting relationships among numerous elements in these arrays configure the open-ended form of presentation that characterizes diagrams. Actuated by a viewer's complicity in bridging the fields of white that both bind together and separate the component parts, the diagrams of the *Encyclopedia* produce a cognitive yield not predicted by the model

of a single observer acting within the technical limits of human sight. Even in those contemporary arenas where situated viewers remained paramount—notably theatrical stagings and history paintings—multiple forms of stimulation and attention began to erode fixed meaning and invite spectatorial improvisation analogous to the cross-references of the *Encyclopedia* and the white spaces of its plates.

Although the authors of the *Encyclopedia* embraced the diagrammatic turn in descriptions of the world, they failed to agree upon its implications. They remained committed to an implicit hierarchy of visualization in which the perceiving human body, and thus the human sensorium, retained pride of place. Their physicalist bias necessarily placed limits on the usefulness of descriptions drawn with equations rather than the tools of geometry. Our trajectory through the nineteenth century has charted those moments when mathematics, especially calculus and probability, were adopted as essential working objects, even if doing so meant displacing sight as the primary vehicle of understanding. With Laplace, probability entered the domain of celestial mechanics to shake the foundations of Newton's positivist reasoning. Legendre and Gauss deployed it as a tool for predicting and correcting errors. For Quetelet, probability became a device to master the data of large samples and to formulate normative extrapolations. Boltzmann used probability to predict physical phenomena beyond the limits of perception and to sidestep the question of Maxwell's daemon. Quantum mechanics, as formulated by Planck, Bohr, and Einstein, dispensed with assumptions that "description" means to visualize in space, and that "observation" occurs from a vantage point independent of what is studied. To accept the findings of quantum mechanics meant abandoning sense perceptions as the foundation of knowledge about the world.

Eventually, the abstract precision of mathematical terms and the implausibility of instruments displaced the coarse-grained, fatigue-prone senses of the human body as the cornerstone of knowledge. Helmholtz, in particular, effected a convergence of physiological studies and mathematical reasoning. His findings—that the limits of human perceptions are predicted and defined by probabilities of error-correction—paved the way to imagining a continuum between the relatively narrow bandwidth of the human senses and the broad-band receptivity of instruments designed to detect wavelengths, particles, and movements both infinitely large and infinitely small.

Although Helmholtz did not liquidate the human subject at the center of life, he did immerse human beings in a blur of discontinuous, only partially registered data constantly shaping the world by means of correlations guided by error-correction. For Helmholtz, perception itself is diagrammatic.

Our survey of the complexities of nineteenth-century diagrammatic culture has necessarily taken a specialized view. We have drawn vividly the migration of correlative processes from the literal white spaces of the *Encyclopedia's* plates, and the pages of Monge's descriptive geometry, to the virtual whiteness of mathematical space inhabited by the algebraic discontinuities of both calculus and probability. By way of anchoring and broadening our discussion, especially as it pertains to the development of mechanical imaging technologies, we now turn briefly to the work of two important, but very different figures from the history of photography: Louis-Jacques-Mandé Daguerre and Étienne-Jules Marey.

History remembers Daguerre for the device that bears his name and was announced with great fanfare in 1839. His invention recorded on a plate of copper the image of whatever a lens might focus. Daguerre discovered, some say by accident, that a plate coated with silver iodide and exposed to light would “develop” an image when fumigated with mercury vapors, and that washing it in saline solution would “fix” the image permanently. Daguerreotype images created a sensation, all the more because the very fine-grained resolution of Daguerre's process, operating at the level of molecules, meant that the degree of visible detail was breathtaking. “The exquisite minuteness of the delineation cannot be conceived,” wrote Samuel Morse in a letter from Paris to his brother in New York, “No painting or engraving ever approached it.”<sup>1</sup> Nature seemed to be mirrored with an hallucinatory rigor and no human intervention, fulfilling at last the Renaissance dream of a fully comprehensive rendering of the world in one-point perspective. Daguerre's device seemed, on the surface, to produce perfectly descriptive tableaux.

The rhetoric of unvarnished objectivity that celebrated early daguerreotypes was, as Joel Snyder points out, deeply flawed and overdetermined by critical expectations informed by that ideal Renaissance tableau.<sup>2</sup> Daguerreotypes were at first so slow to register an image that exposure times of thirty minutes were common. During that time, many elements of the scene might move, especially if the camera was directed

out a window to the cityscape: the bustle of people, carriages, boats, and animals unfolds under the implacable gaze of the lens but is not recorded. Paradoxically, the developed prints showed only a city devoid of people, traffic, and life.<sup>3</sup> Not surprisingly, the long exposures also made satisfying portrait likenesses impossible. It is true that improvements in chemicals and lenses eventually recovered the movements of everyday life—often rendered as blurs across the visual field—and made portraits feasible. But the point is that Daguerre's device was, above all, an austere implement very unlike the human eye, and its shortcomings laid bare the myths of truth and objectivity clinging fiercely to the Renaissance theory of sight.

The history of photography branched importantly in the 1870s. On one hand, technical improvements in emulsions, cameras, and optics pushed photography towards an ever more perfect illusion of completely mimicking an idealized human eye—a central chapter of the story that will not concern us here. A completely different branch of experiment sought to transform photography from merely replicating human sight into a technology that might supplement human vision by making things visible that the eye cannot see. These researchers were both kindred spirits and colleagues of Helmholtz. Foremost among them was Étienne-Jules Marey.<sup>4</sup> Writing in 1878 about some of his devices, Marey makes clear his view of their superiority to human senses: “Not only are these instruments designed to replace the observer, and in such circumstance to carry out their role with an incontestable superiority, but they also have their own domain where nothing can replace them.”<sup>5</sup> At the time he wrote these words, Marey was mainly concerned to design and build mechanical sensors able to register and graph the physiological processes of living bodies. The best-known of these, the sphygmograph, could draw in real time, and with no human intervention, the curve of blood pressure changes produced by a pumping heart. The resulting graph made clearly visible a heart's double-sequence rhythm and made it possible to calculate internal qualities of the human circulatory system such as the speed with which blood flows. These were entirely new forms of knowledge built upon the non-invasive approach to the body of Marey's device and its extreme sensitivity, far beyond the limits of human touch or hearing.

Historians of Marey's long career agree that an important break occurred about 1878, the year he published his influential *La méthode*

*graphique*, a summary of his experiments and inventions to date. The same year, Marey first saw Eadweard Muybridge's photographs of the horse in motion published in the journal *La Nature* by Marey's friend Gaston Tissandier. Within days, Marey asked Tissandier to put him in touch with Muybridge, for he realized that photographs might effectively replace the stylus and moving graphical surface that had, up to now, been his principal mode of recording data. Over the course of the next several years Marey tinkered with the general structure of a camera, effectively deconstructing the tableau-making, Renaissance perspective view of Daguerre's original invention. Muybridge had not truly altered the operating parameters of the photographic apparatus, although he vastly increased the number of cameras and sequenced their triggering using trip wires. Marey, by contrast, introduced several innovations at the very heart of the device that fundamentally changed the camera's relationship to its subject. The first was to use a single light-sensitive plate rather than many plates, and to direct the camera towards a black ground. Ever since Daguerre's original announcement, the photographic apparatus had claimed to be an all-seeing eye on the world at large. Marey's seemingly innocent gesture, which made the camera but one component of a larger recording system, effectively dislodged the photograph as an all-purpose form of representation. Marey's camera "saw" nothing until a figure, dressed in white, moved across its field of view and was registered as a continuous blur of light.

These results led to Marey's second important innovation: the usual single shutter, mechanically limited to a certain speed, was replaced by a spinning, slotted disk that exposed the plate in a series of quick successions, each exposure registering the moving subject in a different place on the plate. The spinning disk shutter, which "sampled" the visual field at a regular rate, produced a systematic set of multiple exposures of the figure's movement upon a single photographic plate (FIGURE 45). We might say that Marey's slotted shutter applied the logic of calculus to the continuous curve traced by the figure in space. He called them chronophotographs. Marta Braun rightly underscores their startling novelty:

Since the advent of linear perspective in the Renaissance, the frame of an image has, with rare exceptions, been understood to enclose a temporal and spatial unity. We read what occurs within the frame as happening at a single moment

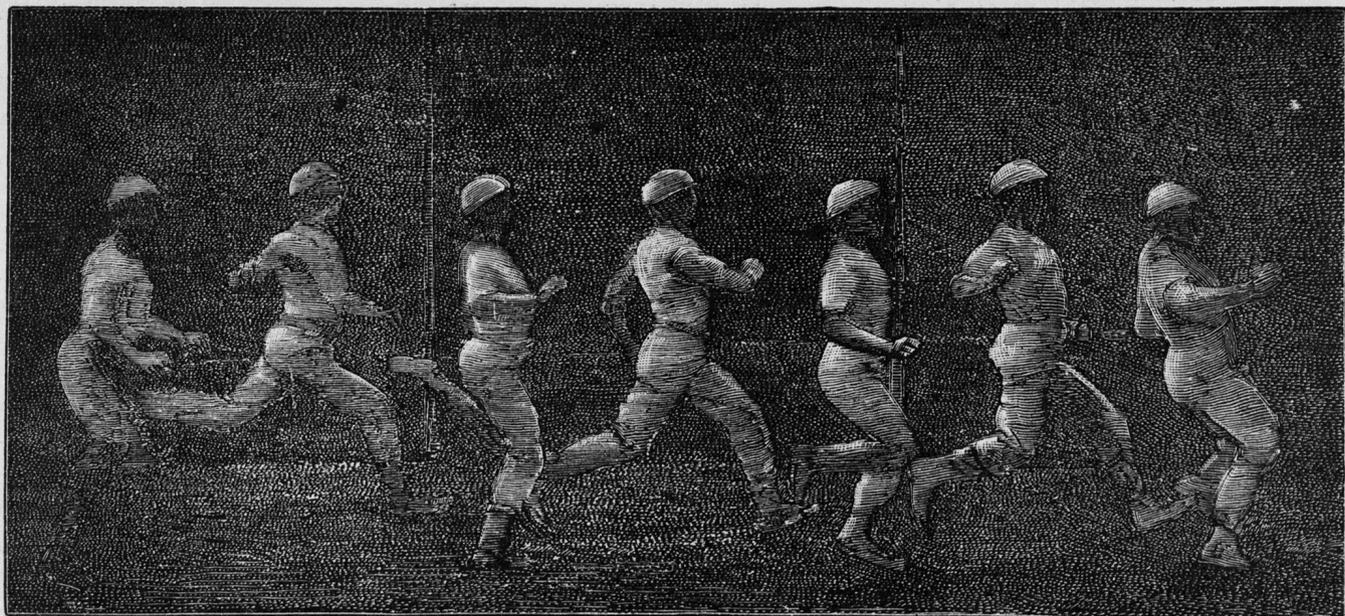
in time and in a single space. Marey's photographs shattered that unity; viewers now had to unravel the successive parts of the work in order to understand that they were looking not at several men in single file, but at a single figure successively occupying a series of positions in space. Viewers had to allow themselves to be led from one figure to another, reading the several images of the single figure as it moved through time and space. The result, a vision that goes beyond sight, was a new reality.<sup>6</sup>

Braun's characterization of the cognitive effort and complicity in reading Marey's chronophotograph dovetails exactly with our description of the correlative process at the core of diagrammatic knowledge. Marey's modifications to the camera transformed it from a device for rendering the world as tableaux into one component of a total system dedicated to diagramming time and motion—a system able to see things well beyond the limits of the human eye.

Marey introduced one final tweak to his system. In his quest for ever narrower slices of timed exposures to multiply the number of images left upon a single plate, Marey realized that the camera's ability to capture

FIGURE 45

Étienne-Jules Marey, "The Successive Phases in the Motion of a Man Running." Similgravure of a chronophotograph from *Scientific American*, vol. 47 (9 September 1882). Courtesy Stanford University Libraries. Photo: Marrinan.



THE SUCCESSIVE PHASES IN THE MOTION OF A MAN RUNNING.

detail actually hindered legibility. He was able to produce photographs with “such numerous superimpositions that the only result is a lot of confusion.”<sup>7</sup> Paradoxically, and in the interest of increased clarity, Marey systematically “blinded” the camera by dressing his models entirely in black, except for shiny buttons at the skeletal joints linked by narrow strips of bright metal. Against the already black ground, only the buttons and lines of these costumes were visible to the camera and were registered on the plate. Marey was thus free to increase greatly the number of takes without losing graphic clarity. The results were astonishing: a walking soldier is registered as pattern of points and lines that seem to articulate fully the motion of his body through time and space (FIGURE 46).

Technically, we have come a long way from the plates of the *Encyclopedia* devoted to military maneuvers (FIGURES 20, 21), yet the goal is identical: the visual rendering of bodies moving in space. Both Marey’s chronophotographs and the military plates analyze bodies under study as points and lines. Both invoke a blank space (one white, the other black) in which we are invited to imagine that movement. Both elicit a kind of seeing that is not an experience of everyday life. The *Encyclopedia* juxtaposes a tableau view to its diagrammatic arrays whereas Marey’s image declares its visual strangeness against the grain of our usual expectations for photographs. These striking similarities separated by more than a century reinforce our claim that the culture of diagram has both an unfolding history and a core set of recurring themes.

Marey undercut the camera’s claim of mirroring the world, neatly packaging it for the viewer’s optical delight, by demonstrating that photographic utility might lie in a completely different, more diagrammatic

FIGURE 46

Étienne-Jules Marey, *Joinville*

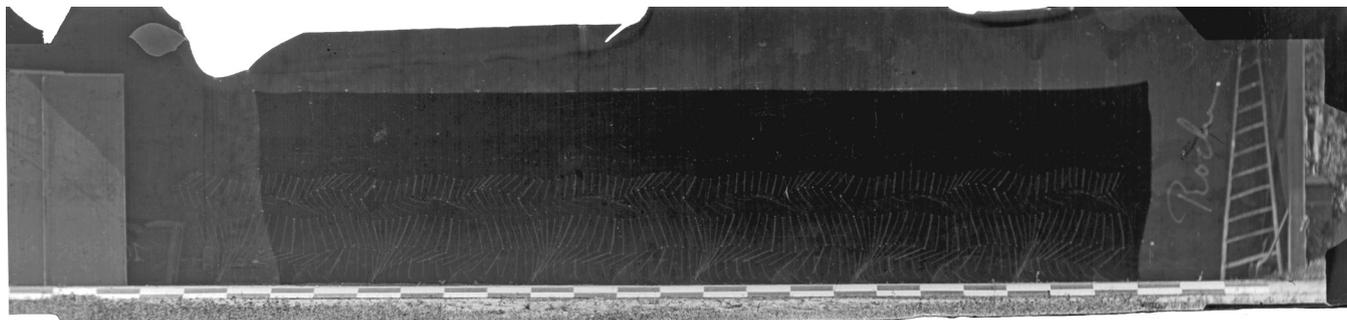
*Soldier Walking*, 1883.

Chronophotograph on glass negative (here printed positive).

Paris, Collège de France, inv.

III-Bb5 (2.8 × 13 cm). Photo:

Archives du Collège de France.



direction. We have sketched some of the ways that others—from Laplace to Legendre, from Monge to Quetelet, from Boltzmann to Bohr—realized that the most useful working objects for understanding our world might have little in common with the protocols of mimesis. But, of course, tableaux did not disappear altogether. They were the staple of most painters working in the nineteenth century, on both sides of the divide between academic and modernist aesthetics. David's taut pictorial formulas of the *Horatii* (FIGURE 36 / PLATE 8) may have instantiated the exertions of natural science in 1785, but no painter—including David himself—dared to push the premises of scientific description as forcefully as Marey's diagrammatic turn from photographic illusion around 1880. This is because painting remained intertwined with the mimetic representation of space throughout most of the nineteenth century: for a painter to imagine a picture that was not of something in space was to cross the threshold of abstraction that few were willing even to approach much before the turn of the century. We want to indicate very broadly why it became possible about 1910.

It is commonplace among cultural historians to detect a convergence between quantum theory and the development of Cubism by Georges Braque and Pablo Picasso between about 1908 and 1911. One of the more amusing documents in this literature is the letter written in 1946 by Albert Einstein to Paul Laporte, in response to an article Laporte had written on the analogies between Cubism and the theory of relativity: "This new artistic 'language,'" wrote Einstein, "has nothing in common with the Theory of Relativity."<sup>8</sup> We will not suggest that Planck's efforts in 1906 to formulate the concept of quantum had any discernible effect on the pictorial explorations of Braque and Picasso, nor that the painters were somehow subsumed in the zeitgeist of their time. Rather, we maintain that quantum mechanics and advanced painting converged at this time—for completely different reasons—on the usefulness of diagrammatic protocols. The concept of a quantum was an indispensable working object of enormous practical value to Planck. For Braque and Picasso, the shift to diagram entailed thinking past the surfaces that separate things in the world, piercing their outer skins, and searching for ways to trigger memories of comprehension that might be tactile, auditory, or olfactory rather than visual. The pictorial tool that made possible connections of

this sort is called *passage*—a material trace on the surface of the canvas lacking any specific reference. Picasso’s use of an arbitrary and artificial element to achieve pictorial coherence was as diagrammatic a gesture as Planck’s invention of the quantum to explain atomic structure.

In his pioneering and still canonical essay on the development of Cubism, Daniel-Henry Kahnweiler situates Picasso’s grasp of this new tool of *passage* in the late summer and fall of 1910.<sup>9</sup> The charcoal drawing of a *Standing Female Nude*, now in the Metropolitan Museum of Art (FIGURE 47), is a good example from just these months that demonstrates Picasso’s experimentation with *passage*. A lattice-work of lines and regular curves establish a density of marks down the center of the sheet that simulates the standing figure’s sculptural presence. Shadings from these linear edges bleed towards areas of white where the spatial placements among the planar edges merge, are confounded, and shuffle against one another. Crucial here is the role of material whiteness to elicit instability and unfixity, a sensation that the subject is not fully apprehended all at once, but is grasped from several different vantage points. Kahnweiler summarizes the effect:

This new language has given painting an unprecedented freedom. It is no longer bound to the more or less verisimilar optic image which describes the object from a single viewpoint. It can, in order to give a thorough representation of the object’s primary characteristics, depict them as a stereometric drawing on the plane, or, through several representations of the same object, can provide an analytical study of that object which the spectator then fuses into one again in his mind.

Kahnweiler effectively summarizes all that we have argued about the nature of diagrammatic knowledge and the user’s role in the processes of correlation. Picasso’s drawing of the nude fails as a study of physical anatomy useful to an orthopedic surgeon, but it does produce an understanding of the figure that is unexpected, perhaps even disturbing. We would call it a working object, one that incites us to ask “what is it?” in an echo of the question posed by Barthes when confronting the exploded body plates of the *Encyclopedia* (FIGURE 4).

Our discussion of Picasso’s 1910 drawing through the lens of Kahnweiler’s appreciation of 1915 demands comparison with an exactly contemporary eruption of diagrammatic whiteness within the matrix of

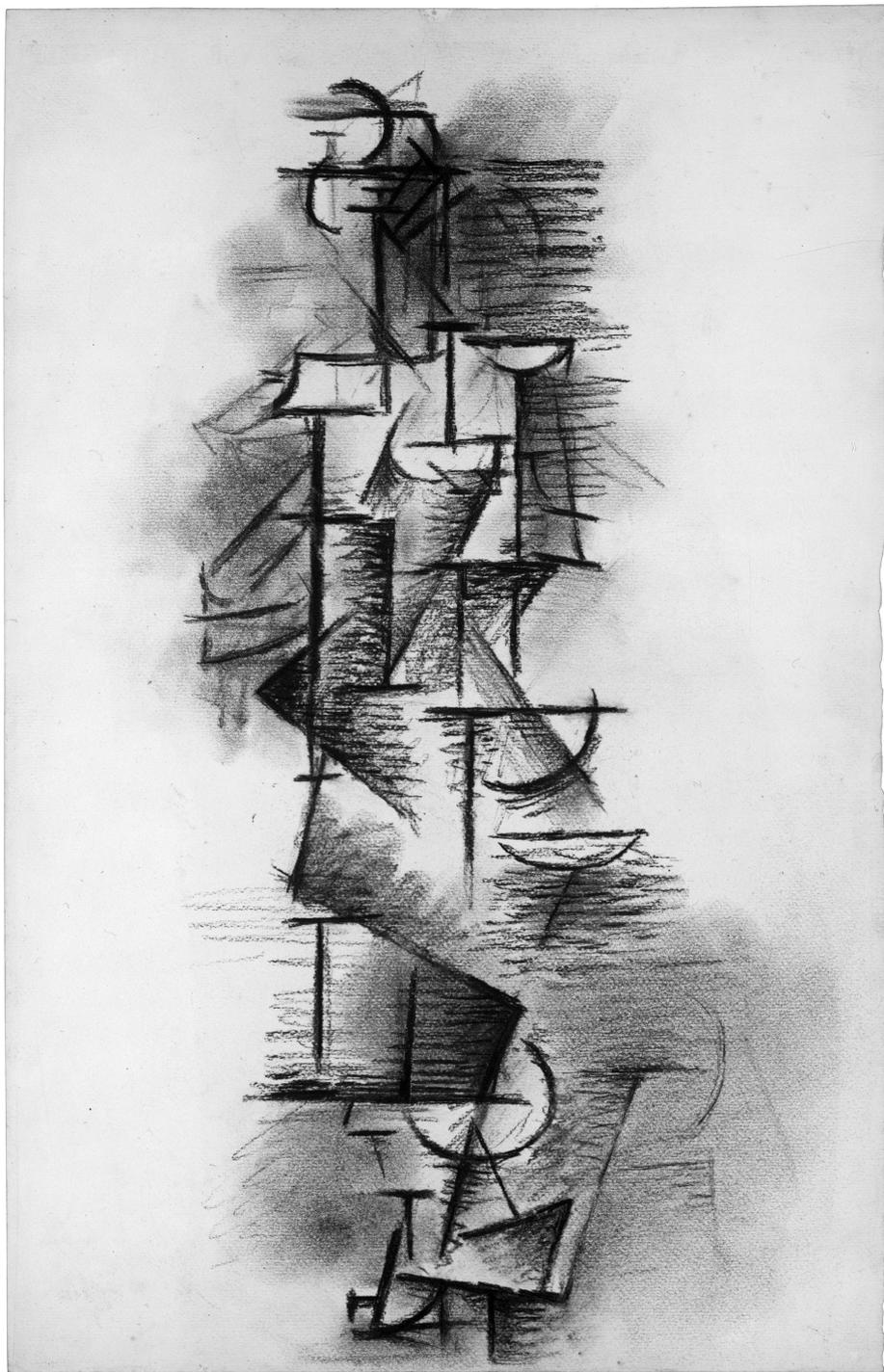


FIGURE 47

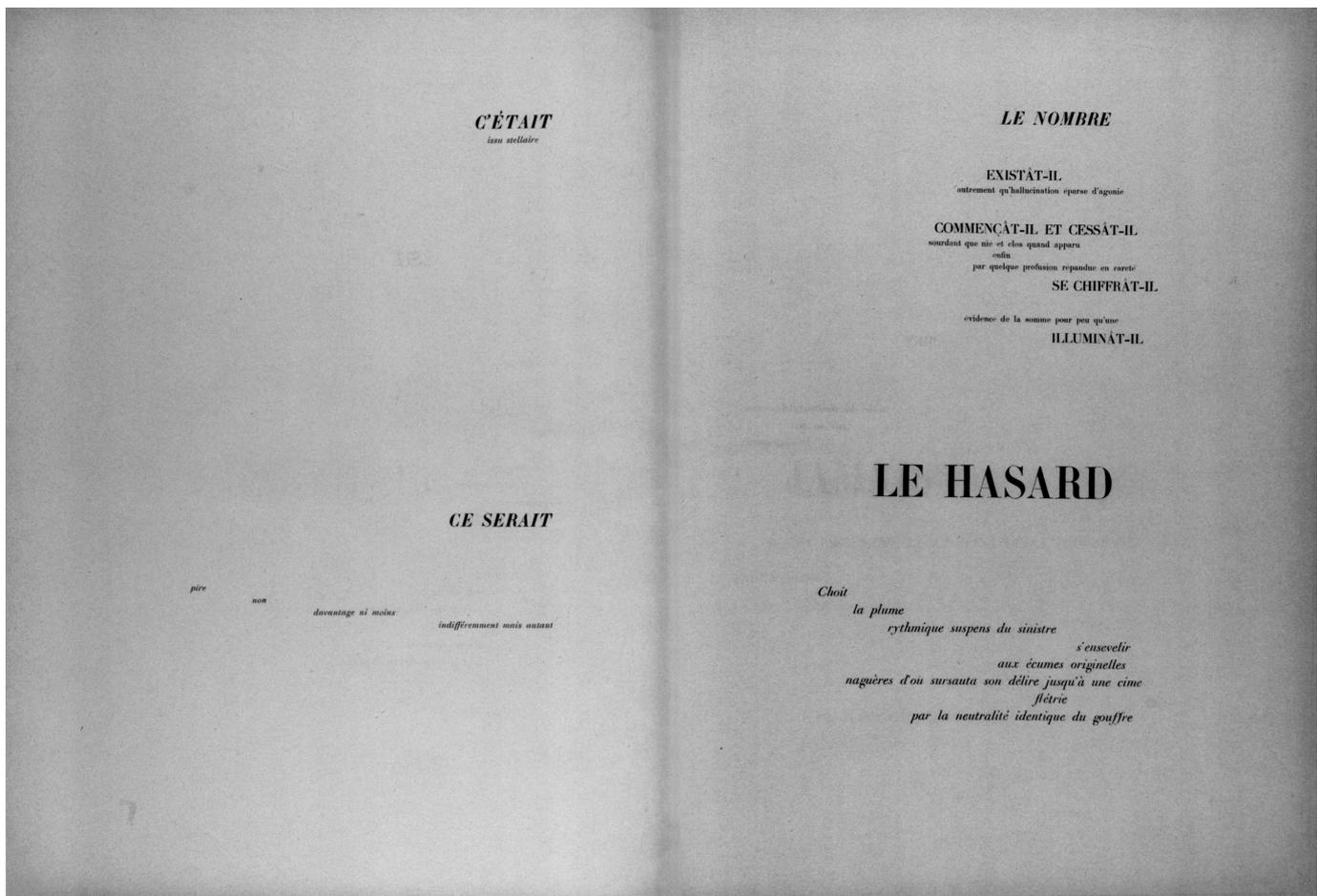
Pablo Picasso, *Standing Female Nude*, summer/fall 1910. Charcoal on paper. New York, The Metropolitan Museum of Art, Alfred Steiglitz Collection 1949, inv. 49.70.34 (48.3 × 31.4 cm). Photo: © The Metropolitan Museum of Art.

FIGURE 48  
Stéphane Mallarmé, *Un coup de  
Dès jamais n'abolira le Hasard*,  
1897/1914. Two pages from  
an unpublished luxury edition  
reprinted in Mallarmé, *Un coup  
de Dès jamais n'abolira le Hasard*  
(2007). Courtesy Stanford  
University Libraries.  
Photo: Marrinan.

language: the posthumous publication in 1914 of *Un coup de Dès jamais n'abolira le Hasard*, Stéphane Mallarmé's 1897 masterpiece of poetic and typographic experiment (FIGURE 48). Mallarmé's preface outlines explicitly the poem's diagrammatic procedure:

The "whites," as a matter of fact, take on importance, strike one first of all; verse requires white, like silence around it, ordinarily, to the point that a piece, lyrical or of a few feet, occupies, in its middle, about a third of the page: I do not transgress this measure, merely disperse it. The paper intervenes each time that an image, of itself, ceases to be or returns, accepting the succession of others.<sup>10</sup>

Mallarmé draws our attention to the uneven pressure of material whiteness against the regular march of words arrayed on the page. Just as



Picasso's drawing invites us to find the nude amidst its weave of lines and space, Mallarmé invites us to participate in making the poem. Correlations among type faces, font sizes, and relative positions present an open-ended aesthetic experience of give-and-take that historians have rightly aligned with modernity itself. We would also align the immersive and collaborative cognitive systems mobilized by Picasso, Mallarmé, and Marey with a tradition of correlation and diagrammatic knowledge that harks back to the plates of the *Encyclopaedia*.

When the eye surgeon with whom we began this book enters an operating room equipped with biofeedback servos to steady her hand, with real-time monitoring of her patient's vital signs, and with video images of a virtual world that places her inside an eye, she becomes one component among many of the descriptive system that will guide the surgery. Her immersion precludes the possibility of forming an objective or external view of the systemic whole. Our surgeon lives the paradox that so fascinated Bohr and his colleagues in the 1920s: the increase of knowledge and experience inside the system entails an awareness of the limits upon our natural powers of perception and the self-consciousness of their expansion from within the machine. We think it is not too extreme to claim that this double-edged attentiveness—both to our human limits and to what we might do when those limits are crossed—explains today's fascination with those virtual reality action games so avidly played by millions of users around the world.

We raised at the outset an issue about trust: how is it that all the parties involved in our eye surgery scenario—doctor, patient, hospital as institution—accept their roles within the panoply of computer, sensors, cameras, and digital encoders with enough confidence to risk an eye under a scalpel? All along the chain of image-capture and production, specialized modules perform error-analyses and corrections to compensate for the inherently discontinuous—albeit very high speed—flow of data through the system. Even the surgeon submits her gestures and expertise to the computerized error-checking of the whole. Our book has traced across time, cultures, and disciplines the trajectory whereby humans came to believe that the body's sensory equipment is actually enhanced by electronic appendages. This journey began with the *Encyclopaedia*, when first-hand enactment of the processes of correlation became cultural practice. Working objects

that emerged from contingent systems of knowledge came increasingly to assume material form, and to be accepted as inventions rooted in multiple realms of experience. A collage of disparate data types is the core of those graphic arrays of juxtaposed information that comprise the plates of the *Encyclopedia*. We have argued that the format and information of the *Encyclopedia's* arrays, fixed by the protocols of print culture, established patterns of presentation and juxtaposition that still influence the design of human-machine interfaces. The ambition of the *Encyclopedia* was clear: to correlate data gathered from diverse points of view, from a range of magnifications, and from different times. These recombinations built new forms of understanding even as they destroyed the priority of normative visualization of objects in space. The plates synthesize information in the patterned arrays of *diagrams*.

Certainly, our surgeon's virtual environment of an operating room organizes even more diverse data into strictly patterned diagrammatic arrays. These are constantly updated by computers unimaginable twenty years ago, much less by the *encyclopédistes*. Nonetheless, we believe the systemic regime of description deployed both in the *Encyclopedia* and the operating theater points to a pattern of similarities more significant than their technological differences. Both systems cut description free from the model of presentation that assumes an observer before an object in space, and both presume a bandwidth of perceptual discrimination far in excess of the human sensorium. What holds together these systems of disparate data? Here we return to the process of correlation [rapport] and the technology of cross-references [renvois] so crucial to Diderot's thinking about the *Encyclopedia*. By our account, the *Encyclopedia* is a panorama of working objects, a labyrinth of information through which users chart routes of understanding in the course of unpredictable and highly personal encounters with the material. The interests, passions, and quirks of users merge with the experience of those materials to shape a cognitive yield. Obviously, our surgeon faces neither white pages nor volumes of text, but she must contend with no less a labyrinthine flow of data presented to her sight and touch. Many of the correlations are orchestrated by an underlying matrix of mathematical relationships that constantly redescribe space—less material but no less real than the *Encyclopedia's* fields of whiteness—and that one now calls virtual reality.

To suggest that convergent data create working objects in time and space, along with new forms of knowledge, does not imply the liquidation of human thought and consciousness: life continues “off line” when the surgery is complete, the computer is shut down, and the patient and doctor see one another with normal vision. Our book suggests that the descriptive regimes of our digital age, bound historically and philosophically to those of the *Encyclopedia*, are capable of producing working descriptions for living, despite—or even because of—their reliance on sampling, calculations, and probability. Digital data technologies may have finally killed off spatial illusion as the most compelling re-presentation of the world. Perceptual certainty has been sacrificed, but human beings are highly adaptable: our fascination with new media means that we have all become creatures of chance. Reality returns as virtual so that we might see.