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Art History and Images That Are Not Art

James Elkins

Most images are not art. In addition to pictures made in accord with the Western concept of art, there are also those made outside the West or in defiance, ignorance, or indifference to the idea of art. In the welter of possibilities two stand out. Non-Western images are not well described in terms of art,[1] and neither are medieval paintings that were made in the absence of humanist ideas of artistic value.[2] Together the histories of medieval and non-Western images form the most visible alternates to the history of art, and they attract most attention in the expanding interests of art history.

But there is another group of images that has neither religious nor artistic purpose, and that is images principally intended—in the dry language of communication theory—to convey information.[3] There is no good name for such images, which include graphs, charts, maps, geometric configurations, notations, plans, official documents, some money, bonds, seals and stamps, astronomical and astrological charts, technical and engineering drawings, scientific images of all sorts, schemata, and pictographic or ideographic elements in writing: in other words, the sum total of visual images that are not obviously either artworks or religious artifacts. In general, art history has not studied such images, and at first it may appear that they are intrinsically less interesting than paintings. They seem like half-pictures, or hobbled versions of full pictures, bound by the necessity of performing some utilitarian function and therefore unable to mean more freely. Their affinity with writing and numbers seems to indicate they are incapable of the expressive eloquence that is associated with painting and drawing, making them properly the subject of disciplines such as visual communication, typography, printing, and graphic design.

Still, it is necessary to be careful in such assessments, because informational images are arguably the majority of all images. If pictures were to be defined by their commonest examples, those examples would be pictographs, not paintings. An image taken at random is more likely to be an ideographic script, a petroglyph, or a stock-market chart than a painting by Degas or Rembrandt, just as an animal is more likely to be a bacterium or a beetle than a lion or a person. The comparison is not entirely gratuitous, and I make it to underscore the final barriers that stand in the way of a wider understanding of images, just as the remnants of anthropomorphism keep the public more engaged with lions than with bacteria. (In the last few decades, art historians have become interested in a wide variety of images that are not canonical instances of fine art, including mass cultural images, commercial and popular imagery, "low" art, and postcolonial images. From the broader viewpoint of images in general, such images remain within the fold of art. Popular imagery draws on the conventions of fine art even when it is not actively quoting or subverting it, but informational images operate at a much greater remove and are often effectively independent. In my analogy, fine art and popular imagery together might be the familiar mammals and other chordates, and informational imagery the many other phyla.

The variety of informational images, and their universal dispersion as opposed to the limited range of art, should give us pause. At the least it may mean that visual expressiveness, eloquence, and complexity are not the proprietary traits of fine art, and in the end it may mean that there are reasons to consider the history of art as a branch of the history of images, whether those images are nominally in science, art, archaeology, or other disciplines. My purpose in this essay is to survey the field of image studies, which is under way in disciplines such as the history of science, and to argue three points about the importance of informational images: that they engage the central issues of art history such as periods, styles, meanings, the history of ideas, concepts of criticism,

I would like to acknowledge help and critical readings by Dennis Des Chene, Harry Marks, Thomas Sloan, Michael Lynch, Andrew Connoly, Margaret MacNamidhe, and Jennifer Tucker.

1. Although the study of non-Western art is taken to be a 20th-century interest, it begins in the 17th century, at the same time as the kinds of scientific images I concentrate on in this essay. A convenient place to start the history of Western attempts to comprehend non-Western images is Vincenzo Cartari, *Imagini de gli dei delli antichi,* Padua, 1626. One of the best and most general meditations on the question of interpreting non-Western ideas is Martin Heidegger, "A Dialogue on Language," in *On the Way to Language,* ed. Peter D. Hertz, San Francisco, 1971, 1–56. For a good summary of the problem in anthropology (which can be read as a guide to issues in art history), see Stanley Tambiah, *Magic, Science, Religion, and the Scope of Rationality,* Cambridge, 1990.

2. As Hans Belting puts it (*Likeness and Presence: A History of the Image before the Era of Art,* trans. Edmund Jephcott, Chicago, 1994, 459), paraphrasing Hans Sedlmayr, in the "humanist definition of art . . . the new presence *of* the work succeeds the former presence of the sacred *in* the work." At that point the "history of the image before the era of art"—that is, from late antiquity to the earliest Renaissance—comes to an end, and the "development of art" commences. In relation to problems of definition I discuss below, the asymmetry in Belting's comparison is crucial: to be a logical parallel, it would have to read: "the new [sacred] presence *of* the work succeeds the former presence of the sacred *in* the work." Like the question of non-Western art, the shift or loss of presence has deep connections to the kinds of scientific and "informational" images I discuss. It is significant in this regard that the historian of science Bruno Latour has written a short essay on presence in Renaissance and Baroque paintings, "Opening One Eye While Closing the Other . . . A Note on Some Religious Paintings," in *Picturing Power,* 15–38. Latour claims in part that linear perspective is the signal that presence is transposable, so that scientific "mobility" begins to cancel religious "immutability" (ibid., 26). I argue differently in *The Poetics of Perspective,* Ithaca, N.Y., 1994, suggesting that perspective has always had an ambiguous role in these questions, and that now it is itself a fading presence. On the general subject of presence in art, the most important accounts are Michael Fried's ongoing interrogation of "presence" and "presentness," and George Steiner, *Real Presences,* Cambridge, 1986.

3. For communication or information theory, as it applies to visual images, see e.g., Reiner Metzker, *Das Medium der Phänomenalität: Wahrnehmungs- und erkenntnistheoretische Aspekte der Medientheorie und Filmgeschichte,* Munich, 1993; Abraham Moles, *Information Theory and Esthetic Perception,* Urbana, Ill., 1966; and Edward R. Tufte, *Envisioning Information,* Cheshire, Conn., 1990 (reviewed by Ian Hacking, "Matters of Graphics," *Science,* CCLII, May 17, 1991, 979–80). An interesting specialized study is W. H. Kruskal, "Criteria for Judging Statistical Graphics," *Utilitas Mathematica,* XXI B, 1982, 283–309.

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and changes in society; that they can present more complex questions of representation, convention, medium, production, interpretation, and reception than much of fine art; and finally, that far from being inexpressive, they are fully expressive, and capable of as great and nuanced a range of meaning as any work of fine art.

Among the disciplines engaged with these images, the history of science is predominant, but interest in nonreligious, nonart images is not limited to science. In many societies such images comprise the principal alternate to religious imagery, and for that reason alone, it is not prudent to assimilate whatever is taken to be informational with science or technology. The idea of counting, for example, has given rise to visual forms as well as written ones. In the West the visual history of numeration extends in time from the earliest Upper Paleolithic "tallies" on bone and slate to the inception of abstract symbols for numbers,[4] and from there to visual elements in the most recent number theory—a significantly longer continuous range than is normally covered by the histories of art or science.[5] The history of visual elements in mathematics also extends beyond the boundaries of the history of science; diagrams occur in modern texts, but also in unscientific constructions such as Ramon Llull's partly illogical "figures" of numerical combinations, and in pseudonumerical marking systems such as the Peruvian string *quipu.*[6] A history of nonart images would also need to consider pictorial elements in writing such as pictographs and ideographs, and their intersection with symbols, rebuses, ciphers, monograms, watermarks, and other images—including not only certain "word-image" questions,[7] but also accounts of the very different symbioses of picture and pictorial writing in Egyptian hieroglyphics and Mayan script.[8] The places where writing approaches images are especially intriguing and underexplored. Semasiography, for example, is the study of signs and morphemes without syntactic context, including rudimentary and isolated nonrepresentational markings of all sorts, from neolithic "symbols" to the enigmatic signs of Neo-Expressionism.[9] A related field is subgraphemics or "picture-writing," meaning pictures that look like writing but have no consistently disjunct signs; there are examples ranging from Nearctic Native American and Siberian visual "stories" and semisystematic Australian sand paintings to calligraphic abstraction as in the art of Cy Twombly.[10] Traditions of invented scripts and pseudowriting also draw on pictorial conventions. Pictorial pseudowriting begins with the prehistoric European Vinča culture, and includes such diverse phenomena as the Baroque misinterpretation of hieroglyphics, and Asian, African, and American invented scripts.[11] Even schemata, the principal objects of study in visually oriented research in the history of science—and arguably the central type of nonart images[12]—include not only modern scientific examples but also genealogical trees, graphs, and charts from the medieval period to the Baroque, representing everything from the macrocosmic-microcosmic universe to angelic scripts.[13] For these reasons it is best to say that scientific images play a part in informational images but are not necessarily its exemplars. Instead of confining nonart images to the sciences, or opposing "fine art" to "scientific images," we should understand visual elements in science as an efflorescence of informational images in general.

Nor is the category of informational images pure, so that it is possible to make too firm a distinction between religious, artistic, and informational images, as if they somehow di-

4. For prehistoric "tallies," see, e.g., Alexander Marshack, *The Roots of Civilization: The Cognitive Beginnings of Man's First Art, Symbol and Notation,* New York, 1972, and subsequent essays such as idem, "The Meander as a System: The Analysis and Recognition of Iconographic Units in Upper Paleolithic Compositions," in *Form in Indigenous Art,* ed. P. V. Ucko, Canberra, 1977, 286–317; idem, "On Wishful Thinking and Lunar 'Calendars,' " *Current Anthropology,* XXX, no. 4, 1989, 491; and idem, "The Taï Plaque and Calendrical Notation in the Upper Paleolithic," *Cambridge Archaeological Journal,* I, no. 1, 1991, 25–61. The recent literature is assessed in J. Elkins, "On the Impossibility of Close Reading: The Case of Alexander Marshack," *Current Anthropology,* forthcoming.

5. I emphasize *continuous,* since the examples of Lascaux and other prehistoric images that usually begin art-historical treatments are not continued in unbroken narrative into the ancient Near East, where the history of art proper gets under way. See Whitney Davis, "Beginning the History of Art," *Journal of Aesthetics and Art Criticism,* LI, no. 3, 1993, 327–50.

6. For the *quipu,* see Marcia and Robert Ascher, *Code of the Quipu: A Study in Media, Mathematics and Culture,* Ann Arbor, Mich., 1981; and the same authors' "Ethnomathematics," *History of Science,* XXIV, 1986, 125–44. For Llull, see first his *Ars demonstrativa,* in *Selected Works of Ramon Llull,* ed. Anthony Bonner, Princeton, N.J., 1985, I, 305–568.

7. On the question of "word-image" relations in this particular context, see J. Céard and J.-C. Margolin, *Rébus de la Renaissance: Des images qui parlent,* Paris, 1986; and the classic study by Ludwig Volkmann, *Bilderschriften der Renaissance: Hieroglyphik und Emblematik in ihren Beziehungen und Fortwirkungen,* Nieuwkoop, 1969. In terms of scientific images, see A. J. Meadows, "The Evolution of Graphics in Scientific Articles," *Publishing Research Quarterly,* VII, no. 1, 1991, 23–32; and Alistair Duncan, "The Requirements of Scientific Publishing: The Example of Chemical Illustrations in the Scientific Revolution," *Publishing Research Quarterly,* VII, no. 1., 1991, 33–53.

8. The best accounts of Egyptian word-image relations is H. G. Fischer, *L'Ecriture et l'art de l'Egypte ancienne,* Paris, 1986; idem, *The Orientation of Egyptian Hieroglyphs: Part I, Reversals,* New York, 1977; and H. Brunner, "Illustrierte Bücher im alten Ägypten," in *Wort und Bild,* ed. H. Brunner et al., Munich, 1979, 201ff. For Mayan script, see W. F. Hanks, "Word and Image in a Semiotic Perspective," in *Word and Image in Maya Culture,* ed. W. F. Hanks and D. S. Rice, Salt Lake City, 1989, 14ff.; and J. Elkins, "The Question of the Body in Mesoamerican Art," *Res,* XXVI, 1994, 113–24.

9. The terms "semasiography" and "subgraphemics" are from the work of I. J. Gelb, e.g., *A Study of Writing: The Foundations of Grammatology,* Chicago, 1974. The most interesting case of semasiography concerns the ostensive "Old European" script, which would have developed before writing in the Near East. The claim that the "Old Europeans" possessed a script is most clearly specified in Marija Gimbutas, *The Civilization of the Goddess,* San Francisco, 1991; see also J. Elkins, "The Signs of Writing: On Some Parallels between the Undeciphered Prehistoric Vinča Script and Andrea Mantegna's *The Battle of the Sea Gods,*" *Semiotica,* forthcoming.

10. For Eskimo and Australian Tjuringa subgraphemics, see Hans Jensen, *Die Schrift in Vergangenheit und Gegenwart,* Berlin, 1969, 3d ed., 36–37, fig. 26. Siberian examples are discussed in I. P. Al'kora, *Iazyki i pis'mennost' narodov severa,* Moscow, 1924, III.

11. For a pictographic writing system invented by a non-Westerner, see Alfred Schmitt, *Die Bamum-Schrift,* Wiesbaden, 1963, 3 vols. Another case, including examples of prophetic pseudowriting, is documented in William Smalley, *Mother of Writing: The Origin and Development of a Hmong Messianic Script,* Chicago, 1990. The Baroque misinterpretation of Egyptian hieroglyphs is exemplified by Athanasius Kircher, *Œdipus Aegyptiacus,* 1652–54, III, 257. For the Vinča script, see Elkins (as in n. 9).

12. I am not defending this claim here, although I think it makes sense to study the forms of the schema in any attempt to systematize the kinds of nonart images. The history of the schema in philosophy and various scientific and nonscientific disciplines is outlined in J. Elkins, "Schemata for the Schema: Seventeen Notes toward a History of the Concept," in *Encyclopedia of Aesthetics,* New York, forthcoming.

13. There is still no general history of schemata. For elements of that history, see the discussion of Proclus in Barbara Stafford, *Body Criticism: Imaging the Unseen in Enlightenment Art and Medicine,* Cambridge, Mass., 1991, 235–38; and books by François Dagognet, cited below, n. 58.

14. There are seven major candidates for names for the images I am discussing: scientific, inexpressive, non- or extra-aesthetic, informational, nonrepresentational (or aniconic), schematic, or notational. Let me consider these in turn. (1) I have already given reasons why they should not be reduced

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vided the domain of images between them. I think it makes sense to employ terms such as "informational images" as convenient labels rather than as definitions, since they say less about pictures than about the current shape of the disciplines that study them: "nonart" images, in the end, are whatever contemporary art history does not study.[14] Art history is centrally positioned in this emerging field because it possesses the most exact and developed language for the interpretation of pictures. Existing art-historical methods, which are normally trained on art objects, can embrace images of any kind, from graphs to ideographic writing; and conversely, art-historical inquiries can be enriched by what is happening in other disciplines. To make that case I will consider nonart images from two vantages: first, as they currently appear within art history, and second, as they are being explored in other disciplines. Between the two inquiries I will pause to consider the possibility that the lines dividing disciplines need not separate art from information, because no image is inexpressive: even the simplest diagram can be replete with meaning.

Nonart Images in Art History

As a general rule, art history has treated scientific and other informational images as ancillary sources for the interpretation of fine art, rather than as interesting images in their own right. Yet it could be urged that the potentially disruptive nature of such images remains invisible as long as they are treated as evidence for other kinds of pictures. As prelude to that possibility—which I discuss later in this paper—it is helpful to review three of the major uses art history has made of nonart images.

1. In the twentieth century especially, artists have looked to science for imagery, and art historians have worked to explain pictures by locating the relevant scientific sources. The artistic tendency to use science to inform art is an extension of a romantic and late-romantic attitude that can be traced back to writers such as Edgar Allan Poe (who made use of scientific and mathematical sources in his stories),[15] and it normally operates by reinventing the "dry" scientific material in order to bring out its expressive meanings. In a complementary fashion, art historians who refer the artworks back to their "objective" sources are performing an antiromantic or modernist gesture, explaining pictures by restoring their scientific origins.[16] Just as some romantic art vivifies science, some contemporary art history reinvests expressive images with scientific or "objective" referents. Even though it is grounded in early romanticism, this dual movement has not exhausted itself, and a number of artists lend themselves to such analyses. Post-Impressionists such as Georges Seurat and Paul Signac were influenced in more or less unscientific ways by books containing color solids and patches.[17] Artists as different as Odilon Redon and Wassily Kandinsky were interested in microscopical images,[18] and modernists from Picasso to Ernst and Duchamp were apparently swayed by misunderstood notions of exotic geometric and physical theories.[19] Although there is less art-historical study of contemporary art, artists such as Robert Rauschenberg, Vito Acconci, Dorothea Rockburne, Frances Whitehead, and Joan Fontcuberta continue to find new ways of incorporating mathematical, physical, botanical, medical, and zoological images in their work.[20]

There is much more to be explored in this vein, but there are both historical and methodological limitations that prohibit the approach from doing wider justice to the relations

to the appellation "scientific" (or mathematical), and I argue below that (2) they are not inexpressive, even if that term is taken in the narrow sense of provoking affective response. (3) There are at least two ways of arguing that the aesthetic comprehends these images as well as fine art: in the text I consider evidence that scientific images in particular preserve an original, pre-Kantian sense of the aesthetic; and it is also possible to stress the cognitive component of aesthetic response, as against Kant's exclusion of it. The second option is a recurring strain in aesthetics; see, e.g., Donald Crawford, *Kant's Aesthetic Theory*, Madison, Wis., 1974. The admission of cognitive aspects is also implicit in Nelson Goodman's account (*Languages of Art*, Indianapolis, Ind., 1976, 2nd ed.) of denotative "systems" that differ partly in their degree of symbolic and syntactic complexity. (4) "Informational" is not an improvement because the concept "information" itself is bound to 20th-century notions of communications theory and the efficient transfer of capital and knowledge, and so it is inapposite for the historical range of image making. (5) These images could be called nonrepresentational or aniconic, except that many of them are strongly iconic, and even more closely similar to their objects than fine-art images. (6) For the same reason they are not necessarily schematic—some are just as fully fleshed as paintings can be. (7) They could be called notations, if it were not that the word has been co-opted by Goodman to describe especially systematic images such as music notation, Labanotation (graphs of dancers' movements), and electroencephalographs. In J. Elkins, "What Really Happens in Pictures? Misreading with Nelson Goodman," *Word & Image*, IX, no. 4, 1993, 349–62, I argue that the logical strictures Goodman applies to notations are transferred from the common desire to systematize paintings. In that respect, paintings are failed notations, and what matters in visual images is not what happens in notations, but why notational strictness fails to happen in pictures. I take it that the difficulty of finding an adequate name for this class of images indicates that they fall outside the current interests of any one discipline. For that reason negative descriptions (that they are not art, or not religious paintings) normally serve best.

15. See *Romanticism and the Sciences*, ed. Andre Cunningham and Nicholas Jardine, Cambridge, 1990.

16. In this sense art historians participate in both directions of the history of ideas: some studies are concerned with romanticism in science, and others with science in (mostly literary) romanticism. See *Romanticism in Science: Science in Europe, 1790–1840*, ed. Stefano Poggi and Maurizio Bossi, Dordrecht, 1994; and in contrast, *Die Deutsche literarische Romantik und die Wissenschaften*, ed. Nicholas Saul, Munich, 1991.

17. See Floyd Ratliff, *Paul Signac and Color in Neo-Impressionism*, New York, 1992; and Robyn Roslak, "The Politics of Aesthetic Harmony: Neo-Impressionism, Science, and Anarchism," *Art Bulletin*, LXXIII, 1991, 381–90.

18. Kandinsky appears to have been influenced by microscopic images ca. 1937; see *Kandinsky: Catalogue Raisonné of the Oil-Paintings*, ed. Hans K. Roethel and Jean K. Benjamin, New York, 1984, cat. 1088 and passim. Redon's interest in microscpical images was sparked by Armand Clavaud; see Douglas W. Druick et al., *Odilon Redon: Prince of Dreams, 1840–1916*, exh. cat., Art Institute of Chicago, Chicago, 1994, 137, 148, 149.

19. The most comprehensive source is Linda Dalrymple Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, Princeton, N.J., 1983. See also C. H. Waddington, *Behind Appearance: A Study of the Relation between Painting and the Natural Sciences in This Century*, Cambridge, Mass., 1970; and Lucy Adelman and Michael Compton, "Mathematics in Early Abstract Art," in *Towards a New Art: Essays on the Background to Abstract Art*, ed. Michael Compton, London, 1980, 64–89. (For an assessment of Waddington's book, which puts him in the context of the "two cultures" debate, see Roy Porter, "The Two Cultures Revisited," *Cambridge Review*, CXV, no. 2324, 1994, 74–80.) There are other studies that are primarily psychological (e.g., Paul Vitz, *Modern Art and Modern Science*, New York, 1984) or formal (as in John Richardson, *Modern Art and Scientific Thought*, Urbana, Ill., 1971). Jean-François Lyotard, *Duchamp's TRANS/formers: A Book*, Venice, Calif., 1990, belongs in a different category since Lyotard does not set out to explain Duchamp's thinking so much as to participate in it.

20. Dorothea Rockburne's fresco described in Brooks Adams, "High Windows: Dorothea Rockburne's Skyscapes," *Artforum*, XXXI, no. 9, 1993, 78–82, utilizes graphs of the earth's electromagnetic field. Frances White head experiments with botanical forms and liquids; see, e.g., the review by Jim Yood, *Artforum*, XXVIII, no. 11, 1989, 146–47. Joan Fontcuberta has made artworks based on scientific descriptions of animals that do not exist; his "Fauna" series is described by Jean Fisher in *Artforum*, XXVII, no. 2, 1988, 141–42.

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between science and art. Since the search for scientific sources depends on specific iconographic parallels, it cannot explain the more indirect (but no less important) relations between early science and Baroque imagery, or between Enlightenment science and Neoclassical imagery,[21] and it cannot come to terms with more abstract influences on twentieth-century art, such as popular notions of the uncertainty principle, nuclear fission, and fractal geometry.[22] Histories of the influence of optical or perspectival theories tend to explain only limited aspects of post-Renaissance art,[23] and even when it comes to explicitly optical art such as Seurat's, scientific explanations may have only a tenuous grip on what makes the paintings meaningful.[24] I mention fractal geometry among other possibilities because connections between chaotic dynamics and art continue to be of interest to a wide range of computer-graphics specialists, artists, and mathematicians. Some scientists have made aesthetic claims about their mathematics that are inappropriate by historical standards (Benoit Mandelbrot, for example, says that his fractal geometry is like minimalist painting),[25] and some art critics have employed scientific terms such as "chaos" or "turbulence" in ways that are not meaningful by scientific standards.[26] These are the kinds of oblique references that the iconographic history of scientific images in art has trouble accommodating. Ultimately the approach lacks the flexibility to demonstrate the full relation between science and art—what twentieth-century art is *not* influenced by modern science?—and it does not yet possess a methodological strategy that would justify concentrating on more literal parallels.

2. Other nonart images have attracted attention because they share fine-art conventions or show vestiges of expressive meaning. The two most important examples are probably medical imaging and computer graphics. Medical images have been of interest not only because they have had direct influence on artistic practice from the fifteenth century onward,[27] but also because medical illustration inevitably evokes affective questions of gender, pleasure, and pain, and commonly employs pictorial conventions very close to those of contemporaneous fine art. Thus Andreas Vesalius's figures have affinities with Italian landscape and figural compositions, Charles Estienne's figures are allied with the School of Fontainebleau, Govard Bidloo's dissections use Dutch still-life conventions, and Bernard Albinus's figures have close parallels to Neoclassical art theory.[28] In a way, medical illustration is the shadow of fine-art depictions of the body, participating in many of its meanings and conventions but remaining hidden within the ostensibly scientific. So many conventions of fine art have been brought over into anatomic illustration that the only major formal difference between the two is that medical illustrators were routinely granted license to portray aspects of death, sexuality, and the inside of the body that were proscribed for fine artists.[29] In the twentieth century those distinctions have collapsed, and artists from Joseph Beuys to Arnulf Rainer and Hermann Nitsch make free use of medical images and scenes of the body's interior.[30]

The same may be said about computer graphics. Even though the relative separation of art history and computer graphics may seem to indicate they have little in common, it is possible to demonstrate an ongoing dependence of computer graphics on the older history of art. The rendering routines that have been developed in the last two decades model light effects that are found in Renaissance and Baroque paintings—that is, even where they set out to mimic nature directly, graphics designers tend to choose phenomena that are not only amenable to computation but are also in line with inherited pictorial versions of naturalism. In so doing, computer software developers recapitulate the history of art in various particulars: the history of three-dimensional rendering rehearses the early history of linear perspective, the current interest in translucent "mylar" layering revives diaphanous Rococo effects of fresco and oil paint, and the routines for lighting gradients (such as Phong and Blinn rendering) recall seventeenth- and eighteenth-century interests in specular and diffuse reflections.[31] In a wider sense, the conventions of computer-generated perspectival scenes in military and scientific simulations, architecture, and commercial games appear "natural" or mathematically driven to their designers, even though they can be shown to derive from Western landscape painting of the last two centuries.

21. For these topics, see Barbara Maria Stafford, *Artful Science: Enlightenment, Entertainment, and the Eclipse of Visual Education*, Cambridge, Mass., 1994.

22. The journal *Leonardo* is a source of information on many of these parallels.

23. For connections between optical science and painting, see Martin Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*, New Haven, 1990; and the discussions of Chardin in Michael Baxandall, *Patterns of Intention: On the Historical Explanation of Pictures*, New Haven, 1985, and of Fra Angelico in Samuel Edgerton, *The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution*, Ithaca, N.Y., 1991. For 19th-century optical themes, see Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century*, Cambridge, 1990.

24. The best work on Seurat's color theories, I think, is still William Innes Homer, *Seurat and the Science of Painting*, Cambridge, Mass., 1964, because it records empirical observations that have yet to be tested. See also the skeptical account in Paul Smith, "Seurat, The Natural Scientist?" *Apollo*, CXXXII, no. 346, Dec. 1990, 381–85; and Alan Lee, "Seurat and Science," *Art History*, X, no. 2, 1987, 223.

25. B. Mandelbrot, *Fractal Geometry of Nature*, San Francisco, 1982, 23, citing F. Dyson, "Characterizing Irregularity," *Science*, CC, 1978, 677–78.

26. I have argued these points in J. Elkins, "The Drunken Conversation of Chaos and Painting," *M/E/A/N/I/N/G*, XII, 1992, 55–60; see also Larry Short, "The Aesthetic Value of Fractal Images," *British Journal of Aesthetics*, XXXI, 1991, 342–55. The entire topic of spurious art-science parallels has been succintly articulated by Leo Steinberg, "Art and Science: Do They Need To Be Yoked?" *Daedalus*, CXV, no. 1, 1986, 1–16.

27. For early anatomical interest, see Bernard Schultz, *Art and Anatomy in Renaissance Italy*, Ann Arbor, Mich., 1985. For the relation between anatomy and painting in Michelangelo, see J. Elkins, "Michelangelo and the Human Form: His Knowledge and Use of Anatomy," *Art History*, VII, 1984, 176–86; and for parallels between anatomy and French Academy drawing, see idem, "Two Conceptions of the Human Form: Bernard Siegfried Albinus and Andreas Vesalius," *Artibus et Historiæ*, XIV, 1986, 91–106, with reference to David G. Karel, "The Teaching of Drawing in the French Royal Academy," Ph.D. diss., University of Chicago, 1974.

28. For Vesalius's figures, see *The Illustrations from the Works of Andreas Vesalius of Brussels*, ed. J. B. Saunders and Charles O'Malley, Cleveland, 1950. Charles Estienne, *La Dissection des parties du corps humain*, Paris, 1546, is the subject of a work in progress by Valerie Traub (Vanderbilt University), which brings out their connections to Renaissance eroticism and the pornographic booklet *I modi*. Bidloo's compositions are discussed in Mario Perniola, "Between Clothing and Nudity," trans. Roger Friedman, in *Fragments for a History of the Human Body*, ed. Michel Feher, Cambridge, Mass., 1989, II, 236–65, esp. 258. Albinus's Neoclassical affinities are discussed in Elkins (as in n. 27). See also Marie-Hélène Huet, *Monstrous Imagination*, Cambridge, Mass., 1993, and the review by Lorraine Daston, *Isis*, LXXXV, no. 1, 1994, 132.

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Many kinds of computer graphics inadvertently (and sometimes intentionally) draw near to fine-art traditions from the Renaissance onward, and those parallels are a major reason why computer graphics are presented and studied as independent works of art.[32] Both medical illustration and computer graphics are marginal to the mainstream interests of art history, but they are also firmly connected with that history by virtue of their formal and expressive borrowings.

3. Finally, art history has taken an interest in nonart images that can be used to illuminate the history of visuality, even if they do not contribute directly to the production of artworks. Celestial and terrestrial maps, panoramas and dioramas, pictures made during scientific voyages, and botanical, paleontological, geological, and zoological illustrations are among the prominent examples. These subjects are never without their links to fine art, even though they may be limited or oblique. Parallels between maps and paintings have been widely discussed in art history, for example in the "mapping impulse" that Svetlana Alpers has analyzed in seventeenth-century Dutch painting, the interest in "topographical" scenes in nineteenth-century American art, and the coincidence of navigation, astronomy, and the inception of linear perspective.[33] Dioramas and panoramas are even more directly implicated in fine-art production, since the history of panoramas is the story of ongoing searches for talented landscape artists and architectural draftsmen.[34] As Barbara Stafford has shown, travel illustrations made for geological, archaeological, anthropological, and botanical purposes are testimony not only to the meanings the scientists wished to extract from what they saw,[35] but also to contemporaneous notions of the sublime, the picturesque, and the landscape genre.[36] Unlike images in the first two categories, these tend to be used to make general points about the ideas that drove picture-making in the fine arts, and so they are less tightly bound to the forms of individual paintings and drawings. That freedom is a strength, since it avoids the search for direct influences, but it is also a weakness because it elucidates tendencies in art and the history of associated concepts more than individual artworks.

I list these examples to evoke the general outlines of the field. When art history encounters nonart images, it tends to use them to illustrate the history of fine art. In each of these cases what attracts art-historical interest, and gives the images a relatively independent meaning, is their closeness to fine art. Those images that have less to do with painting and drawing get less attention. The outlandish distortions of many map projections tend to be overlooked in favor of those projections that resemble the distances and angles of vision common in painting,[37] just as the less naturalistic and intuitive aspects of computer graphics, or the less spatially resolved strategies of medical illustration, tend to appear less meaningful than their more pictorial instances. There are many studies of gendered figures in the history of medical illustration, fewer of pictures of body parts, and virtually none of histological and sectional anatomies. In general, the supposition behind the art-historical studies might be put like this: some scientific and nonart images approach the expressive values and forms of fine art, but many more are encased in the technical conventions of their fields. Those images are a kind of desert where pictures are stunted and far between. They are inherently informational and without aesthetic value, and they are properly considered as kin to equations or spreadsheets; they are notations, and not images in a deeper sense.

Wider Meanings in "Inexpressive" Images

I think it is important to resist this conclusion, both for the sake of the expanding discipline of art history—which would otherwise find itself against an unbreachable barrier at the "end" of expressiveness, interest, or aesthetic value—and also because it is demonstrably untrue. An especially significant text in this regard is a study written by the sociologist of science Michael Lynch and the art historian Samuel Edgerton, on the ways in which astronomers handle images. Astronomers routinely make two kinds of images: "pretty pictures" for coffee-table books and popular-science magazines such as *Scientific American,* and "scientific" images, normally in black-and-white, for publications such as the *Journal of Astrophysics.* "Pretty pictures" are often given

29. The best recent text on medical images is Stafford (as in n. 13). See also the reviews of Stafford by Dorinda Outram, "Body and Paradox," *Isis,* LXXXIV, 1993, 347–52; and J. Elkins, *Art Bulletin,* LXXIV, no. 3, 1992, 517–20.

30. An interesting essay on Beuys and anatomy is Matthias Bunge, "Joseph Beuys und Leonardo da Vinci, Vom 'erweiterten Kunstbegriff' zu einem erweiterten Kunstwissenschaftsbegriff," *Das Münster,* XLIV, no. 2, 1993, 93–106, and ibid., XLVI, no. 3, 1993, 227–36. For Rainer and Nitsch, see, e.g., Robert Morgan, "Gunther Brus, Hermann Nitsch, Arnulf Rainer," *Arts Magazine,* LIX, May 1985, 196.

31. Each of these is argued in J. Elkins, "Art History and the Criticism of Computer-Generated Images," *Leonardo,* XXVII, no. 4, 1994, 335–42, and col. pl.; and a complementary case regarding virtual reality is made in idem, "There Are No Philosophic Problems Raised by Virtual Reality," *Computer Graphics,* XXVIII, no. 4, 1994, 250–54.

32. The parallel between scientific and "fine-art" computer-generated images can be demonstrated by comparing the "science" and "art" portions of the annual SIGGRAPH conference. For intentional copies of Old Master works and architectural monuments, see John R. Wallaca, "Trends in Radiosity for Image Synthesis," *Photorealism in Computer Graphics,* ed. Kadi Bouatoch and Christian Bouville, New York, 1992.

33. For the first, see Svetlana Alpers, *The Art of Describing: Dutch Art of the Seventeenth Century,* Chicago, 1983. For an assessment of "topographical" painters, see, e.g., Angela Miller, *The Empire of the Eye: Landscape Representation and American Cultural Politics, 1825–1875,* Ithaca, N.Y., 1994, 152. The conjunction of mapping and perspective is explored in Jane Aiken, "Renaissance Perspective: Its Mathematical Source and Sanction," Ph.D. diss., Harvard University, 1986; and Samuel Edgerton, *The Renaissance Rediscovery of Linear Perspective,* New York, 1975.

34. See first R. Hyde, *Panoramania! The Art and Entertainment of the 'All-Embracing' View,* London, 1988; and also S. Bordini, *Storia del Panorama: La visione totale nella pittura del XIX secolo,* Rome, 1984; S. Oetterman, *Das Panorama,* Frankfurt, 1981; and H. Ruddemeier, *Panorama, Diorama, Photographie,* Munich, 1970.

35. For examples of the construction of scientific meaning in these contexts, see Bernard Smith, *Imagining the Pacific: In the Wake of the Cook Voyage,* New Haven, 1992; Brian Ford, *Images of Science: A History of Scientific Illustration,* London, 1992; and Martin Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World,* Chicago, 1992; and Brian Ford, *Images of Science: A History of Scientific Illustration,* New York, 1993.

36. Barbara Maria Stafford, *Voyage into Substance: Art, Science, Nature, and the Illustrated Travel Account, 1760–1840,* Cambridge, Mass., 1984. See also Timothy Mitchell, *Art and Science in German Landscape Painting, 1770–1840,* Oxford, 1993. For a discussion of pictorial values in dioramas, see J. Gage, "Loutherbourg: Mystagogue of the Sublime," *History Today,* XIII, 1963, 332–39.

37. Technically, it would be better to say that out of the sum total of mappings, art history pays most attention to projections, and within that class to gnomonic and related projections. A good introduction to the full diversity of the field is Georg Scheffers, "Wie findet und zeichnet Man Gradnetze von Land-und Sternkarten?" in *Mathematisch-physikalische Bibliothek,* ed. K. Strubecker, Leipzig, 1934, Reihe 1, LXXXV–LXXXVI.

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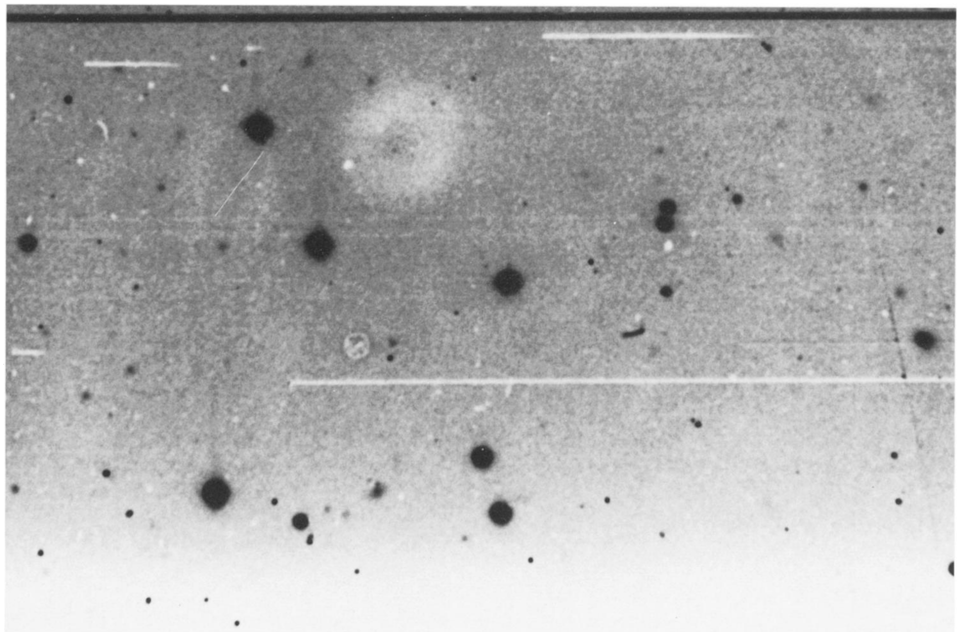
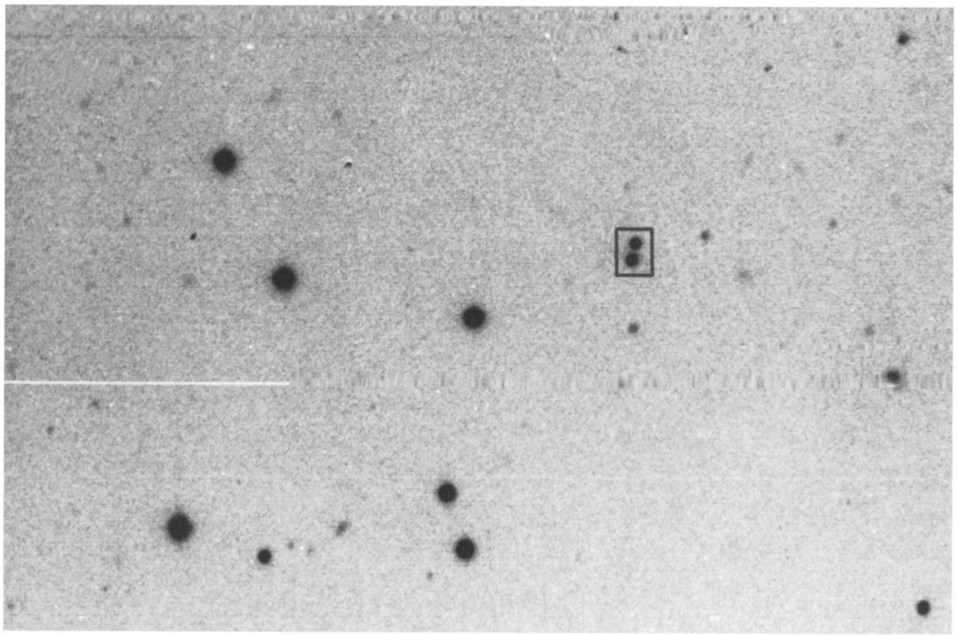


1 "Noisy" CCD image (from Michael Lynch and Samuel Edgerton, in *Picturing Power,* fig. 3; courtesy Michael Lynch and Rudolph Schild, Harvard-Smithsonian Astrophysical Laboratory)



2 Processed image, with cursor box drawn around the object QSO 0957+561 (from Lynch and Edgerton, fig. 4; courtesy Michael Lynch and Rudolph Schild, Harvard-Smithsonian Astrophysical Laboratory)

strongly chromatic false colors, and initially Lynch and Edgerton hoped to find evidence that Expressionist painting might lie behind that practice, making the astronomical images interesting examples of the diffusion of fine art. But according to their informants in the laboratory, fine art influences neither the "scientific" images nor the "pretty pictures."[38] Even though the astronomers may set aside time to make "pretty pictures," they do not consider them seriously in terms of the history and meanings of art, or even intend them to be anything more than eye-catching or decorative. On the other hand, they are intensely concerned with their "scientific" images because they want to make them as clear, unambiguous, simple, graphically elegant, and useful as possible. To that end they employ a range of image-processing tools to "clean up" the raw data provided by the telescopes. To make the "noisy" image in Fig. 1 into the "clean" image in Fig. 2, the astronomers used image-processing software to remove "electronic bias" (which makes the top of Fig. 1 darker than the bottom), a "donut" caused by out-of-focus dust in the telescope (top center), rows of "burnt out pixels" (the bright and dark horizontal lines), a spot of epoxy glue (left of center), and cosmic ray traces (the smaller dark spots). At first it seems that this has little to do with anything that might concern a history of art. But Lynch and Edgerton point out that this kind of care is not outside aesthetics. It precisely *is* aesthetics: it is the original, pre-Kantian sense of aesthetics as the "perfecting of reality"—the very doctrine that governed Renaissance painting.[39] Even when the astronomers use false colors for their scientific images, they do so in order to make natural forms clearer and more susceptible to quantitative measurement. Their images always aim to give what they consider to be the

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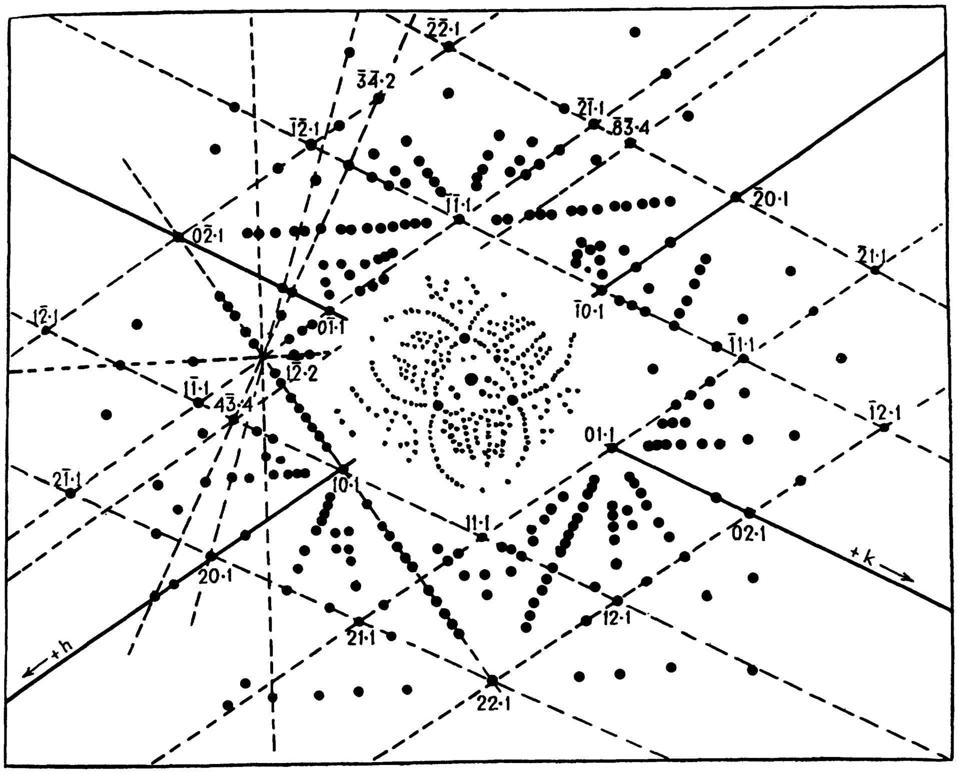

3 Gnomonic projection of Laue pattern of rhodochrosite ($MnCO_3$) (from Wheeler Davey, *A Study of Crystal Structure and its Applications,* New York, 1934, fig. 13)

most rational version of phenomena. This, I think, is a fundamentally important result, and no work on nonart images should proceed without taking it into account. What happens in nonart images can be just as full of artistic choices, just as deeply engaged with the visual, and just as resourceful and visually reflective as in any painting, even though its purposes may be entirely different. Lynch and Edgerton agree with Leo Steinberg, Thomas Kuhn, and others that not much is to be gained by comparing the scientists' criteria of elegance, clarity, and simplicity with artistic criteria, and that the two senses of images are worlds apart[40]—but in terms of the attention scientists lavish on creating, manipulating, and presenting images, the "two cultures" are virtually indistinguishable.

Where images are the objects of such concerted attention, then affective, historical, and social meanings—in short, the panoply of meanings that concern art history—cannot be far behind. Affective meanings, for example, are present in even the driest informational images. Nicole Oresme, who was one of the originators of graphs in the mid-fourteenth century, understood his invention in partly numerical and partly expressive terms.[41] The vertical axis on his graphs represented "difform qualities" such as heat,[42] and so a graph plotting rising heat against distance would result in a triangle, which Oresme called a "sharp" heat. The history of graphing is as yet largely unknown,[43] but there is still a pictorial remnant in our sense of graphs—think, for example, of the buoyant look of a stock-market graph that goes "off the chart."[44] If an image as "inexpressive" as a medieval x–y graph contains both affective and pictorial elements, then it is not surprising to find wider meanings in more recent—and more elaborate—scientific images.

An image of a crystal, for example, performs several operations on ordinary space that have parallels in nineteenth-century experiments in technical drawing and the fine arts (Fig. 3). The curvilinear image at the center is a

38. M. Lynch and S. Edgerton, "Aesthetics and Digital Image Processing: Representational Craft in Contemporary Astronomy," in *Picturing Power,* 184–220, esp. 193. See also Michael Lynch, "Laboratory Space and the Technological Complex: An Investigation of Topical Contextures," *Science in Context,* IV, no. 1, 1991, 81–109.

39. Lynch and Edgerton (*Picturing Power,* 214, 218 n. 26) quote Hans-Georg Gadamer (*Truth and Method,* NewYork, 1984, 74–75) to the effect that science has usurped the original sense of aesthetics, making everything that is not scientific imaging merely what the astronomers call a "pretty picture."

40. Lynch and Edgerton, *Picuring Power,* 185, citing Steinberg (as in n. 26); and Kuhn, "Comment on the Relation Between Science and Art," *The Essential Tension: Selected Studies in Scientific Tradition and Change,* Chicago, 1977, 340–51.

41. For Oresme, see E. J. Dijsterhuis, *The Mechanization of the World Picture,* Oxford, 1961, 194. The primary text is Oresme, *Tractatus de configurationibus intensionum* (also called *De uniformitate et difformitate intensionum*). See also Marshall Clagett, *Nicole Oresme and the Medieval Geometry of Qualities and Motion: Treatise on the Uniformity and Difformity of Intensities Known as* Tractatus de configurationibus qualitatum et motum, Madison, Wis., 1968; and Heinrich Wieleitner (who also wrote on painter's perspective), "Über den Funktionsbegriff und die graphische Darstellung bei Oresme," *Bibliotheca Mathematica,* XIV, 1914, 193–243.

42. For "difform qualities," see Marshall Clagett, *The Science of Mechanics in the Middle Ages,* Madison, Wis., 1959, 354–55.

43. See also the interesting (and to my mind, unexplained) demonstration by Laura Tilling, "Early Experimental Graphs," *British Journal for the History of Science,* VIII, 1975, 193–213, that with the exception of Johann Heinrich Lambert, graphs were virtually unused from the beginning of the 18th century to the beginning of the 19th. The most interesting work on 17th-century graphs is Henk J. M. Bos, "Arguments on Motivation in the Rise and Decline of a Mathematical Theory: The 'Construction of Equations,' 1637–ca. 1750," *Archive for the History of the Exact Sciences,* XXX, 1984, 331–80, documenting the idea that a polynomial is not solved until its roots are graphically constructed. See also James Garrison, "Geometry as a Source of Theory-Ladeness in Early Modern Physics," Ph.D. diss., Florida State Universty, 1981.

44. Graphs also *dramatize* their data in the sense that they link discrete events in time to produce or reestablish temporal continuity. For this argument, see Françoise Bastide, "The Iconography of Scientific Texts: Principles of Analysis," in *Representation in Scientific Practice,* ed. Michael Lynch and Steve Woolgar, Cambridge, Mass., 1990, 187–230, esp. 215.

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Laue pattern, produced by shining X-rays through the crystal; the crystal's atoms diffract the X-rays in determinate directions, creating a pattern that reflects the atomic structure. Laue photographs are not easy to decode, and the crystallographer, Ralph Wyckoff, has superimposed a second projection of the Laue pattern that straightens its arcs into lines. Although it is not easy to see, the larger pattern of dots ranged along the straight lines repeats the central pattern arranged on curves; the trefoil arcs, for example, become a large inverted triangle. With the addition of straight lines, it is possible to correlate the spots with conventional notations for crystal facets. Given the numbers ("indices") on the grid, a crystallographer could name the crystal and make an ordinary representational picture of it.[45] The Laue pattern is a stereographic projection and the surrounding field a gnomonic projection—both cartographic methods first applied to crystals in the early and middle nineteenth century. The ways in which space is bent and realigned in the two projections can also be found in eighteenth- and nineteenth-century perspective treatises, written by theorists interested in spatial constructions that did not correspond to the intuitively available fictive spaces of simpler perspectival projections. Those drawing conventions are descended, as we might expect, from related sources—especially early nineteenth-century mapmaking and engineering drawing.[46] But the image can also be interpreted in terms of late eighteenth-century painting: it behaves partly like the early panoramas (the images are wide-angle views, and the central image curves space as the large panoramas did), and the larger projection flattens space in a way analogous to the simplified relief spaces of Neoclassical painters such as those students of Jacques-Louis David who were called Les Primitifs.[47] A full reading of this image would acknowledge various influences: from the Neoclassical modes of picture making to the spare conventions of descriptive geometry, and from the austerities of crystal symmetries to the techniques of scientific engraving. Wyckoff's graphic innovation in this image—superimposing the stereographic and gnomonic projections—is a typical twentieth-century move toward greater complexity. In a way that is not unrelated to modernist strategies in painting, his composite image both distorts and fragments space, making it impossible to read the image as a consistent whole.

I give these brief examples of astronomical images, graphing, and crystal drawing to suggest that there is no dearth of expressive, historically grounded meaning even in pictures that seem most distant from art history's ordinary concerns. It is important, I think, not to let the hierarchy of images creep back under the guise of relative "interest." In a more reflective view there is no such thing as an image that merely provides information, and scientific and other nonart images can be just as rich as paintings.

These are logical considerations, and they lead in some unexpected directions. With more thorough interpretations of nonart images, it would begin to make sense, for example, to tell the history of art through the history of some scientific discipline such as crystallography. I think it is possible to make a reasonable attempt at doing just that—finding "Renaissance," "Romantic," "modern," and even "postmodern" crystallographic drawings, and beginning to tell the history of crystallographic illustration *as* the history of Western art.[48] It is a thought experiment—H. W. Janson's *History*

45. To be exact, the Miller indices in the gnomonic projection in Fig. 3 could be used to draw a picture of a plausible appearance of a crystal of rhodochrosite, since the physical appearances of individual crystals of any given substance may vary widely. Such a picture would only be a "representational picture" in a special sense, since it is likely to be a clinographic parallel projection and not a perspective picture. See Ralph Walter Graystone Wyckoff, *The Structure of Crystals,* New York, 1931, 2d ed.

46. For a historical introduction, see Harold Belofsky, "Engineering Drawing—A Universal Language in Two Dialects," *Technology and Culture,* xxxii, no. 1, 1991, 23–46.

47. For parallels between late 18th-century perspective treatises, engineering drawing, and paintings, see J. Elkins, "Clarification, Destruction, Negation of Space in the Age of Neoclassicism," *Zeitschrift für Kunstgeschichte,* lvi, no. 4, 1990, 560–82, which elaborates some observations made by Robert Rosenblum about the character of spatial explorations ca. 1800. For "Les Primitifs," see Robert Rosenblum, *Transformations in Late Eighteenth-Century Art,* Princeton, N.J., 1969, 183–85.

48. I consider the possibilities in J. Elkins, "On the Idea of Inexpressive Pictures: Art History as the History of Crystallography," work in progress.

49. In addition to the sources cited elsewhere in this essay, see John Halverson, "Art for Art's Sake in the Paleolithic," *Current Anthropology,* xviii, no. 1, 1987, 63–89, which presents an argument about the meaninglessness of cave art—a notion that has connections with the received idea that certain images, including Paleolithic "tallies," are inexpressive. For a study of archaeological representations, see Charles Goodwin, "Professional Vision," *American Anthropologist,* xcvi, no. 3, 1994, 606–33.

50. In some of the most conceptually wide-ranging work, Phil Johnson-Laird has studied simple schemata—mental pictures—that are used to solve problems in lieu of full logical analysis. See Phil Johnson-Laird and Ruth M. Byrne, "Précis of *Deduction,*" *Behavioral and Brain Sciences,* xvi, 1993, 323–80, including criticism by various writers; and "Author's Response: Mental Models or Formal Rules?" (ibid., 368–80); Phil Johnson-Laird, Ruth M. Byrne, and Walter Schaeken, "Propositional Reasoning by Model," *Psychological Review,* xcix, no. 3, 1991, 418–39; Phil Johnson-Laird, "Mental Models and Probabilistic Thinking," *Cognition,* l, nos. 1–3, 1994, 189–209; and idem, "How Diagrams Can Improve Reasoning," *Psychological Science,* iv, no. 6, 1993, 372–78. There are also psychological studies of ordinary graphics, which tend to suffer from an art-historical standpoint because they concentrate on very simple graphics of a kind that has few parallels before the mid-20th century. See *Comprehension of Graphics,* ed. Wolfgang Schnotz and Raymond Kulhavy, Amsterdam, 1994.

51. Journals include *Visual Anthropology, Cambridge Archaeological Journal,* and *Current Anthropology.* A related work is J. Fabian, *Time and the Other: How Anthropology Makes Its Object,* New York, 1983.

52. Works relevant to art history include Fernando Dogana, *Le parole dell'incanto: esplorazioni dell'iconismo linguistico,* Milan, 1990; and Elizabeth Chaplin, *Sociology and Visual Representation,* London, 1994.

53. Graphic design remains more commercial, but there are exceptions: see Massimo Vignelli, *Grids: Their Meaning and Use for Federal Designers,* Washington, D.C., 1978.

54. The journal *Visible Language,* e.g., publishes essays on train timetables, charts, and maps; see, e.g., the special issues "Diagrams as Tools for Worldmaking," *Visible Language,* xxvi, nos. 3–4, 1992, and "Inscriptions in Paintings," ibid., xxiii, nos. 2–3, 1989.

55. The principal journal is *Historia Mathematica;* see, e.g., Marcia Ascher, "Graphs in Cultures: A Study in Ethnomathematics," *Historia Mathematica,* xv, 1988, 201–27. The *Journal of Graph Theory* is sometimes also relevant to historical concerns.

56. These are three separate disciplines. Their respective associations in the United States are the History of Science Society, with its publication *Isis;* Society for Social Studies of Science, with its publication *Science, Technology, and Human Values* (and the associated *Social Studies of Science*); and Philosophy of Science Association, with its publication *PSA,* which collects the proceedings of the annual conferences. The three societies are abbreviated HSS, 4S, and PSA respectively.

57. Several new journals mark this trend: *Configurations, Perspectives on Science,* and *Metascience.* The three societies named in n. 56 had a joint annual meeting for the first time in 1994. This is not to say that their objectives and methods do not remain distant from one another; see, e.g., Michael Ruse, "Do the History of Science and the Philosophy of Science Have Anything to Say to Each Other?" *PSA,* ii, 1992, 467ff; and Steve Fuller, *Philosophy, Rhetoric, and the End of Knowledge: The Coming of Science and Technology Studies,* Madison, Wis., 1993, reviewed by Michael Lynch in *Contemporary Sociology,* xxiii, no. 2, 1994, 312–14.

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of Art could not really be rewritten using pictures of crystals—but it serves to make a point that bears crucially on the confluence of disciplines that study images. If these images are to be understood in their wider senses, then it is necessary not to restrict interpretation so that it can only tell the history of one kind of image in terms of some other kind. This is the context in which it makes sense to say inexpressive images are not only expressive but are fully expressive, and as such they can effectively question the way we think of the domain of the visual.

Images beyond Art History

Other disciplines are already exploring the possibilities of expressive images outside art. At the moment aspects of informational images are being studied principally in archaeology,[49] cognitive psychology,[50] visual anthropology,[51] visual communication,[52] graphic design,[53] some aspects of "word-image" discussions,[54] the history of mathematics,[55] and the history, social study, and philosophy of science.[56] Most of the work is taking place in the various disciplines that study science, and a new interdisciplinary field of science studies is emerging from the blurred differences between the criticism, history, and practice of technology and the sciences.[57] The last five years in particular have seen a dramatic increase in research that interprets science through its images.[58] Although some has to do with the role of specifically artistic images in science, more is concerned with images that appear unallied with fine art.[59] The examples range from thumbnail sketches and notations of thought experiments to formal graphs and even "maps" of entire disciplines.[60] Recently historians and sociologists of science have introduced schemata to understand what the scientists do, and those graphs have themselves become objects of study.[61]

The field is still young, and the material has not yet been collected into a synthetic account, but it is already possible to discern two basic directions in the research: some scholars are interested in scientists' images for what they have to say about the process of scientific discovery,[62] and others are intrigued by the way in which images can serve as "nonpropositional" substitutes for rational argument.[63] These orientations raise two complementary questions: the first asks about the ways in which the history of images should be told, and the second is concerned with the philosophic and cognitive nature of the images themselves. In this context the historical research is more important, and so far it has shown remarkable variety.[64] A number of topics relate to the three kinds of art-historical research I have outlined: studies of scientific objectivity, for example, could be brought to bear on issues in the rise of photography.[65] But I want to veer away from those possibilities, since they lead back toward the kind of art history in which nonart images are used to explain painting. Instead, I want to cast some of the issues at stake in image studies as fundamental challenges to the methodological and theoretical customs of art history. Five subjects in particular show how the two disciplines might illuminate one another.

1. In the fine arts, if a drawing is associated with a painting, the two are likely to be similar. In Charles de Tolnay's classic examples, Filippino Lippi's sketch for the *Resurrection of Drusiana* "is like a dream image, lacking consistency and structure," but it is also clearly a way of getting ready for the details of the final composition; while Ghirlandaio's drawing

58. French and Anglo-American researchers draw two different genealogies for this interest: in France François Dagognet has written widely on the theory of images in science, and in the United States Martin Rudwick has written on the importance of images in the history of geology and paleontology. The two are very different: Dagognet's work is the more abstract and is concerned with the nature of the image as such; Rudwick concentrates mostly on the detailed workings of scientific discovery. The difference has impelled Anglo-American scholars to emphasize the relevance of images to the history of science. See M. Rudwick, "The Emergence of a Visual Language for Geological Science, 1760–1840," *History of Science*, XIV, 1976, 149–95; and F. Dagognet, *Tableau et langages de la chimie*, Paris, 1969; idem, *Pour une théorie générale des formes*, Paris, 1975; and idem, *Philosophie des formes*, Paris, 1986. For the bifurcated genealogy (but not the conclusion I draw from it), see Alberto Cambrosio, Daniel Jacobi, and Peter Keating, "Ehrlich's 'Beautiful Pictures' and the Controversial Beginnings of Immunological Imagery," *Isis*, LXXXIV, 1993, 662 n. 1.

59. Among studies of scientific images that partake of fine-art conventions, see Martin Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World*, Chicago, 1992; and idem, review of A. B. Van Riper, *Men Among the Mammoths: Victorian Science and the Discovery of Human Prehistory*, in *Nature*, CCCLXVI, no. 6453, Nov. 25, 1993, 388. For related material, see S. M. Czerkas and D. F. Glut, *Dinosaurs, Mammoths and Cavemen: The Art of Charles R. Knight*, New York, 1982; and Susan Leigh Star and James Griesemer, "Institutional Ecology, 'Translations,' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39," *Social Studies of Science*, XIII, 1989, 205–28. The historian of science Gregg Mitman ("Hollywood Technology, Popular Culture, and the American Museum of Natural History," *Isis*, LXXXIV, 1993, 637–61) has studied the influence of Hollywood filmmaking on discovery in natural science; the images include footage of Komodo dragons and natural-science dioramas.

60. For a study of "maps" of disciplines, see Peter Taylor, "Mapping Ecologists' Ecologies of Knowledge," *PSA 1990*, 95–109.

61. Bruno Latour, Philippe Mauguin, and Geneviève Teil, "A Note on Socio-Technical Graphs," *Social Studies of Science*, XXII, 1992, 33–57. The graphs map distances between the world (or the "artifact," or the "evidence") and the scientific theory, by arranging connections according to successive "abstractions," "modalizations," "translations," and syntagmatic and paradigmatic alterations. They can be interpreted by the *historical* study of schemata, which can elucidate the epistemological constraints that are imposed by their formal structures. See J. Elkins (as in n. 12). The influential article on geological images by Rudwick ([as in n. 58], 178) sums up its findings in a "highly diagrammatic representation" of the "visual language" of geology. For conceptual diagrams in social theory, see Michael Lynch, "Pictures of Nothing? Visual Construals in Social Theory," *Sociological Theory*, XCI, no. 1, 1991, 1–22.

62. An influential text in this vein is Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts*, 2d ed., Princeton, N.J., 1986, although the authors' description (45ff) of measurements as "literary inscriptions" also privileges writing over images, as Karin Knorr-Cetina points out (*The Manufacture of Knowledge: An Essay in the Constructivist and Contextual Nature of Science*, New York, 1981, 14 n. 49). Although three-dimensional works are not my subject here, there are also studies of architecture's influence on science: see Randy Swanson, "Art and Science in Transition: Four Laboratory Designs of Louis I. Kahn Considered as Mediative Representation," Ph.D. diss., University of Pennsylvania, 1993.

63. See Johnson-Laird's work (as in n. 50). The questions asked in this kind of inquiry depend on what is meant by the claim that pictures are "nonpropositional." According to Eugene Ferguson ("The Mind's Eye: Nonverbal Thought in Technology," *Science*, CXCVII, Aug. 26, 1977, 827–36, esp. 835), pictures enhance "nonverbal reasoning ability," putting them somewhere between propositional and nonpropositional forms. These questions are distinct from studies that treat pictures as propositions—e.g., Mark Roskill and David Carrier, *Truth and Falsehood in Visual Images*, Amherst, Mass., 1983.

64. For an interesting study of the ways in which scientific illustrations can be conceived as " 'model organisms' for the study of conceptual evolution," see James Griesemer and William Wimsatt, "Picturing Weismannism: A Case Study of Conceptual Evolution," *What the Philosophy of Biology Is*, ed. Michael Ruse, Dordrecht, 1989, 75–137, esp. 129.

65. See Lorraine Daston and Peter Galison, "The Image of Objectivity," *Representations*, no. 40, 1992, 81–128.

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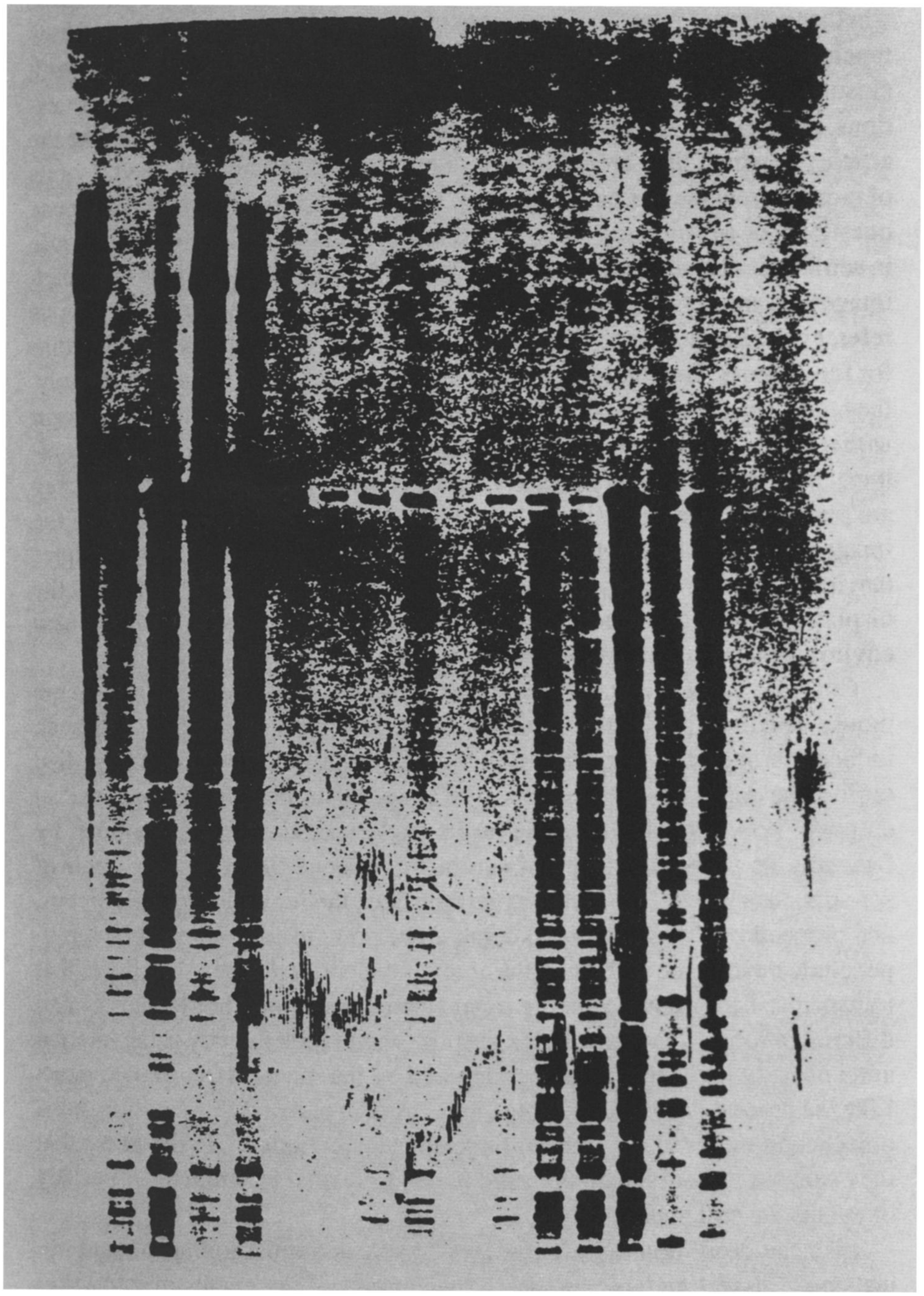

4 Autoradiograph (from Karin Knorr-Cetina and Klaus Amann, "Image Dissection in Natural Scientific Inquiry," *Science, Technology, and Human Values,* IV, no. 3, 1990, fig. 1)

for the *Visitation* in S. Maria Novella already adumbrates the fresco's structure—it is an "*a priori* rationalistic conception . . . the work of a rationalistic mind."[66] De Tolnay's analysis is heuristic, and he does not make it the basis for a wider theory of Italian drawing; but it goes to show the permissible differences between drawings and paintings. Some drawings can be rational scaffolds for paintings, and others may be nothing more than intuitive glimpses, but they must share objects, formal elements, or principles of organization with their associated paintings—the very idea of association depends on such affinities.

In scientific images the differences between sketches and completed illustrations can be much greater, and a single image might be associated with many kinds of images. Fig. 4 is an autoradiograph, recording the seepage of chemicals through a viscous jelly. It was made by spreading an "electrophoresis gel" between two glass plates, and letting radioactive chemical samples diffuse along channels in the glass. The image is a print from an X-ray film placed on top of the glass. Autoradiographs are common images on television, since they are used in DNA identification in criminal trials. Their salient features are the positions and densities of the horizontal dark bands, together with the relation between bands in different columns (called "lanes").

This particular plate is the subject of a study by the historians of science Karin Knorr-Cetina and Klaus Amann, who are interested in how biologists discuss and interpret images, and in how images like this one, which is full of

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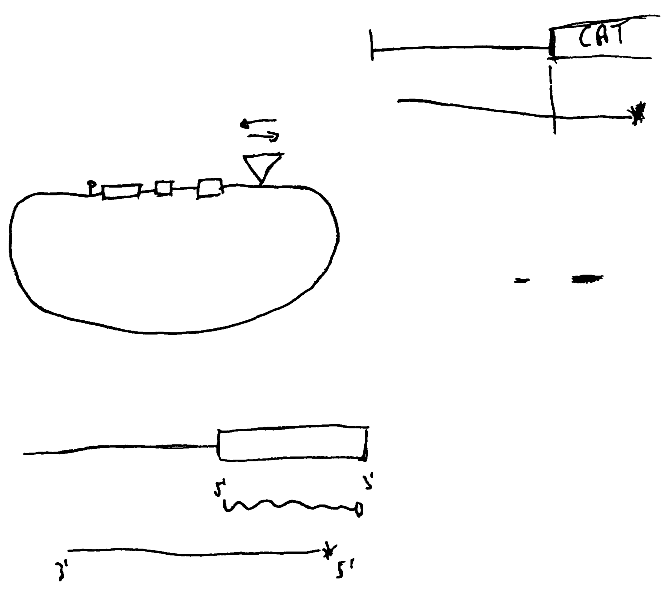
experimental flaws and irrelevant bands, are altered to produce plates fit for publication—plates that represent the truth.[67] In this case the scientists were unhappy with the results, and they discussed rephotographing the gel, editing the image by cutting and pasting portions of it to make a cleaner version, and repeating the experiment from scratch. There are potential parallels here with other strategies for image making—for example, the astronomical images studied by Lynch and Edgerton—though the issues are more complex because the image cannot just be "cleaned" as if it were a print that had become stained. Instead, it needs to be compositionally adjusted to erase and alter marks that are integral to the objects under study—that is, the bands and lanes themselves. A comparative account of the strategies for producing acceptable images might reveal the ways that nonart images are partly the products of certain theories about images and about the world (the astronomers, for example, run "image-sharpening" procedures, like those available on commercial software, to enhance their images). As in the fine arts, images are built to represent the world in certain ways.

I want to point out, however, a different characteristic of the autoradiograph, one that sets it apart from the ways in which images are connected to one another either in astronomy or in the history of art. Knorr-Cetina and Amann document no less than five different kinds of images that are either invoked or produced by the scientists in the course of attempting to correct the autoradiograph. The scientists recall other autoradiographs in the way an artist might think of other paintings, but they also think of the very different physical reality they are trying to represent. The object of the image is not to depict bands but to understand the transcription of RNA, and so the scientists are also thinking of molecular models and of laboratory apparatus that does not look anything like their autoradiograph. Knorr-Cetina and Amann reproduce several such drawings, done on the spur of the moment to help explain questions raised by the autoradiograph (Fig. 5). The sketches depict a schematic "shorthand" version of RNA transcription within a gene labeled "CAT" (at the top right), and they are intended to clarify hypotheses about the linking of genes that might account for anomalous bands on the autoradiograph. Nothing in the drawing resembles the autoradiograph in form or scale. Art history rarely has to deal with connections between images this different from one another, and it makes the act of interpretation—and the imbrication of *visual* meanings—especially difficult. Knorr-Cetina and Amann call the different acts of interpretation "image dissection" and "image arithmetic," and although their study is only a preliminary one, it is certainly true that new terms would have to be



5 Genetic "design" language on scraps of paper (from Knorr-Cetina and Amann, fig. 5)

coined in order to explain the ways in which such images are connected.

2. Nonart images can also contain unexpected combinations of what Nelson Goodman calls the "routes of reference."[68] A typical image in the fine arts will have a predominant referential mode—it will participate in the terms of realism, naturalism, expressionism, and so forth. Western images are rarely pure examples of any one mode, and it could be argued that the interest of a particular painting—by Caravaggio, for example, or Courbet—largely depends on the ways it negotiates several partly incompatible relations to whatever is construed as reality.[69] Informational imagery shares those impurities, but it can also blend more widely disparate modes. The sonar chart excerpted in Fig. 6 shows water depths from 20 to 130 feet, and has inverted V-shaped marks indicating fish. Even though the marks are partly naturalistic—they record the relative sizes of the fish, and their depths in the water—they are also partly symbolic, since they record the *motions* of the fish relative to the boat that is passing over them. A fish moving with the boat will make a more concentrated mark, and one that is diving, surfacing, or moving in some other direction will produce various tails on the Vs. The image as a whole resembles a naturalistic landscape: it looks like a hill against a bright evening sky, and it is not difficult to reimagine it as an

66. Charles de Tolnay, *Handbook of Old Master Drawings*, Princeton, N.J., 1943, 19, 20.

67. Karin Knorr-Cetina and Klaus Amann, "Image Dissection in Natural Scientific Inquiry," *Science, Technology, and Human Values*, XV, no. 3, 1990, 259–83; and cf. K. Amann and K. Knorr-Cetina, "The Fixation of (Visual) Evidence," in *Representation in Scientific Practice*, ed. M. Lynch and S. Woolgar, Cambridge, Mass., 1990, 85–122.

68. Nelson Goodman, "Routes of Reference," in *Of Mind and Other Matters*, Cambridge, Mass., 1984, 55–70.

69. In this regard the early Baroque negotiations of varieties of naturalism and nonnaturalism are exemplary. See, e.g., the discussion of *vero* and *verosimile* in Charles Dempsey, "Mythic Inventions in Counter-Reformation Painting," in *Rome in the Renaissance: The City and the Myth; Papers of the Thirteenth Annual Conference of the Center for Medieval and Early Renaissance Studies*, ed. P. A. Ramsey, Medieval and Renaissance Texts and Studies XVIII, Binghamton, N.Y., 1982, 55–77.

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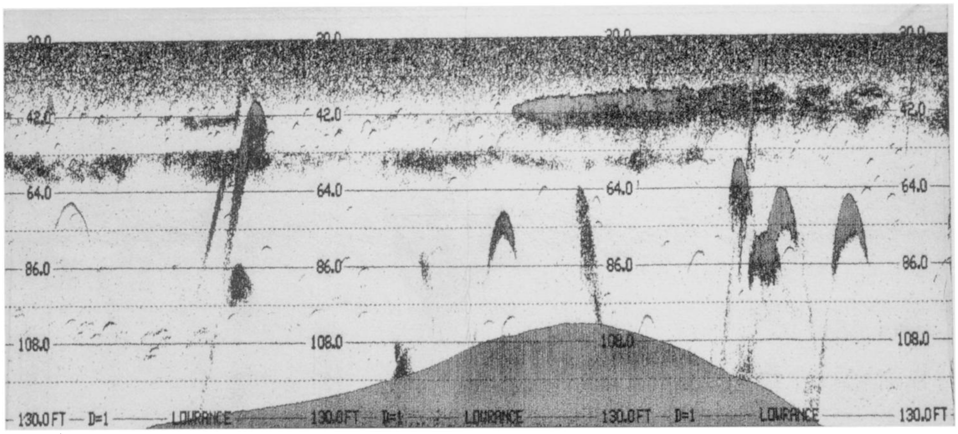

6 Portion of a sonar chart of Cayuga Lake, near King's Ferry, N.Y., courtesy Bob Dutcher (photo: author)

underwater vista. At the same time, it has no fictive space, because the sonar only records what is directly under the boat: the V-marks and the contour of the bottom of the lake are produced by a series of vertical sections through the water, so that the shapes recorded in the image are more like cardboard cutouts than silhouettes of objects at different distances. Since the boat might move along an irregular route, the "scene" is not even a conventional cross-section, but a serpentine path flattened onto the plane of the paper. The sonar chart is a composite of very different routes of reference: it is an *x–y* graph, a naturalistic scene, and a collection of symbols for the motion of fish. It needs to be read, seen, and deciphered, and a viewer must switch between modes of interpretation in order to comprehend it.[70]

These unruly routes of reference are typical of many images that are not fine art, and I want to adduce a very different example to show how widespread the possibilities are. When writing began in the ancient Near East around 3,200 B.C., clay tablets were sometimes marked by rolling a cylinder seal across their surfaces before they were otherwise incised or impressed. The seals left shallow, repetitive patterns, and the numerals or glyphs that were then stamped into them left deeper hollows, as in this tablet from Susa, Iran (Fig. 7). Cylinder seals functioned as proprietary markers, and they are rarely mentioned by those scholars who study the inscriptions that were placed on top of the seal impressions. As the archaeologist Denise Schmandt-Besserat has demonstrated, counting was once done with the help of small fired-clay sculptures in various geometric shapes, representing quantities of different agricultural goods.[71] At first, the tokens were kept in sealed containers, so that their physical presence guaranteed the possession (or debit) of goods. In this case, cylindrical tokens denoting one large measure of grain and two small measures have been impressed into a surface already marked by a cylinder seal. The conjunction of pattern and impression is significant, and familiar from bonds and printed money where patterns constitute the authentication and frame for numbers indicating value. In ancient practice, the cylinder seals were conceived as potentially infinite patterns, and they were often rolled over the tablets without attention to centering or quality of impression. In other words, the pattern was itself a signifier, and it was not essential that the component forms be entirely legible. The numerals and early pictographs stamped into the seal patterns were not subject to the same freedoms, and they were set down according to a number of shifting rules of formating. Sometimes numerals and their signs were put down in the rows, columns, and rectangular fields characteristic of writing, and at other times they were placed at one side or, as here, carefully centered like modern pictures. Recent work on the undeciphered and probably multilingual inscriptions at Uruk suggests that the position of numerical signs on tablets was sometimes used to change the *meaning* of the signs, so that numbers would not have had stable meanings apart from their positions on the marked surface.[72]

The tablet is like a picture (in that it has central forms in a decorative "frame"), and it is also a number, a bond or guarantee, and a sentence (that the bearer of the seal owns or guarantees a certain measure of grain). It depends on sculpture (in the form of the tokens, and the cylinder seal), but it uses a pictorial surface to organize its meaning. Its routes of reference are just as various, in their ways, as those in the sonar chart. The two are very different multiple routes of reference, and I am not implying they are somehow linked. But the fact that simultaneous routes of reference are so common among nonart images suggests that the normal state of affairs may be more referentially disordered than it appears in painting and drawing; or to put it another way, the very subtle distinctions between concepts of realism, naturalism, and kinds of antinaturalism that art history has elaborated may be the purified remnants of more heterogeneous origins. In both examples, art history could help elaborate the working concepts such as picture, decoration, landscape, and naturalism, and the history of science (or in the case of the tablet, archaeology) could elucidate how the routes of reference are combined.

3. Images outside art can be marked by unusually complex relations to one another (as in the autoradiograph and its associated drawings [Figs. 4, 5]) or to their referents (as in the sonar chart and the clay tablet [Figs. 6, 7]). They can also have unexpectedly intricate histories of reception. Art-historical images change meaning continuously, in accord with shifting contingencies of critical reception and historical circumstance. Nonart images are even less stable, because

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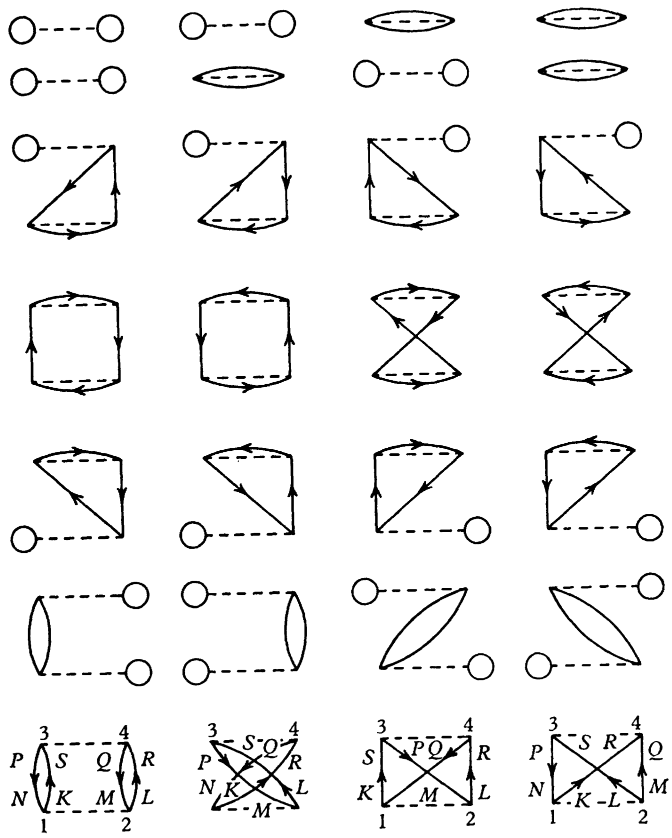
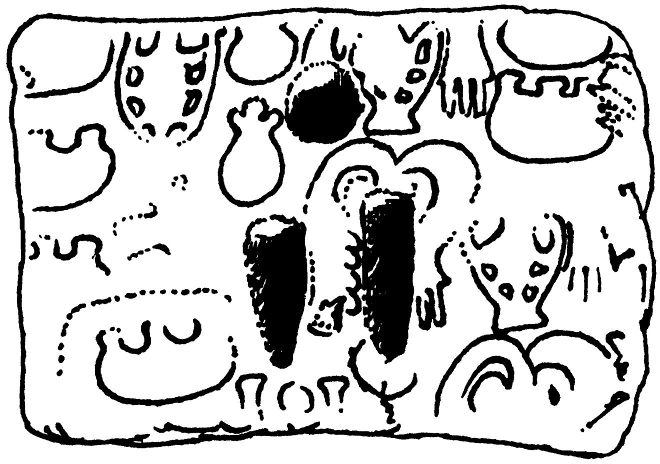
they depend less on resemblance and more on specialized interpretive skills that are easily shifted and lost over time. As a result, one of the problems in the history of science is the way that images are reinterpreted and used to make very different points, often within a single generation. Although the history of science has tended to view this occurrence as a property of images in general, art historians might be more apt to say that new interpretations follow conventional responses to different kinds of pictures. The historian of science David Kaiser has studied interpretive change in relation to the Feynman diagrams used in particle physics (Fig. 8).[73] When they were first introduced by Richard Feynman, the diagrams were graphs of the possible interactions of particles (for example, an electron and a positron decaying into two photons). Later they became more conventional graphs that were understood as if they plotted position in relation to time, and finally they were taken to be representational pictures, as if they showed objects in two-dimensional space. Kaiser calls such mutating meanings "dynamical appropriations." Several of them can be understood as attempts to use the diagrams of subatomic particles as naturalistic pictures, in the sense of photographs. Even contemporary physics textbooks repeatedly warn that the angles of the lines, the lengths of the dashed "interaction lines," and the positions of the "vertices" are unimportant, and that virtually all the formal properties of the diagrams are "aesthetic." Because the only thing that matters is the number, direction, and kind of lines converging at a vertex, Feynman diagrams are not easy to "picture" as naturalistic



8 Second-order diagrams in perturbation theory (from Norman Marsh, W. H. Young, and S. Sampanthar, *The Many-Body Problem in Quantum Mechanics,* Cambridge, 1967, fig. 4.15)



7 Tablet from Susa, Iran, late 4th millennium B.C. Paris, Musée du Louvre, Département des Antiquités Orientales, Sb 4839 (adapted from Denise Schmandt-Besserat, *Before Writing*: I. *From Counting to Cuneiform,* Austin, Tex., 1992, fig. 91)

representations or as normative *x–y* graphs: they are a new kind of image that is neither naturalistic picture nor conventional graphs. For the same reason they are strongly dependent on their surrounding text, and largely opaque without it. Nonart images are often weak in this sense, but their frailty as independent pictures is offset by their powerful rearrangements of viewers' pictorial expectations. Art history can contribute to these studies by explaining the specific expectations viewers bring with them (and therefore the reasons for the successive reinterpretations), and the history of science can demonstrate how those expectations can be held in check by sufficiently powerful new ways of lodging meaning in images.

In another case, the population geneticist Sewell Wright introduced landscapelike diagrams into the study of population growth, intending to help visualize the way in which a group of organisms might change (Fig. 9). The viewer is

70. In J. Elkins, "What Really Happens in Pictures? Misreading with Nelson Goodman," in *Word & Image,* IX, no. 4, 1993, 349–62, this image is analyzed as an example of one that narrowly misses Goodman's criteria for a notation, thus suggesting that many such images can well be accounted for by his strictures. What escapes them, however, remains most interesting.

71. Denise Schmandt-Besserat, *Before Writing:* I. *From Counting to Cuneiform,* Austin, Tex., 1992; and for the shapes of the tokens—which may be considered an early sculptural form—see Cyril S. Smith, "A Matter of Form," *Isis,* LXXVI, no. 4, 1985, 586.

72. See Hans J. Nissen, Peter Damerow, and Robert K. Englund, *Frühe Schrift und Techniken der Wirtschaftsverwaltung im alten Vorderen Orient, Informationsspeicherung und -verarbeitung vor 5000 Jahren,* Bad Salzdetfurth, 1991; in English (less well illustrated), as *Archaic Bookkeeping: Early Writing and Techniques of Economic Administration in the Ancient Near East,* trans. Paul Larsen, Chicago, 1994; and review by Piotr Michalowski, *Science,* CCLXIV, May 13, 1994, 1019–20.

73. David Kaiser, "Dynamical Interpretations of Feynman Diagrams," unpublished MS, 1994. Feynman diagrams have also been adapted for string theory; see *Superstring Theory,* ed. Michael Green, John Scharz, and Edward Witten, Cambridge, 1987.

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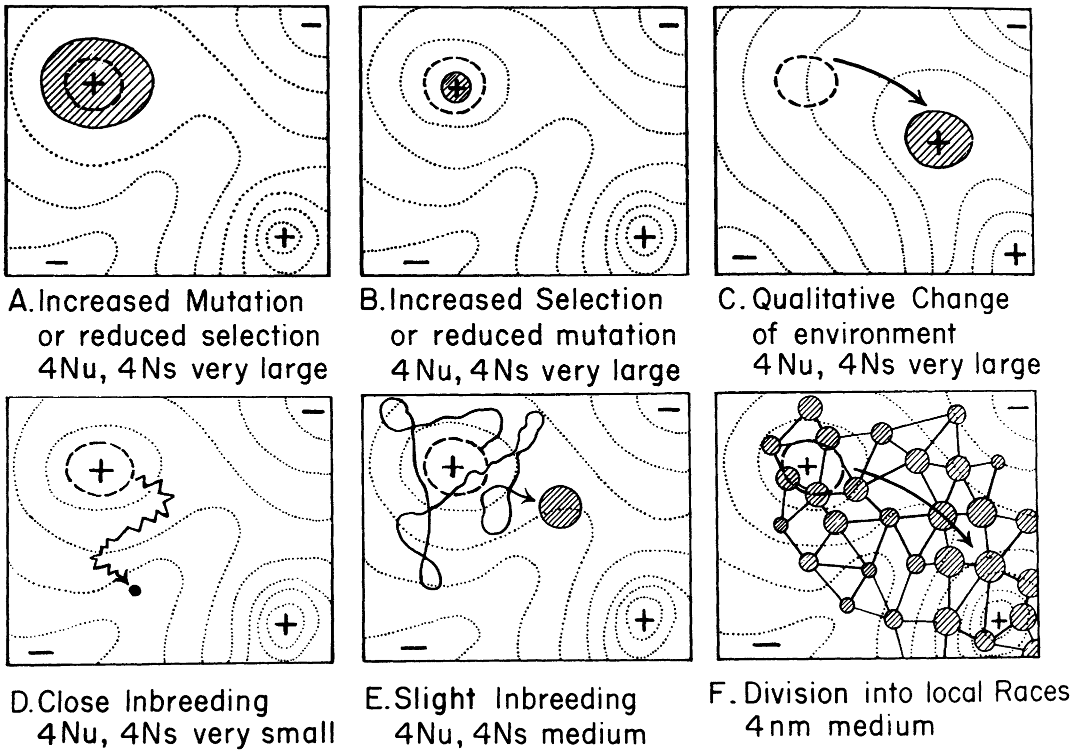

9 Hypothetical multidimensional field of gene combinations (from Sewell Wright, *Evolution and the Genetics of Populations:* III. *Experimental Results and Evolutionary Deductions,* Chicago, 1977, fig. 13.1)

supposed to think of topographic maps, but here the altitude lines are "fitness contours," leading to "fitness peaks," and the "landscape" is a "hypothetical multidimensional field of gene combinations . . . represented by two dimensions."[74] In other words, the genetic content of the populations—shown inside the heavy dotted lines—alters under the pressure of mutation, or environmental change, or random shifting (lower left and center), or adaptive change (lower right). The elegance and intuitive quality of these images comes directly from their analogic appeal to topographic maps, and even to the thought of walking through the genetic "landscape." The historian Michael Ruse has shown that Wright's images were used by other scientists in new ways: a paleontologist, for example, appropriated the landscape metaphor but used it to map morphological differences instead of genetic ones.[75] Again, it is the specific appeal to pictorial conventions that insured both that the images would be influential and that their influence would be partly unpredictable. Nothing in Wright's mathematical modeling predicts the zigzag path in the "map" at the lower left, or the smoother meanderings in the next image. But they correspond to imaginary walks, and that is enough to set in motion the pictorial meanings that are familiar in the history of art. Feynman diagrams changed meaning because they did not look enough like known kinds of images; Wright's maps changed meaning because they looked so much like a particular kind of image that their content was occasionally of secondary interest.

4. So far I have been sketching properties of nonart images that have to do with their relation to one another, their ways of denoting the world, and their receptions by successive interpretive communities. Nonart images are also interesting—and extreme—examples of the relation between pictorial and linguistic marking. "Word-image" relations that occur in fine art tend to take the form of incursions of the linguistic or propositional into the realm of the pictorial—for example, in Cubist collages that include words.[76] Images outside art reverse and critique that distinction since they are normally taken as propositions that may include nonessential pictorial elements. A good way to put the difference is to consider the notion that images can function as theories about the world. The interest in that formula, which is widely invoked in the histories of art and science, lies in the ambiguity of the word "theory": a theory might be a claim or other proposition, so that the picture would almost literally say something about the world, or it might be a nonpropositional fact, a mute form that could suggest any number of things. In the history of science the difference is acutely marked, because images are normally taken to be especially condensed or convenient propositions. When they begin to work as art does—that is, by giving up any secure meaning in favor of a halo of possibilities—then their place in science becomes problematic and their pedagogic utility is unpredictable. Wright's diagrams can mean anything that a topographic map might mean, and with different scientific concepts in play, the topographic allegories are potentially unlimited. A recently studied case concerns the German immunologist Paul Ehrlich, who in 1900 produced a series of eight drawings of the operation of antibodies (Fig. 10). At the top left, black toxins approach a cell, uniting with "side-chains" on the cell that are normally used to enable the cell to ingest nutrients. In response, the cell produces more side-chains, which detach and float into the bloodstream (top right). There the toxins bond to them, floating away harmlessly and letting the cell receive its fill of nutrients. Ehrlich's sequence accounted for the body's ability to cope with toxins, and successfully visualized the notion of an antitoxin. It was

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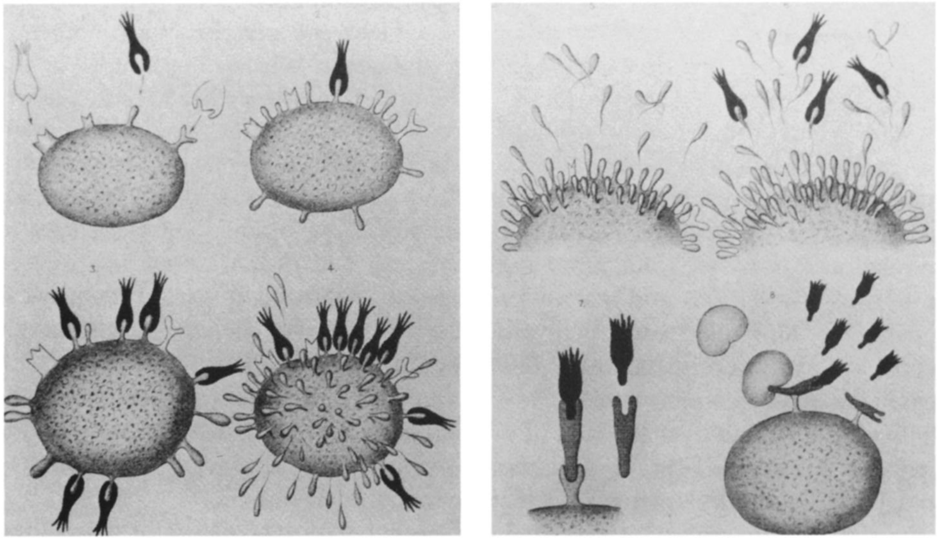

10 Diagrams used by Paul Ehrlich in his 1900 Coonian lecture (from Ehrlich, "On Immunity with Special Reference to Cell Life," *Proceedings of the Royal Society of London,* LXVI, 1900, facing 438–39)

widely influential, giving rise to the Y-shaped diagrams that are still used in biology textbooks to help students imagine how antibodies operate. The remarkable thing about this sequence is that at the time, Ehrlich had no knowledge at all of the forms of these objects, or even of the existence of "side-chains." The pictures *became* the theory, and spurred the research that eventually grew into modern immunology. Initially, there was resistance not only to the specific theory but to the very idea of positing shaped entities instead of "forces" or abstract "experimental facts."[77] Even Ehrlich cautioned that his images "must be regarded quite apart from all morphological considerations"—that is, they should be seen as "a pictorial method," a "diagram" of abstract dynamic ideas.[78] But as the authors of the modern study point out, the diagrams initiated and partly guided the subsequent experimental practice, and they remain indispensable to the ways in which immunology is understood.

James Griesemer, Ruse, and others have argued that pictures in science can work both propositionally and nonpropositionally: sometimes they illustrate or propose theories, and in other cases they merely *exist,* taking a certain place in the chain of written discourse and modifying it in ways that are difficult to describe.[79] In the case of Wright's genetic "landscapes," Ruse has asked if the theory could have developed as it did without the pictures. Were they "really part of the thought"—that is, were they propositional elements of the theory—or were they ancillary to Wright's argument? He finds that even though they were initially mostly metaphorical, they *became* the theory for those geneticists who could not follow Wright's advanced mathematics.[80] In art history, I think both possibilities are better developed than in the history of science: "propositional" influence takes the form of doctrinal, compositional, or iconographic influence from one painting to the next, and "nonpropositional" influence is described in terms of styles or techniques. Since the two occur together in paintings, they are not analytically separable. In Ehrlich's diagrams the shape of the front of the toxins (the portion that fits onto the cell's "side-chains") is propositional, since it implies a specific kind of physical coupling, and the shape of the back of the toxins is nonpropositional, because it suggests motion or perhaps just toxicity. The toxins are therefore representationally hybrid—half propositional theories and half nonpropositional theories. That very conjunction may have insured their influence: that is, it could have been the admixture of picture and proposition that gave later immunologists room to maneuver. Informational images that do not achieve that balance may not be fruitful for later workers, and conversely, images that are more thoroughly nonpropositional may be too vague to have a hold on succeeding generations. It is a dichotomy that art history rarely studies in this stark a form, and it may be that the study of informational images could benefit from art history's awareness of the multivalent relation between propositional and nonpropositional meanings,[81] just as art history might see new possibilities in the strict sense of "proposition" at work in these examples.

5. Finally, images of all sorts must grapple with the problem of what is representable. Historians of science have studied how scientific visualization depends on simplifying, abstracting, labeling, marking, and schematizing the chaotic

74. Sewell Wright, *Evolution and the Genetics of Populations:* III. *Experimental Results and Evolutionary Deductions,* Chicago, 1977, 446, 452.

75. Michael Ruse, "Are Pictures Really Necessary? The Case of Sewell Wright's 'Adaptive Landscapes,'" *PSA 1990,* 63–77, esp. 70.

76. See, e.g., Louis Marin, *To Destroy Painting,* trans. Mette Hjort, Chicago, 1994.

77. See Cambrosio, Jacobi, and Keating (as in n. 58), 666, 667.

78. Ibid., 681, quoting Paul Ehrlich, "On Immunity with Special Reference to Cell Life," *Proceedings of the Royal Society of London,* LXVI, 1900, 437.

79. James Griesemer, "Material Models in Biology," *PSA 1990,* 79–83, proposes three case studies of biological images that also function both propositionally and nonpropositionally.

80. Ruse (as in n. 75), 72.

81. Louis Marin's are among the most developed of many theories of linguistic structures in artworks. See, e.g., Marin, "The Order of Words and the Order of Things in Painting," *Visible Language,* XXIII, 1990, 188–203.

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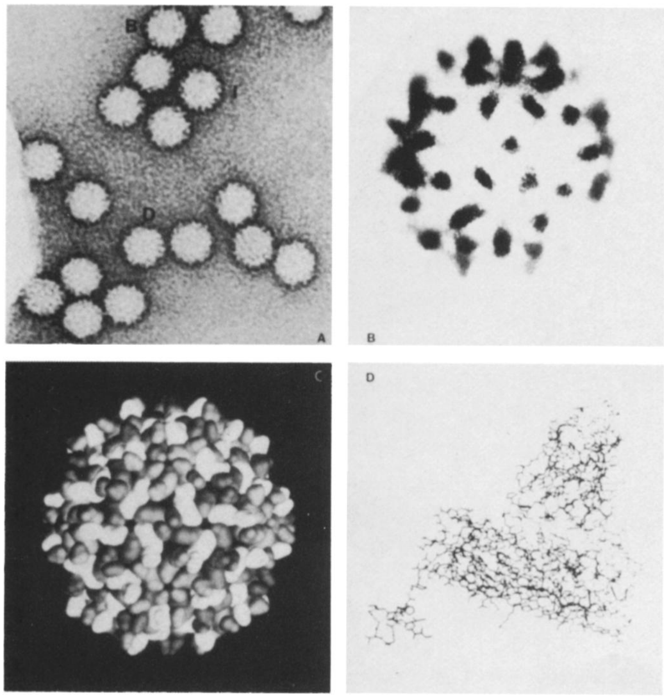
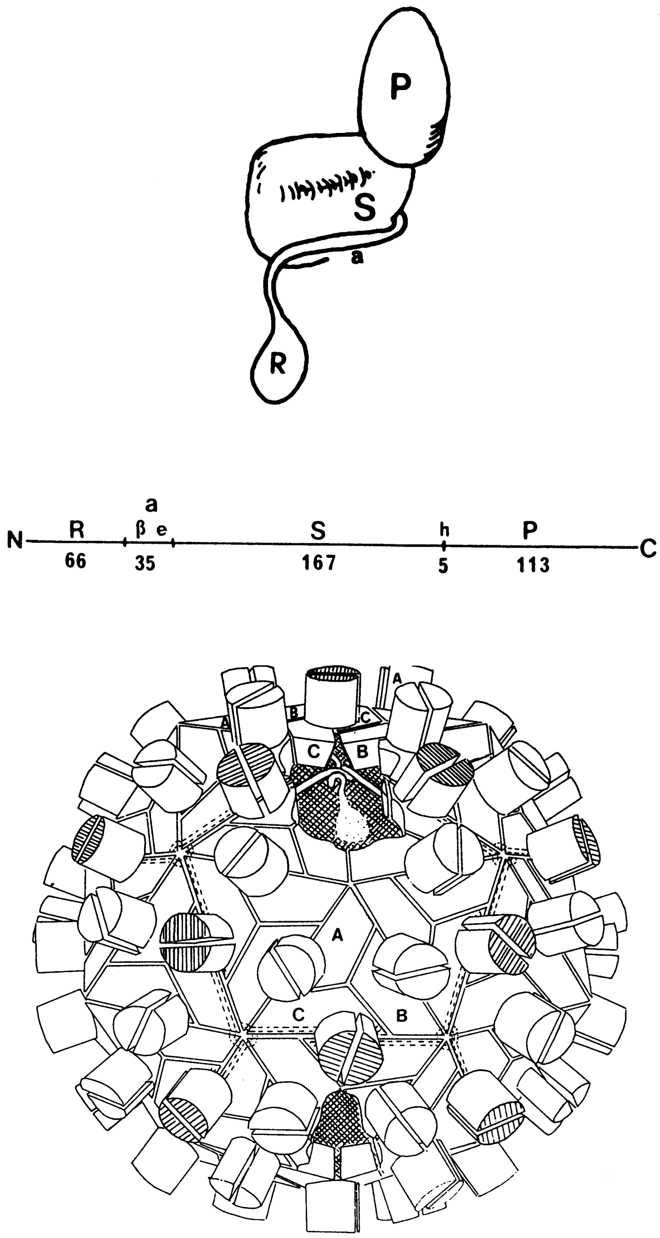


11 Four images of the tomato bushy stunt virus. Top left: electron micrograph, negatively stained eith uranyl acetate. Top right: three-dimensional image reconstruction, based on the top-left image. Bottom left: surface view, based on crystallographic determination. Bottom right: complete atomic model of one subunit (from Stephen Harrison, "What Do Viruses Look Like?" *The Harvey Lectures,* LXXXV, 1991, fig. 2)

phenomena of nature into orderly graphic forms.[82] The idea that science operates by successive abstractions from natural disorder has many points of contact with theories of representation in the arts.[83] Bruno Latour, Françoise Bastide, Michael Lynch, and others have written about the "cascade" of successive abstractions that propel scientific images away from the chaos of phenomena and into an interminable sequence of quantified "traces"—samples, field notes, sketches, graphs, archives. The same questions of abstraction arise in the arts, though it could be argued that the history of science tends to gloss over concrete differences in favor of an open-ended "cascade" of "traces," instead of attending to the exact moments of change that transform one level of detail, or one visible structure, to the next.[84] But as interesting as these parallels are, they pertain to a domesticated sense of the unrepresentable, in which pictures need only to simplify an existing confusion or complexity. In more radical terms, what is unrepresentable can *never* be adequately put in an image because it is nonpictorial, unimaginable, forbidden, or transcendental. This other sense of the unrepresentable is a crucial subject in modernism and abstraction,[85] and it is especially bound up with questions of subjectivity,[86] and with the relation between medieval images and the sacred.[87] Scientific images share this sense, but the terms of their involvement are different because they are routinely called upon to represent objects that have never had conventional visual equivalents. In the case of mathematical objects such as quantum wave packets or the Feigenbaum tree of population growth, the object is beyond full visualization not only because it is infinitely complex—most objects of fine art and science are complex beyond what the medium can render—but also for the irreducible reason that it is mathematical and not pictorial.[88] The question of the "reality" of mathematics (especially geometry), as well as its susceptibility to pictorial representation, has been a central issue from the seventeenth-century practice of finding graphical solutions to equations through contemporary debates about the inflationary universe.[89] The mathematical history of unrepresentability might well complement the art-historical account, since both entail symbols, surrogate forms, and other visual metaphors.

The problem of the unrepresentable also surfaces when



12 Three images of the tomato bushy stunt virus. Top: diagram showing the folded subunit. Middle: modular organization of the polypeptide chain, showing numbers of amino acid residues in each segment. Bottom: the packing of subunits in the virus particle (from Harrison, fig. 4)

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the objects to be depicted do not exist in three-dimensional space.[90] William Wimsatt observes that it is common in scientific visualization to have to depend on more than one pictorial strategy, because the information is both figuratively and literally multidimensional.[91] In a lecture titled "What Do Viruses Look Like?" the biologist Stephen Harrison uses more than ten different ways of picturing viruses in order to help describe their structure.[92] Taken individually, each one explains only a few properties of a virus, and they cannot be fused into a single image. A sample shows how the images complement one another without combining into a single picture. Two early images (Fig. 11, top) show what the "tomato bushy stunt virus (TBSV) 'looked like' twenty years ago," in a negatively stained electron micrograph (top left) and in a three-dimensional image reconstruction (top right). Since then X-ray crystallography has improved scientists' abilities to deduce molecular structure, and the TBSV virus now also "looks like" a surface view of clusters of molecules (Fig. 11, bottom left). Each of the 180 bumps on the surface view is a "subunit" comprised of a chemical chain, folded into a certain shape (Fig. 11, bottom right). The shape has the blurry outlines of two lumps or "domains," with an "arm" hanging down to the left—a structure that is sometimes schematized as three organic forms (Fig. 12, top). Virologists also unravel the subunits into single polypeptide chains (Fig. 12, middle), but to explain how the subunits build themselves into a spherical virus, it is better to redraw them as hard-edged geometric forms (Fig. 12, bottom). There are several other kinds of images, and among them is a three-dimensional schema that is widely used in contemporary microbiology (Fig. 13), depicting the structure of one of the "domains" in a subunit. (The continuous molecular chain can be followed beginning at the lower left. The image also shows how the next subunit, marked "A" at the lower right, twines inside this one.)

Even in this brief sample there is an astonishing variety of pictorial means: from photographs to computer graphics to hand-drawn pictures, from geometric abstractions to organic approximations, from scales to perspectival views to projections, from shaded pictures to wire-frame schemata. It is not surprising that certain chemists have become interested in the aesthetic values of their visualizations, and some pictorial conventions do seem to influence the way that science gets done.[93] But the deeper connections have to do with the ways in which pictures are used to try to see what can never be seen. As in the history of art, images of unrepresentable objects put a strain on the pictorial conventions they inherit, finally breaking them and becoming different kinds of pictures. Several of the images Harrison reproduces are already near the point of unintelligibility: the wire-frame picture is an incomprehensible tangle, and the final schema could not be much more detailed without becoming illegible. The question of the unrepresentable is not yet part of either the history of science or the history of art, and it offers an exemplary opportunity for collaboration.

I have tried to characterize the shape of the larger domain of images, "outside" art and often outside art history. At the moment image studies are at an interesting juncture, where art-historical interest could enrich the discourse in other disciplines, and those disciplines could help art history to rethink its central concepts—including the privileging of fine art, the tendency to use oil painting as a synecdoche for pictures in general, and perhaps most fundamentally, the ultimately indefensible allegiance to Western and non-Western work that can be understood using the categories of art, in the face of the almost bewildering variety of other kinds of images.

In the course of this essay I have described several relations that might obtain between art history and the study of "inexpressive" images. The major possibilities could be put in a sequence of three progressively more difficult configurations. Most often, when nonart images appear in art history they are used to explain how artists brought science into their art. As important as that approach is for Post-Impressionism and some aspects of modernism, I have suggested that it is methodologically limited: it does not explain periods when influence was indirect, or account for the more pervasive influences of science on modern art in general. In terms of the confluence of disciplines, that

82. See Bruno Latour, "The Pedo-fil of the Boa Vista: Visualization, Reference, and Field-Work in the Amazon," paper given at the 1994 History of Science Society conference; and Michael Lynch, "Discipline and the Material Form of Images: An Analysis of Scientific Visibility," *Social Studies of Science,* XV, 1985, 37–66.

83. Above all, parallels and contrasts could be drawn between Latour's work (as in n. 82) and E. H. Gombrich's theories of making and matching. See, e.g., E. H. Gombrich, *Art and Illusion: A Study in the Psychology of Pictorial Representation,* London, 1960; and idem, "The Heritage of Apelles," in *The Heritage of Apelles: Studies in the Art of the Renaissance,* Ithaca, N.Y., 1976, 3–18.

84. For the "cascade" and the "trace," see Bruno Latour, "Drawing Things Together," in *Representation in Scientific Practice,* ed. M. Lynch and S. Woolgar, Cambridge, Mass., 1990, 19–68, esp. 40. For a closer analysis, see Michael Lynch, "The Externalized Retina: Selection and Mathematization in the Visual Documentation of Objects in the Life Sciences," in ibid., 153–86, esp. 160–64.

85. Rosalind E. Krauss, *The Optical Unconscious,* Cambridge, Mass., 1993.

86. Whitney Davis, "Sigmund Freud's Drawing of the Dream of the Wolves," *Oxford Art Journal,* XV, no. 2, 1994, 70–87, analyzes the relation between unrepresentable scenes and actual pictures whose formations and interpretations depend on fine-art and scientific illustration.

87. In addition to the sources cited above (n. 2), see Georges Didi-Huberman, *Devant l'image: Question posée aux fins d'une histoire de l'art,* Paris, 1990; and idem, *Fra Angelico, dissemblance et figuration,* Paris, 1990.

88. The Feigenbaum tree is studied from this standpoint in Griesemer and Wimsatt (as in n. 64), 126–31.

89. In certain interpretations of cosmology, geometric relations are what are "real" and preexist the universe. For a sampling of discussions, see Michael Resnick, "Between Mathematics and Physics," *PSA 1990,* 369–78; Quentin Smith and Adolf Grünbaum, *The Uncreated Universe,* New York, forthcoming; and Michael Friedman, *Foundations of Space-Time Theories,* Princeton, N.J., 1983. Partly analogous questions are raised about chemical representations in Roald Hoffmann and Pierre Laslo, "La Représentation en chimie," *Diogène,* CXLVII, 1989, 24–54.

90. I mean this in the mathematical sense of objects that are described by more than three sets of parameters. Such objects may or may not correspond to actual three-dimensional objects.

91. William Wimsatt, "Taming the Dimensions—Visualizations in Science," *PSA 1990,* 111–35.

92. Stephen Harrison, "What Do Viruses Look Like?" *The Harvey Lectures,* LXXXV, 1991, 127–52, esp. 128.

93. Roald Hoffmann, "Molecular Beauty," *Journal of Aesthetics and Art Criticism,* XLVIII, no. 3, 1990, 191–204.

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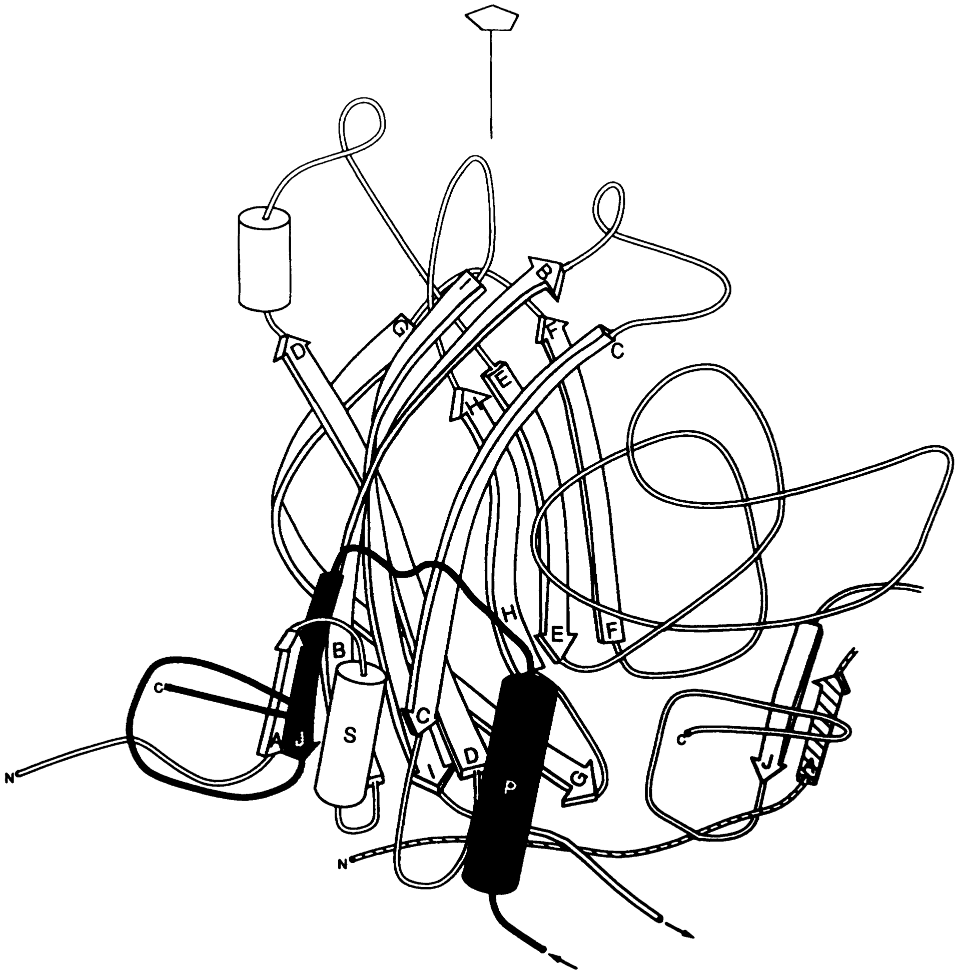

13 A virus subunit (from Harrison, fig. 11)

approach also slights nonart images by restricting them to explanatory roles, and it rarely makes contact with real science (as opposed to the popularized accounts that normally reach artists).[94]

A second possibility is to look at nonart images as independent visual objects. I have suggested two ways in which that might be done. First, it would be possible to study the borrowing of artistic means from fine art. Artistic conventions are nearly universal in scientific illustration, and the images could easily be recounted as independent histories of art. Entire histories of fields such as crystallography, astronomy, genetics, and microscopy have yet to be written from that standpoint.[95] Art history is in possession of such a large stock of concepts and examples that bear on artistic production that its explanations could easily complicate discourse on nonart images in general. A second possibility arises in those cases where relatively few artistic conventions contribute to the making of nonart images. As Lynch and Edgerton have suggested, image studies of contemporary scientific material are not concerned with narrow technical questions, but with fully developed alternate ways of working with images. The strategies that scientists use to manipulate images might well be called aesthetic in the original sense of that word, since they are aimed at perfecting and rationalizing transcriptions of nature. As such, scientists are among the legitimate inheritors of the forms of classical and Renaissance idealism that continue to occupy art-historical research.

The second possibility is a rich vein, and it remains largely unexplored. Still, there is a third possibility that is more fundamental than either of the first two. Instead of preserving the differences between the histories of art, science, and

94. In Elkins (as in n. 2) I suggest that in the 20th century debates about perspective, vision, and art intersect real science in only one place—where they encounter Rudolf Luneburg's analyses of binocular vision. Unlike other theories of vision, Luneburg's are still partly untested, and therefore they so not belong to the history or polarization of science but to ongoing scientific inquiry. Such moments are exceedingly rare in fine art: even Duchamp's games and Seurat's theories were based on popular and out-of-date accounts, sometimes (deliberately or inadvertently) misconstructed.

95. This is a point I made in relation to Kemp (as in n. 23), in J. Elkins, *Zeitschrift für Kunstgeschichte*, LIV, no. 4, 1991, 601. It has been developed most extensively by Michael Serres; see esp. M. Serres, *Eclaircissements: Cinq entretiens avec Bruno Latour*, Paris, 1992.

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mathematics, and studying the "science of art" or the "art of science," we should perhaps acknowledge that in the end many divisions between kinds of images are untenable, and that it is possible to begin writing the history of images rather than of art. Images are found in the history of art, but also in the histories of writing, mathematics, biology, engineering, physics, chemistry, and history itself—to name only examples I have given here. If there is a moral for art history, it is simply that there is a tremendous amount waiting to be seen.

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James Elkins has written on nonart images in The Poetics of Perspective *(Ithaca, N.Y., 1994) and* The Object Stares Back *(forthcoming), and in essays in* Leonardo, Computer Graphics, *and* M/E/A/N/I/N/G. *He is at work on a book on the place of logic in the humanities and sciences [Department of Art History, Theory, and Criticism, School of the Art Institute of Chicago, 37 S. Wabash, Chicago, Ill. 60603].*

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