Visual Practices Across the University

Edited by James Elkins

[*Note to readers: this is the front matter (table of contents, preface) and the Introduction to the book* Visual Practices Across the University *(Munich: Wilhelm Fink Verlag, 2007).*

This book is in English, and is also available on Amazon Deutschland, here.
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Preface

This is an experimental book. It is an attempt to think about images beyond the familiar confines of fine art, and even beyond the broadening interests of the new field of visual studies. Outside of painting, sculpture, and architecture, and outside of television, advertising, film, and other mass media, what kinds of images do people care about? It turns out that images are being made and discussed in dozens of fields, throughout the university and well beyond the humanities. Some fields, such as biochemistry and astronomy, are image-obsessed; others think and work *through* images.

So far visual studies has mainly taken an interest in fine art and mass media, leaving these other images — which are really the vast majority of all images produced in universities — relatively unstudied. Outside the university, scientific images crop up in magazines, on the internet, in popular-science books, and in the familiar "art meets science" exhibitions. In those contexts images are often drastically simplified, shorn of much of the significance they had for their makers. Here I try to pay close-grained attention to the ways people make and talk about images in some thirty fields across all the faculties of a typical contemporary university. There are examples in these pages of the study of dolphins' fins, of porcelain teeth, of Cheddar cheese. I am less interested in what might count as art or science, or in what might be of interest from an aesthetic (or anti-aesthetic) point of view, than I am in simply *listening* to the exact and often technical ways in which images are discussed.

A great deal is at stake on this apparently unpromising ground. It is widely acknowledged that ours is an increasingly visual society, and yet the fields that want to provide the theory of that visuality — visual studies, art history, philosophy, sociology — continue to take their examples from the tiny minority of images that figure as art. At the same time, there is an increasingly reflective and complicated discourse on the nature of universities, which has as one of its tropes the notion that the university is "in ruins" or is otherwise fragmented. One way to bring it together, or at least to raise the possibility that the university is a coherent place, is to consider different disciplines through their visual practices. To begin a university-wide discussion of images, it is first necessary to stop worrying about what might count as art or science, and to think instead about how kinds of image-making and image interpretation might fall into groups, and therefore be amenable to teaching and learning outside their disciplines. Above all, it is necessary to look carefully and in detail, and not flinch from technical language or even from the odd equation.

All these points are theorized in the Introduction, but the book can also be read by browsing the chapters and picking up the themes as they occur. If you encounter them singly, the chapters may seem fixated on facts and procedures, and short on connections. This is intentional and important. Large-scale, generalized notions of images and visuality weigh down visual studies. (Even those few scholars who *do* look at images outside of art tend to theorize them all together, substituting general theories of images for general theories of images in art.) If we are to move beyond that critical inertia, then we need to let individual image-making practices exist in all their splendid particulate detail. There are five large and several smaller themes threaded through this book, and some large-scale claims about the place of visuality in the humanities and in the university (all are set out in the Introduction); but I have tried not to let any one discourse subsume the quirkiness and texture of real practices. It is crucial, I think, to resist the desire to create continuous narratives out of specific practices, to decline the temptation to soften jargon, to refuse—at least temporarily—to assign meaning to apparently inarticulate computational practices. Those desires are typical of the humanities when they look to the sciences. Hence the particulate, sometimes rebarbative nature of this book: it is an experiment in mingling the humanities' passion for image theory with the many modest and local practices that constitute image-making throughout the university.

There isn't any easy way to acknowledge the people who helped with this book. Each chapter has been extensively rewritten in collaboration with the authors, in some cases as many as fifteen times, and sometimes from scratch. Each chapter also existed as wall text in the original exhibition in 2005, and over half the authors also wrote PowerPoint presentations and gave lectures to a class I supervised on the subject the following year. Twenty other proposals did not go into either the exhibition or the book, two others were in the class but not the book; and about twenty outside specialists were consulted on various points. (Special thanks to Aileen Dillane, Áine Hyland, and Frank van Pelt, who gave lectures in the class but were not in the book or the exhibition.) Some authors worked on numerous revisions from summer 2003 up to the exhibition in April 2005, to the class in winter 2006, and on to the book in May 2006.

So: a massive amount of work was involved for everyone, involving many times the page count of this book, and I am tremendously grateful. I also want to acknowledge the staff of the Lewis Glucksman Gallery at University College, Cork, and in particular Fiona Kearney, the Gallery's enthusiastic and committed Director; René Zechlin, an innovative curator who had the unenviable task of printing the almost 25,000 words of text that went onto the walls at the exhibit; my colleague Sabine Kriebel; and many others, especially Nora Hickey, the very skilful James Cronin, and Veronica Fraser, the truly remarkable Department secretary who not only managed everything connected with these events, but read the texts and participated in the reading groups. Finally, special thanks to Gerard Wrixon, then President of the University, who was directly responsible for the development of arts, the Gallery, and the new Department of the History of Art.

Introduction

This book began with an exhibition of the same name, held in Cork, Ireland, in 2005. The exhibition was originally intended to be published along with a conference called "Visual Literacy," in a single large book. In fact the conference will appear as two separate books.[1] (More on that in the Afterword.)

For the exhibition, I sent an email inquiry to all the faculty in the sixty-odd departments at University College Cork, asking for proposals from anyone who used images in their work. The initial responses developed into thirty displays; each was accompanied by up to a thousand words of wall text. The exhibition represented all the faculties of the university, from Arts to Medicine, Food Science to Law. It only had a couple of displays of fine art: one proposed by a colleague in History of Art, and another by a scholar in the History Department. Fine art was swamped, as I had hoped it would be, by the wide range of image-making throughout the university. This book is a rethought and rearranged version of the wall texts in the original exhibition; each one has been rewritten and expanded, to bring out themes that emerged during and after the exhibition.

This Introduction is divided into four parts. First, some distinctions between what is done here, and what happens in exhibitions and books that present science as art or look for the art in science. Then a sketch of how images might be understood when the art-science distinction is not the crucial one. Third, a review of the principal themes that emerged in the course of the exhibition, which I have tried to bring out in the book; and fourth, the possibility that this kind of material might be used in a university-wide introductory course on visual practices.

Attempts to Present Science as Art, and Vice Versa

Among the things that this book is not, it is primarily not a contribution to the many exhibitions and books that present scientific images as art, or as possessing the aesthetic properties or even the "richness" that supposedly inhere in art. In this book I will be ignoring the intermittent temptation to say such-and-such an image is beautiful, and I will not be presenting any image, no matter how luscious, as possessing any aesthetic properties that its maker or its intended audience have not already claimed for it. My interest is the particular ways of talking about images in different fields. (It happens that some ways of talking about images incorporate the kinds of broad claims about art or science that I want to avoid, and it often happens that people call one another's images "beautiful," but reporting on other people's use of such claims is different from using them to organize the argument.)

The most widely publicized recent conferences on science-art themes are Felice Frankel's two "Image and Meaning Initiative" conferences, the first at MIT in June 2001, and the second at the Getty Center in Los Angeles in June 2005.[2] Frankel is a science photographer, originally trained as a landscape and garden photographer, who rephotographs scientific experiments for publication.[3] In the past her work has raised interesting questions about the relation between her artistic choices and the scientists' visual preferences, especially when her rephotographs have helped scientists discover new features of their work that they had not seen.[4] Her books *On the Surface of Things* and *Envisioning Science: The Design and Craft of the Science Image* present accomplished, colorful photographs of various physical and chemical phenomena. Frankel's conferences and books provide a chance for art photographers to think about scientific images, and for scientists to ponder such things as the place of beauty or art in visualization. Phenomena such as iridescence on an oil surface, colors generated by opal, and patterns of crystals on a surface, are visualized in great detail and with attention to composition and symmetry. The photographs' formal properties are, however, untheorized. Frankel presents her work as "scientific photography" and writes only as a technical photographer. She does not articulate the artistic influences on her own work, even though that history is pertinent because it guides her choices of compositions, colors, symmetries, and textures. Frankel's books therefore lack the analysis of artistic influences that might have been able to account for her photographic preferences. Her compositional choices, for example, are influenced — I assume mostly indirectly, without deliberation — by Abstract Expressionism, and by realist projects such as the Boyle Family's fiberglass castings. In art historical terms, her practice derives from several strands of modern painting and photography from the 1940s to the 1980s. Those precedents are not irrelevant, because they can illuminate the aesthetic decisions that appear, unexplained, simply as "beauty." And because she does not know the science except to the extent that it is explained to her, the scientific content of her images is seldom broached except in the most general terms. For the book *On the Surface of Things,* a prominent chemist provided very brief, nontechnical summaries of the relevant science — not enough to account for individual passages in Frankel's very complex and detailed images. As a result Frankel's projects miss the many specific connections between photographic decisions informed by the history of art, on the one hand, and by the scientists' purposes, on the other. Her photographs can only appear as mute testimony to her "eye," her unarticulated judgment of what counts as an interesting image. *On the Surface of Things* is a brilliant coffee-table book: it can be read by scientists and artists; both will recognize meanings that are not spelled out, but neither will know how to make a bridge between the two domains. What is needed, I think, is an inch-by-inch analysis of her photographs, to bring out the individual artistic decisions and their histories, together with — matched line by line with — an inch-by-inch account of the scientific meaning of each form.

Frankel also writes a column called “Sightings” in *American Scientist* magazine, interviewing scientists about their images. One column is an interview with Jeff Hester of Arizona State University, who was one of the scientists who made the widely-reproduced Hubble Space Telescope image of young stars in the Eagle Nebula (1995; plate 1).

The interview is brief, only a few paragraphs; and because of its brevity, it is a good example of what I think of as the abbreviated, impoverished structure of much art-science discourse. Hester describes how the image was combined from thirty-two images taken by four separate cameras, and how the images were stitched together, cleaned up, and given false colors. Blue, for example, stands for emissions from doubly ionized oxygen. The colors appear "representational," in Frankel's phrase — that is, they make it seem the photograph is a picture of mountains. Hester explains the image is more like a "map of the physical properties of the gas," but that, fortuitously, "it is also closer to what you might see through a telescope with your eye than is a picture taken with color film."[5] Toward the end of the one-page interview, Hester says "the beauty of the image is not happenstance. When people talk about 'beauty,' they are talking about the presence of pattern in the midst of complexity." Several things need to be asked about that claim if it is to make sense. It would be good to know why Hester felt he should mention beauty at all; I assume it was on account of the popular-science context of the interview, and the idea that beauty might serve as a bridge to a wider public. But what kind of bridge is beauty here? Instead of bringing beauty in, why not present the image as something wonderfully and unexpectedly complex — that is, after all, another alleged art-world value — by saying, as he had a moment before, that "there is one hell of a lot of information present"? And having mentioned beauty, why identify it with pattern recognition? That is not an association I think many people in art would have, unless they are following psychologists such as Rudolph Arnheim.

There are at least five assumptions at work in Hester's mention of beauty, and in Frankel's silence about it: that beauty is relevant, that the image is beautiful, that the meaning of beauty is clear, that beauty can help the image communicate to non-scientists, that beauty is an idea shared across the arts and sciences. Hester remarks that "the same patterns present in the image that make it aesthetically pleasing also make it scientifically interesting." If that were true — and to assent I would have to agree that beauty is present, and that beauty can be identified with pattern recognition — then it would have to mean something like this: If I appreciate the patterns in this image, I also appreciate the science. I think that is untrue, and it is not supported by what Hester says. He concludes that he and his collaborators "use color in the image in much the same way that an artist uses color," as an "interpretive tool." That may mean that the false colors he and his collaborators chose to represent emissions of oxygen, hydrogen, and sulfur are like the false colors artists chose, and it might also mean that artists also choose false colors that are at the same time like representational colors. Either way the parallel is too loose to do much work, and that is one of the reasons conversations like these are often so short.

An artist like Emil Nolde, who chose "false" colors as well as naturalistic ones, made his decisions for completely different reasons — and even using a different palette — than physicists who make false-color astronomical images. Scientists' choice of colors have specific histories, just as artists' choices. Some of the more garish productions of astronomical images owe their color choices to 1960s hallucigenic art like *Yellow Submarine* or tie-dyed T-shirts. The Eagle Nebula image owes its color choices to the history of landscape painting and photography. It has a saturated, Kodachrome look that derives from nostalgic reworkings of 1950s photography, and it also owes something to the kitsch paintings popular in "starving artist" sales and exemplified for North American consumers by the painter Thomas Kinkade. (He paints tumble-down English-style thatched cottages, decorated with rainbow-colored flowers.[6]) In terms of forms, the Eagle Nebula image as it is presented here (it could have been cropped and oriented quite differently) belongs to the history of romantic landscape painting, from Arnold Böcklin and other German and French painters to the exaggerated mountains of the Hudson River School painters. It may even belong to the lineage of fantastical mountainscapes in Chinese painting, beginning in the Song Dynasty and continuing to the present. I do not mean any of this as a put-down: I want to say scientific images have their own lineages in the history of art, their own aesthetic histories. They are not merely or simply "beautiful"—and not that "pattern" has nothing to do with these historical lineages.

And even if artists were to agree that they use false and yet "representational" color "in much the same way," it would still be unclear what about the science that has been explained aside from the fact that the colors were chosen to aid communication. Frankel's column does not explain how the image was generated, except in generalities; it does not explain the link that is proposed between art and science; and it does not explain the scientific content of the image. She asks no follow-up questions to Hester's opinions about beauty, art, and pattern.

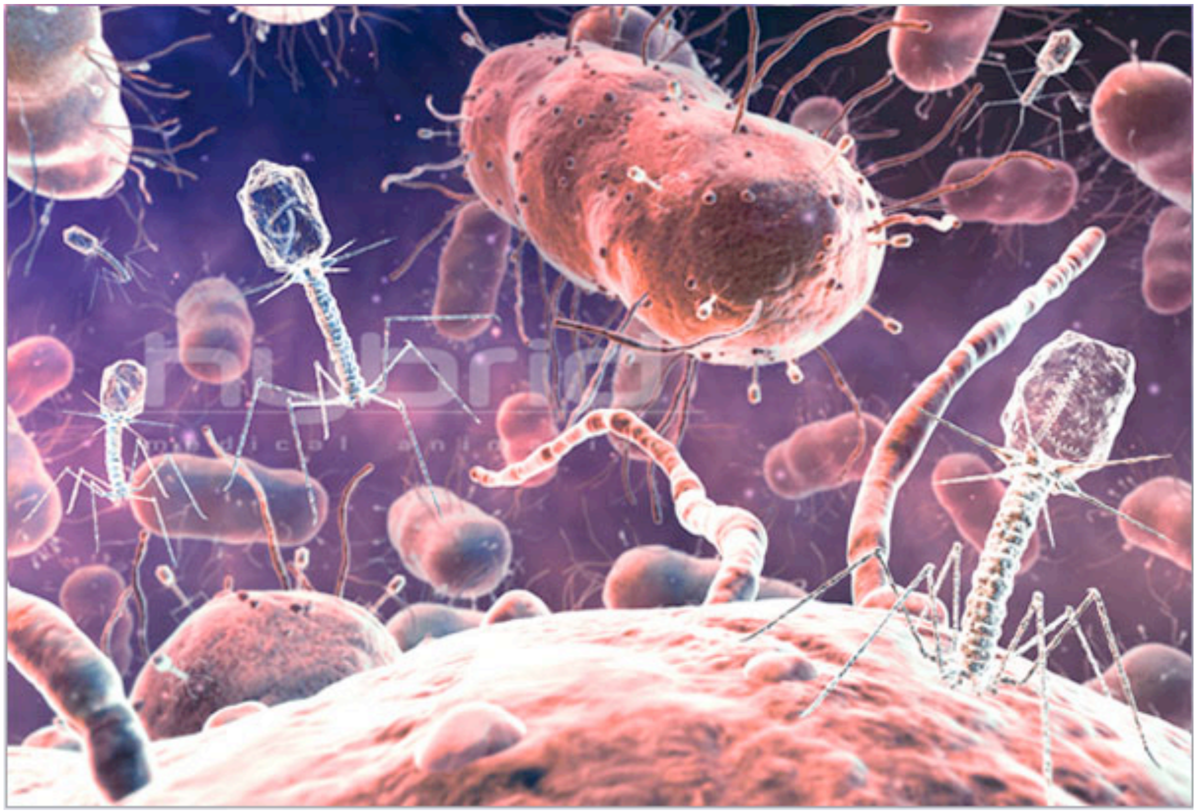
Hester's brief comments are made in an informal context, but they follow a logic that can be found in many other places.[7] Examples could be multiplied indefinitely. In 2005 an article in *California Monthly,* Berkeley's alumni magazine, showcased the research of Berkeley scientists. In this kind of article, a "pretty picture" (the term was apparently adopted by astronomers to denote images they prepared for calendars and posters) is briefly glossed by a text identifying the scholar who produced it. A full-page photograph of a moss-covered tree, for example, is accompanied by a text describing a Berkeley scientist who recovered medicines from moss, especially "a family of chemicals called flavenoids" (plate 2).

Nothing more is said. In the context of an alumni magazine, all that is expected is a nice picture and a reference, and it would be assumed that anyone who wanted could follow up and find out more. But these clipped contexts are ubiquitous, and so it is significant that the text explains neither the photograph (What kind of tree? What kind of moss? Was the picture used in the research?) nor the science (What are flavenoids? How are they extracted?). A reader perusing the article is treated to several dozen photographs and short paragraphs. If they are interested, they can learn the names of the Berkeley scientists and guess at what they are doing, but the article is not really meant to teach anything. It is a wash of colorful images and new names, which suggests that lovely photographs can help laypeople understand a little science.

In a lecture given in spring 2005 as part of the Einstein centenary, the physicist Michael Berry of Bristol University visited Ireland and gave a talk about the patterns of light that form on the bottom of swimming pools and the ceilings above swimming pools. The "caustics" and wave fronts were the object of his own scientific research, he said, and he also talked about the motion of wave packets and the physics of rainbows. He compared those phenomena to David Hockney's paintings, and to passages about reflections and light patterns in A.S. Byatt, Thomas Pynchon, and John Banville. The occasion was a "Café scientifique" sponsored in part by the British Council, and in that setting it would not be appropriate to introduce much scientific content. Berry worked on the assumption that the audience found the images as beautiful as he did (I found them garish), and the theme throughout was that an appreciation of the beauty would provide a way to appreciate the science. The audience was appreciative because he talked in a persuasive and animated way and because the images were full of color and light, but both the science and the art (I mean the Hockney) were done a disservice. Nothing could be gleaned about the physics of caustics from Berry's images, and his impoverished sense of artistic beauty made the parallels between artists like Hockney and the high-chroma scientific photographs unconvincing.

In the art world, the same strategies of juxtaposing art and science, and implying that one seeps naturally into the other, produce work that can be taken tongue-in-cheek, as kitsch. An example at the margins of the art world is the company DNA 11, which will make framed pictures of your DNA.[8] Although their website simply identifies the images as DNA — and as "great art," and "one-of-a-kind masterpieces" — actually they are electrophoretograms, arranged in strips. They are unlabeled, making it virtually impossible to extract any scientific content from them. "The procedure we use," they write, allaying the possible objection that someone could extract information from their "art," "creates a unique fingerprint that does not provide any information about your genetic code. It is a unique, artistic representation of your genetic fingerprint." Their art is beholden to a popularized aesthetic derived from minimalism: the color schemes they offer, and the frames that consumers can choose, all derive from second-generation minimalism in the 1990s. Their project can also be taken as just fun—which is to say as campy pseudo-science, or even kitschy sciencey minimalism. DNA 11's art credentials include the fact that it is advertised specifically as having no content: you can't learn about your DNA from your DNA art.

"Beauty" and "art" do not have much analytic purchase in any of these instances. Was Berry's use of the word that different from Ed Bell's praise of the computer graphics company Hybrid Medical Animation, when he said their animations "extend beyond the boundary of highly informative graphics: they enter the realm of high art, achieving a combination of Truth and Beauty"? Hybrid Medical Animations make Hollywood-style digital movies of proteins, antibodies, bacteriophages, and other microscopic phenomena (plate 3).



They use the latest textures (translucent surfaces, shining and viscous surfaces), vivid colors (magentas, lavenders) and all the bells and whistles of *Star Wars*-style action (tracking shots, zooms, fly-throughs, rapid point-of-view changes, simulated shallow focus). Their movies are like *Star Wars* (or, more recently, *Starship Troopers*) or a Universal Studios theme park ride, but with molecules instead of actors. Bell is Art Director of *Scientific American;* his endorsement appears on Hybrid Medical Animation's web pages. "Beauty" would seem to mean something like "dazzling post-production-style visual effects" — different, I think, from Berry's "beautiful" which means something like "elegant curvilinear patterns not unlike Op Art," and from Hester's "beautiful" which means something like "patterns that can be universally recognized."

There is a longer history of displaying scientific images for their beauty. André Kertesz composed scientific images that way, but the most influential example was the philosopher Jean-François Lyotard's exhibition *Les Immatériaux,* which displayed bubble-chamber images as if they were analogues of gestural painters such as Cy Twombly or Antoní Tapies. Bubble chamber images are actually intended to be *measured* and then discarded — more on this later — and not appreciated for any aesthetic property. The exhibition, "Visual Practices Across the University," was intended to break with the tradition of Kertesz and Lyotard and the many people who follow in their wake. In this book, each chapter gets a single large image, as it was in the exhibition: these are lures, and in the exhibition they were meant to give the impression that beauty might be important after all. Visitors were meant to be attracted by the large, unusual images, the way a reader of *California* Monthly might be attracted by the pictures of outer space, molecules, and mossy trees. Then when the visitors approached more closely, they found that the pictures only *appeared* to be accessible, and what little they shared with art—their compositions, their colors—wasn't helpful or interesting.

So one reason to try to stop paying attention to the art-science difference is the impoverished discourse that is built on words like "beauty," "elegance," and "pattern." The opposite also happens: scientists write about artworks as if art's main interest is its scientific content. Thomas Rossing and Christopher Chiaverina's *Light Science: Physics and the Visual Arts,* which finds scientific themes in pointillism, anamorphosis, and op art, is an example: it argues that a principal source of interest in the art is its illustration of basic scientific concepts.[9] Leonard Shlain's *Art and Physics: Parallel Visions in Space, Time, and Light* is a more concerted effort to find links between science and art, but Shlain is too easily satisfied by chance coincidences, metaphoric connections, and miscellaneous affinities.[10] The same could be said of other books, including John Latham's *Art After Physics* and Arturo Gilardoni's *X-Rays in Art*.[11] The common ground of these books is a dual claim: first, that art can be interesting because it demonstrates science; second, that it is not incumbent on someone writing about the science in art to account for the apparent irrelevance of the existing non-scientific interpretations of the art.[12]

A large critical and journalistic literature rose in the wake of a book by David Hockney and Charles Falco called *Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters,* which claims that some old masters used mirrors and other optical devices to help them make naturalistic paintings. There was an enormous conference on the theme in December 2001 at New York University, and several of the people involved continued to publish on the subject in the years following. (My criterion of an enormous conference is that 90 seats were set aside just for journalists, and lines went halfway around Washington Square in Manhattan.) Essentially Hockney and Falco claimed that painters from Van Eyck onward had access to optical aids such as mirrors, camera lucidas, and lenses that helped them achieve the feats of naturalism that have been traditionally attributed to their innate skill. The book and conference were a sensation in the media, in part because they seemed to empower ordinary viewers — at last, so it was said, viewers do not have to listen to the increasingly arcane meditations of academics, because they can see for themselves how the paintings were made.[13]

Ellen Winner, a psychologist who gave a paper at the conference, later wrote an essay called “Art History Can Trade Insights With the Sciences,” calling for a mutual respect that she felt was missing at the conference. “True,” she writes, “Falco and Hockney did not speak to the meaning or beauty” of the art, but that does not imply there are no lessons to be learned by considering the science. “When art historians argue that artists did not *need* lenses because they were so talented, they seem not to realize that the argument does not rule out the use of lenses.”[14] The gulf of misunderstandings I have been trying to describe is nicely contained in that sentence, because regardless of the truth of Hockney’s clam, it is not true that “art historians argue that artists did not *need* lenses”: they don’t argue about those things at all. The two discourses are much further apart than Winner’s claim implies, and it is not likely that more than a half-dozen humanists and cognitive scientists are “going to be teaming up to study humanistic phenomena from a scientific perspective.” In order for that to happen, there has first to be an agreement over the common problems, whether they are beauty or optics.

Sidney Perkowitz, another scientist who attended the conference on Hockney’s book, had written a book called *Empire of Light* (1996). In the article he contributed to the conference, he says he is neither surprised nor dismayed that some artists used optical aids. “Should the use of a tool diminish the value of the art?” he asks, and he illustrates a painting by Chardin, an Op-Art abstraction, and Mondrian’s *Broadway Boogie-Woogie.*[15] The question isn’t wrong, but wrongheaded. To whom does it matter that Chardin or Mondrian “reflect principles of visual cognition”? That has seldom been a part of their significance, and if the idea is to find examples of visual cognition, there is no good reason to adduce art to begin with. At the conference I had a brief argument with Perkowitz. I suggested that very few contemporary artists even use science in their work — I named Vija Celmins, Dorothea Rockburne, and Mark Tansey — and he said I was wrong, that his book had many examples of “new forms of art” produced by the use of science. His essay features an artist named Dale Edlred (I had not heard of him), and his book has many more minor artists. I wonder if their marginality in the art world does not prove the point. Art that is strongly inclined to technology or science often — though not always — ends up on the margins of the art world. The large annual conferences of SIGGRAPH and ISEA are cases in point; both organizations feature digital art, and both are almost completely ignored by the mainstream art world. In some measure that is a prejudice, and a fault, of the art world: but in some measure it shows that scientific and technological themes just aren’t part of the mainstreams of postmodernism.[16]

The principal humanist scholars who study the science of art, such as Martin Kemp and John Gage, have done much of what can be done on the scattered appearances of scientific content in Western art.[17] The end point of such research is the fact that science has rarely constituted much of what matters in art. The complementary end point of the scientific interest in art, such as Thomas Rossing and Christopher Chiaverina's, or Leonard Shlain's, should be that scientific explanations rarely matter in humanist discourse on art. If discourse on science-art connections is rum, uninformed, unhelpfully abbreviated, unjustifiably optimistic, alienating, and generally unhelpful, then it may be time to find new ways of talking about images that are not art.

What Might Happen when Art and Science are Not Privileged

This book is not my first attempt to find a way of thinking that could include all sorts of images at once. The other projects are relevant here, because they form the background and justification for this book. The first was *The Domain of Images,* which divides images first into three groups (writing, pictures, and notation), and then into a set of seven.[18] The triad writing, pictures, and notation was intended to capture the fact that mathematical images are used and talked about differently than written language or visual images. The division into seven was partly borrowed in part from Ignace Gelb, who was Derrida's source for "grammatology." The seven included allography (calligraphy, typefaces, and the visual elements of writing), subgraphemics (writinglike fragments of images), and emblemata (highly organized symbolic images). *The Domain of Images* is a long and complicated book, and it has the conceptual narrowness that any taxonomy imposes on itself. Its crucial limitation, as the art historian Robert Herbert pointed out, is that it has to renounce some of the history of the objects, and virtually all of their political and social contexts, in order to make sense of how they have been received. Emblemata, for example, are interpreted in distinct and definable ways — they have an inner logic, a lexicon, and protocols of reading that make them recognizable and legible — but in order to analyze the differences between emblems and other, less organized images, it is necessary to suspend an interest in the history or social contexts of individual emblems. *The Domain of Images* subordinates the purposes images serve to the ways people interpret them, and in that respect it is, in the end, a formalism.

The book *How to Use Your Eyes* took an entirely different approach.[19] It has thirty-odd very short chapters—the length of the chapters in this book—describing such things as "How to Look at the Night Sky," "How to Look at a Twig," "How to Look at a Shoulder," "How to Look at an Engineering Drawing," and "How to Look at Sand." Each chapter gives as many names and terms as I could find about each subject: the half-dozen sources of light in the night sky aside from the moon and stars; the "leaf scars" that make it possible to identify trees in the wintertime; the names and motions of muscles in the shoulder. The book is full of pictures and unusual words. Half the chapters are objects made by people — the script Linear B, Japanese calligraphy, paintings, scarabs — and half are natural objects — moths' wings, sunset colors, twigs, grass, sand. *How to Use Your Eyes* is empirically minded, and was rightly said to depend on technical nomenclature: its methods do not work on objects that have few names or parts. As one reader said, it ends up making seeing into reading. I am not sure of the force of that claim, because it can be argued that the world only becomes visible through language, when an object has a potential name — but the book is certainly limited to visual objects that have already been extensively labeled.

The exhibition that is recorded here was my third attempt to speak about images in general, without the boundaries of fine art. It is more technical than *How to Use Your Eyes,* and more careful about the disciplines that produce knowledge than *The Domain of Images.* The exhibition was intended as an example of what the field of visual studies might accomplish if it were to relinquish its lingering interest in art. Visual studies continues to grow very rapidly but I think it effectively remains in an academic ghetto, confined by its concerns with mass media, fine art, and politics.[20] First-year classes taught as introductions to the visual world continue to take most of their examples from Western fine art and mass media, and to a lesser extent from design, craft, and non-Western practices. When objects outside of art are considered, they are treated in a general way, as examples of production or politics. Scientific and other non-art images are adduced to enrich the cultural contexts of fine art or to explain references in individual artworks. Science is seen indistinctly, from a distance.

(This is more true in North America and the U.K. than in German-speaking countries and in Scandinavia. There, visual studies is frequently more attentive to non-art images. Examples include Gottfried Boehm's and Andreas Breyer's "Iconic Criticism" initiative in Basel, Horst Bredekamp's work at the Humboldt-Universität Berlin, and individual projects in Karlsruhe, Copenhagen, Aachen, Stockholm, Magdeburg, Leipzig, and Lund. This book fits more with German-language scholarship than with English- or French-language work, which continues to stress political, gender, and wider social meanings. I explore this issue in the Afterword.)

The founding gambit of visual studies in English-speaking countries is that in a world of proliferating images, it no longer makes sense to have specialists on every conceivable kind of image, as it had once been useful for art history departments to have specialists on medieval, Renaissance, Baroque, and modern art. Visual studies posits that what matters is a more abstract, reflective concept of the production and dissemination of images, and a methodology capable of revealing the ways images are made to seem compelling, and how they reform their viewers and shape their desires. That has been a fruitful direction for several decades, and it may continue to be: but it does not address what happens in the sciences, for the simple reason that it elides the specific content of non-art images even as it pays close attention to the specific content of art and mass media. The American World War I poster with the legend "I want you!" has been analyzed in several visual studies publications, but there is still nothing in visual studies that analyzes a gene map in such a way that a student could explain what its parts signify. The exhibition was intended to discover what it would sound like to pay attention to all images, art and non-art alike, with the level of detail used by their makers and their intended public. (Detailed engagement is, I think, indispensable: in this book, I made a few images myself, using scientific software and laboratory equipment — the opening images in Chapters 1 and 10, for example. Only by operating the instruments, and learning the software, is it possible to see the limits of a humanities-based visual studies.)

The exhibition was difficult for viewers, and likewise this book is not easy to read. Its chapters are like a collection of short stories: they have different characters and plots, but like stories by a single author, they share a number of themes, passing them back and forth, sometimes developing them, sometimes not. An editor who saw this book in manuscript said that it was too "particulate"; to her, the chapters seemed disconnected and too much concerned with the recitation of facts. This book is designed that way, instead of as a single continuous narrative, because I think that disjunctions are exactly what the field of visual studies needs in order to move forward. Texts on visual studies by W.J.T. Mitchell, Nicholas Mirzoeff, Mieke Bal, and others are limited by their strengths, as it were: they offer continuous theorizations in non-technical prose, but in doing so they exclude ideas that cannot be accommodated by humanities-style narration. What is at issue here, from the standpoint of visual studies, is the sense of appropriate theorization. The thirty practices in this book embody a number of themes, as I will propose below, but the individual visual practices are not subsumed by those themes. Discontinuous, "inappropriately" factual, surprisingly technical, "particulate," apparently under-theorized visual encounters are exactly what I think will produce a genuine advance in theorizing the visual, an advance that will propel visual studies out of the humanities and into the wider practices of the university.[21]

Five Themes in This Book

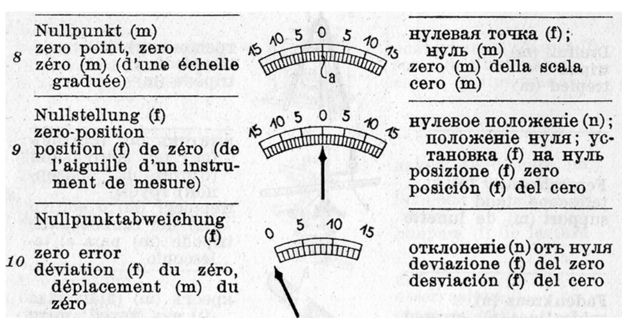
These are the problematics that emerged as the material for the exhibition was being gathered. They were not posed ahead of time, but worked out as the images were being discussed. In this book they are threaded through the chapters, appearing intermittently, providing what I'd like to call a discontinuous continuity.

1. *How much of the world can be pictured?* When the proposals for exhibits started coming in, I was struck by the fact that some departments that I would have thought were very visually oriented had not responded. We had no proposals from the Departments of Process and Chemical Engineering, Electrical and Electronic Engineering, Politics, or Statistics. (There were a couple of near misses: a scholar in Statistics was thinking of investigating Florence Nightingale's statistical graphics of childbed mortality; and a lecturer in Electrical and Electronic Engineering was pondering an exhibit showing the potentially harmful radiation from a cell phone entering a listener's brain — he decided against it because it might be both misleading and disturbing.)

At the same time, we got a number of proposals from disciplines that are not especially known for their engagement with the visual. A member of the German Department proposed an exhibit of concrete poetry in German, and a member of the French Department proposed the *cadavre exquis,* the Surrealist game in which a figure is drawn on sections of folded paper, so no one can see the full monster until the paper is unfolded. Both would have been interesting exhibits, but we decided not to develop them because they did not seem representative of what scholars in those departments ordinary did. Concrete (shaped) poetry has been practiced in the German language since the middle ages, and there is wonderful material that would have been suited to an exhibition — garlands and elaborate knots made of micrographic script, entire pictures made of tiny letters — but concrete poetry was also made in Latin and in most European languages. The *cadavre exquis* is a visual game played from the 1920s onward, but it does not have a direct relation to scholarship in the French language. We had several other proposals along those lines. One display in the exhibition exemplifies that issue: Chapter 5, on Irish Ogam script, is a very specialized study of early Irish writing, as it is discussed in a particular medieval manuscript. The scribe assigns a color to each letter in the Ogam alphabet, making it into a system of hidden color symbolism. The scholar who prepared this material, Caitríona Ó Dochartaigh, wanted to make the point that it is very difficult to find visual material in her field. It took some sleuthing, and an especially arcane example, to locate visual interest in medieval Irish manuscripts.

Comparing the list of departments that routinely use images with those that normally do not, I noticed a disparity: most visual work in the university is done outside the humanities, but most of the claims to be doing visual work came from within the humanities. The large body of philosophic scholarship on relationships between the world and images can obscure the fact that visual images are peripheral to the concerns of people who work in the languages, and the same is true of linguistics itself. On the other hand, the routines of image making and image interpretation in fields such as chemical engineering can make it seem as though nothing of pressing interest needs to be said about the images themselves, because all that matters is what the pictures represent and the science they make possible. The most interesting question that can be asked of this, I think, is the extent to which the world, as it is seen from the perspective of any given discipline, seems to be amenable to visualization. How much of the world — that part of it studied by a discipline —can be pictured?

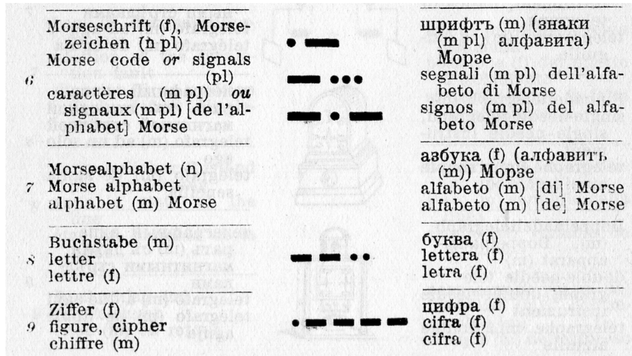
For some disciplines, the answer would be that very nearly everything of interest can be represented; for others, such as French or German, the answer might be very different. This question, and several I will be asking later in this Introduction, can be nicely exemplified by a multi-volume atlas of electrical engineering that I came across in a used book store. It's a thick, stubby book, intended as a handbook but too chunky to fit in a pocket. In exactly 2,100 thin pages and 3,773 tiny pictures it purports to illustrate every concept in electrical engineering.[22] A typical page on the different meanings of "zero" on analog meters shows how the book might be useful (plate 4).


8 Nullpunkt (m)
zero point, zero
zéro (m) (d'une échelle graduée)
нулевая точка (f); нуль (m)
zero (m) della scala
cero (m)

9 Nullstellung (f)
zero-position
position (f) de zéro (de l'aiguille d'un instrument de mesure)
нулевое положенie (n); положенie нуля; установка (f) на нуль
posizione (f) zero
posición (f) del cero

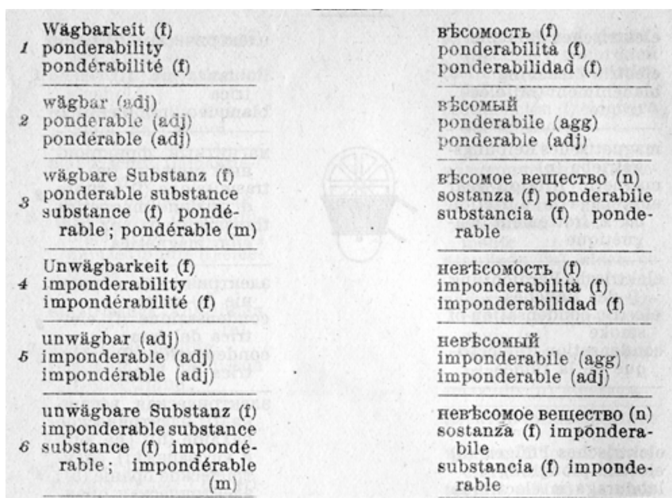
10 Nullpunktabweichung (f)
zero error
déviation (f) du zéro, déplacement (m) du zéro
отклоненie (n) отъ нуля
deviazione (f) del zero
desviación (f) del cero

"Zero point," "zero position," and "zero error" are clearly distinguished in the pictures. But it is easy to overestimate what can be visualized. The page on Morse code is much less useful (plate 5).



6	Morseschrift (f), Morsezeichen (n pl) Morse code *or* signals (pl) caractères (m pl) *ou* signaux (m pl) [de l'alphabet] Morse	шрифтъ (m) (знаки (m pl) алфавита) Морзе segnali (m pl) dell'alfabeto di Morse signos (m pl) del alfabeto Morse
7	Morsealphabet (n) Morse alphabet alphabet (m) Morse	азбука (f) (алфавитъ (m)) Морзе alfabeto (m) [di] Morse alfabeto (m) [de] Morse
8	Buchstabe (m) letter lettre (f)	буква (f) lettera (f) letra (f)
9	Ziffer (f) figure, cipher chiffre (m)	цифра (f) cifra (f) cifra (f)

It exemplifies Morse code with some samples, and then omits the Morse alphabet entirely for lack of space, even though it would have been reasonable to expect it to be illustrated. "Letter" and "figure, cipher" are then illustrated with their Morse equivalents, though I can't quite see why. Elsewhere in the book, the editor gives up entirely when it comes to illustrating concepts related to ponderability (the capacity of an object to be weighed). There are no illustrations at all for the page including "ponderability," "ponderable," and several grammatical variants (plate 6).

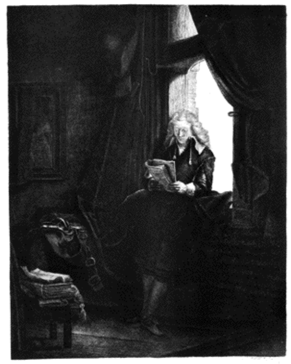


1	Wägbarkeit (f) ponderability pondérabilité (f)	вѣсомость (f) ponderabilità (f) ponderabilidad (f)
2	wägbar (adj) ponderable (adj) pondérable (adj)	вѣсомый ponderabile (agg) ponderable (adj)
3	wägbare Substanz (f) ponderable substance substance (f) pondérable; pondérable (m)	вѣсомое вещество (n) sostanza (f) ponderabile substancia (f) ponderable
4	Unwägbarkeit (f) imponderability impondérabilité (f)	невѣсомость (f) imponderabilità (f) imponderabilidad (f)
5	unwägbar (adj) imponderable (adj) impondérable (adj)	невѣсомый imponderabile (agg) imponderable (adj)
6	unwägbare Substanz (f) imponderable substance substance (f) impondérable; impondérable (m)	невѣсомое вещество (n) sostanza (f) imponderabile substancia (f) imponderable

It is hard to judge how much of electrical engineering is amenable to being illustrated; my guess would be no more than a quarter of it.

This question, about how much of the interesting world can be pictured, is tricky. The chapters in this book imply answers ranging from nearly none of the world (as in Chapter 5 on Irish Ogam script, or Chapter 29 on words for "light" and "dark" in Russian and Arabic) to almost all of it. Chapters 15 and 26 are the ones that represent aspects of art history, my own field and the one that might seem most thoroughly visual among the humanities. Art history and its intermittent companion studio art do take visual objects as their principal subject of study, but that does not mean that they visualize those objects *economically.* It is easy to demonstrate that art history and studio art use visual objects that are more detailed than the disciplines can accommodate. Their excess visuality is a remainder, left untheorized or even unremarked.

Consider this nineteenth-century photoetching made after a print by Rembrandt (plate 7).



Photoetchings have virtually the same detail as original prints; a teacher of mine once told me some Prints Rooms in museums used to bring out photoetchings to test novices. (If the young historian didn't know the difference between the photoetching and an original print, she would only be given photoetchings from then on.) For these purposes the photoetching has the full detail of an original impression. Plate 8 is a detail of it.

The next three plates show, in order: the best available reproduction in a book (plate 9);

the view a student in the back of a seminar room would have of the best slide of the print from the slide collection of the University of Chicago (plate 10);

and the best available image on the internet, which in many cases is all a student might be able to find (plate 11).

The second-to-last picture was taken in a darkened seminar room, from a seat toward the back, so it is a reasonable representation of what a student would see.

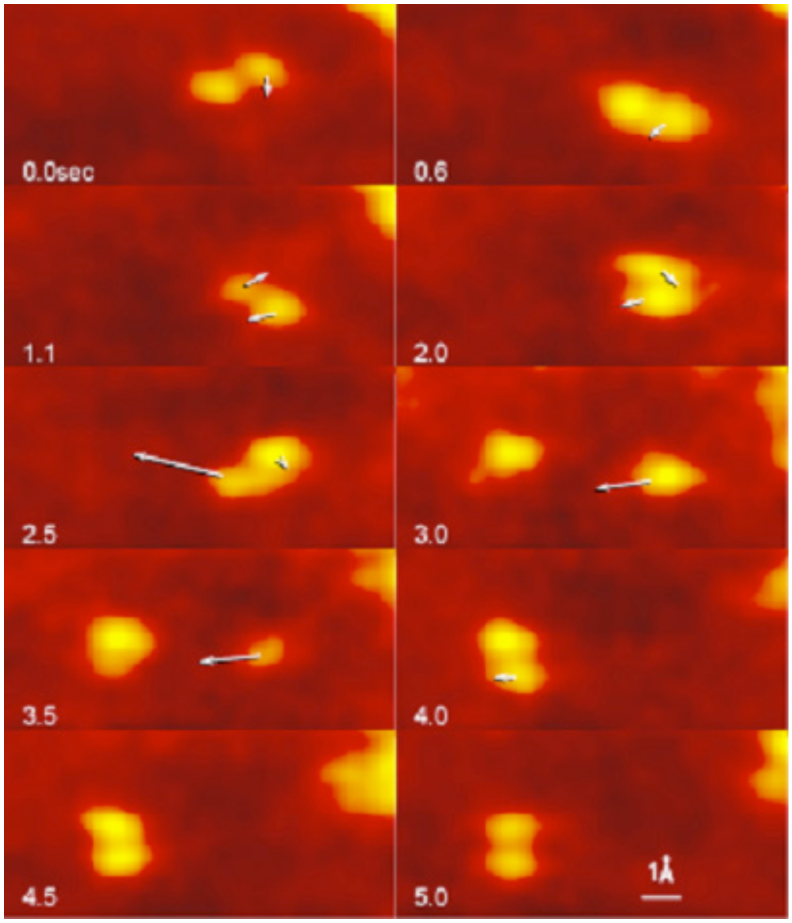
The salient point here is that none of these images, except perhaps the last, would be an impediment to any of the existing art historical accounts of the print. What art history says about visual objects is routinely far less than what is contained in the objects. In a sense that's a truism, but it also points to a kind of excessive visuality, which itself has a value even if it is not articulated: in art history it means, roughly, that the objects are art.

Other disciplines are both strongly visual and also maintain a closer correspondence between the content of images and the content that is understood to be significant. Here the preeminent field, as I write this in summer 2006, is probably the study of protein folding. It has only been possible to visualize molecular folding for ten or fifteen years, because of the computing power that it requires. Now some truly amazing films have been produced showing, frame by frame, the calculated positions of some very complex molecules. (At this point books are no longer the optimal medium, and I will be pointing to several URLs and laboratories rather than reproducing individual frames. It is best to read this with a computer at hand, and see the films for yourself.) The visualization of molecular movements began in the 1980s, when it became possible to calculate the static properties of molecules such as electron density surfaces. Some sophisticated versions of those early graphics, transformed into movies, are now routinely available.[23] The new movies reveal molecules as twitchy, shuddering things, not at all the way they had seemed in the many elegant and unmoving "ribbon diagrams" of older textbooks.[24] At the most sophisticated levels, distributed computing has made it possible to make animations of the folding of large molecules like t-RNA. Such molecules fold in thousands of similar ways, and by sharing the calculations across a number of computers, researchers have found the commonest path from unfolded to folded molecule.[25]

Protein folding animations preserve a closer correspondence between forms in the images and forms that are analyzed, simply because each "ball" or "stick" or "ribbon" (each component of a molecule in the animations) is calculated. In the art historical example, the sitter's hair and wrinkles, the texture of his clothes, and the play of light and shadow, are taken to be outside the purview of the discipline.

Massive, computed visualization of proteins is different from what is taking place in other disciplines that are equally entranced with the visual. Astrophysics is one such discipline, and another is the electron microscopic imaging of individual atoms. Both are concerned with the limits of what can be resolved using their instrumentation. Chapter 12 compares images of the Galactic center over the last thirty years as astronomers have looked more and more closely at the tiny area just around the very center of the Galaxy, where a number of stars orbit a black hole. Chapter 6 is about one of the current limits of resolution in astronomy, an ingenious technique that allows astronomers to exceed the theoretical limits of resolution of their telescopes and visualize the dynamics of binary stars. The imaging of individual atoms using various kinds of electron microscope is another example of imaging technologies that are concerned with the limits of instrumentation, but there is an interesting difference. Still images of atoms in crystal lattices can be fairly sharply defined, almost as if the atoms are little billiard balls and the pictured are just a little out of focus. But the laws of quantum mechanics make it impossible to sharpen the blur, whereas in astronomy it is always possible to imagine larger telescopes.

Movies of individual atoms can be wonderful to watch. The pixellated blurs that show the positions of the atoms—or, in other cases, the smoothed bumps that stand for atoms—move in and out of visibility, like soft little stars. In some movies atoms race around after one another, twirling under the influence of mutual attraction and speeding apart when repulsive forces become stronger (plate 12).[26]



One of the masters of this medium is Jan-Olov Bovin of Lund University; his films show individual gold atoms hovering over the surface of a gold crystal, shifting in and out of visibility, as if they were thinking about landing on the crystal.[27] Again I hesitate to reproduce individual frames. In the hands of the best technician, like Bovin, the movies are strange and compelling.[28]

I have briefly opened four questions within this first theme, just to show how rich it is. Within the question of how much of the world is understood to be visual, there are also the questions of the non-visual nature of the humanities; the unthematized, excess visuality of disciplines like art history; the profligate visuality of fields such as molecular biology; and the interest in the limits of visuality in fields like atomic physics. When I said that genuine theoretical progress can only be made by paying close-grained attention to the languages of different disciplines, this is what I meant: whole books could be written about each of those four sub-themes.

2. *Abuses of the visual.* Sometimes images accompany research papers, conferences, and textbooks, even though they are not used to support the science. In some fields images are customary; they are made habitually, and their absence would seem odd. As the exhibition

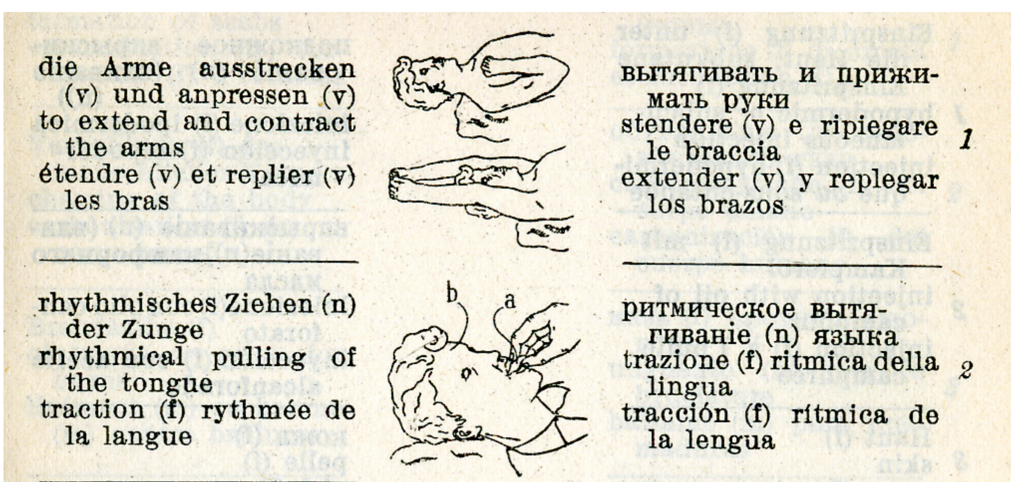
developed, it became clear that a fairly high percentage of the production of images across the university was of this kind: images were expected, but it wasn't always clear what function they fulfilled. I call these occurrences "abuses" just to give them a provocative label: I don't mean that images are used wrongly, just that they are unexpectedly *not* used, or used for unexpected purposes given their contexts. I will distinguish four kinds of abuses: visualization that is habitual, compulsive, forced, and useless.

Habitual visualization. A good example of the first is Chapter 24, which explores a blue and white image of the proteins in Cheddar cheese. The scientist who sent me this image, Paul McSweeney, at first thought I would use it as it was, without much explanation. If I had, it might have become one of the "beautiful" images that are thought to communicate some of their content simply by their aesthetic appeal. We wrote back and forth about his image, and it emerged that his laboratory does not always make such images, even though his research was on the subject of proteins in cheeses. Much less "beautiful" versions of the image are good enough for research purposes, and in fact they do not even need to be dyed blue. But every once in a while the lab needs a "beautiful" image to advertise itself. Gel electrophoretograms, as they are called, are a stock-in-trade of such laboratories; they are made for the posters scientists display at conferences, for teaching, for the covers of scientific journals, and for publicity inside and outside the university.[29] Labs that use gel electrophoresis are typically capable of producing these more "beautiful" versions of their ordinary images on demand.

In this book another instance of habitual visualization is in Chapter 8, which describes a software package called Nagios, used to keep an eye on computer systems like those found in large companies. Nagios normally runs in the background, but if there is a problem with one of the company's servers or with its internet connections, the full-screen view gives information about each component of the network. One of Nagios's selling points is its "3-D" view of a network, which displays servers and computers connected to one another by a web of lines, rendered in simple perspective. David O'Byrne, the computer scientist who introduced me to this software, said that he doesn't actually use the 3-D view. He prefers the tabular view or the 2-D map because when there is trouble, they give more information than the 3-D view. Nagios sells in part because of its capacity to produce useless, "pretty" pictures. In this case as in the Cheddar cheese images, visualization is habitual or customary, but not necessarily pertinent.

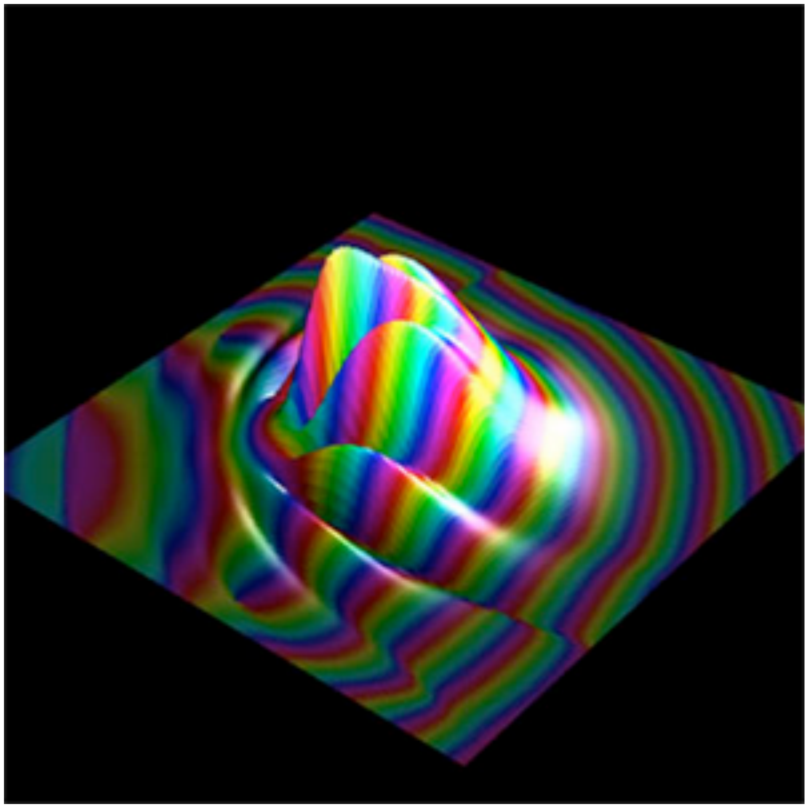
Compulsive visualization. My little encyclopedia of electrical technology is full of pictures that seem to have been made under a nearly incomprehensible compulsion to picture everything. One page offers vignettes of different kinds of "shops": machine shops, erecting shops, pattern shops, repair shops (plate 13).

I can't recognize anything in them except a few workbenches. I wonder for whom these could possibly be useful: if I had an intimate knowledge of German machine shops in the 1920s, then I might find it helpful to compare the pictures of different shops, but somehow I doubt it. My favorite section in the encyclopedia is the one on first aid, which includes pictures of a man who has fainted, together with instructions on how to extend and fold his arms in order to revive him, and even how to pull his tongue (plate 14).



I have no idea why it was considered helpful to pull an unconscious person's tongue, but the encyclopedia shows how to do it, and even labels the tongue and the man. The compulsive production of pictures is—one might argue, following for example Jean Baudrillard—a feature of late capitalism in general, but its disciplinary forms have not yet been studied. It occurs in this book in several forms; the most intriguing is Chapter 19, where a mathematician shows how to solve a problem once posed by Lewis Carroll using a series of graphs. His effort is part of an on-again, off-again tradition of visualizing mathematics: Should mathematical truths always be susceptible to being visualized? Or is the truth non-visual, and images its ornament? It's a foundational disagreement, played out most lucidly in mathematics. The mathematician who devised the visual solution to Lewis Carroll's problem didn't need to do so, but he was interested in the possibility. There is a compulsiveness about some scientists' use of the visual, and a compulsiveness about other scientists' refusal of the visual. The project in Chapter 19 is too extensive to illustrate in this book—it ran to over fifty diagrams—but it effectively demonstrates that the problem can be solved using entirely graphical means.

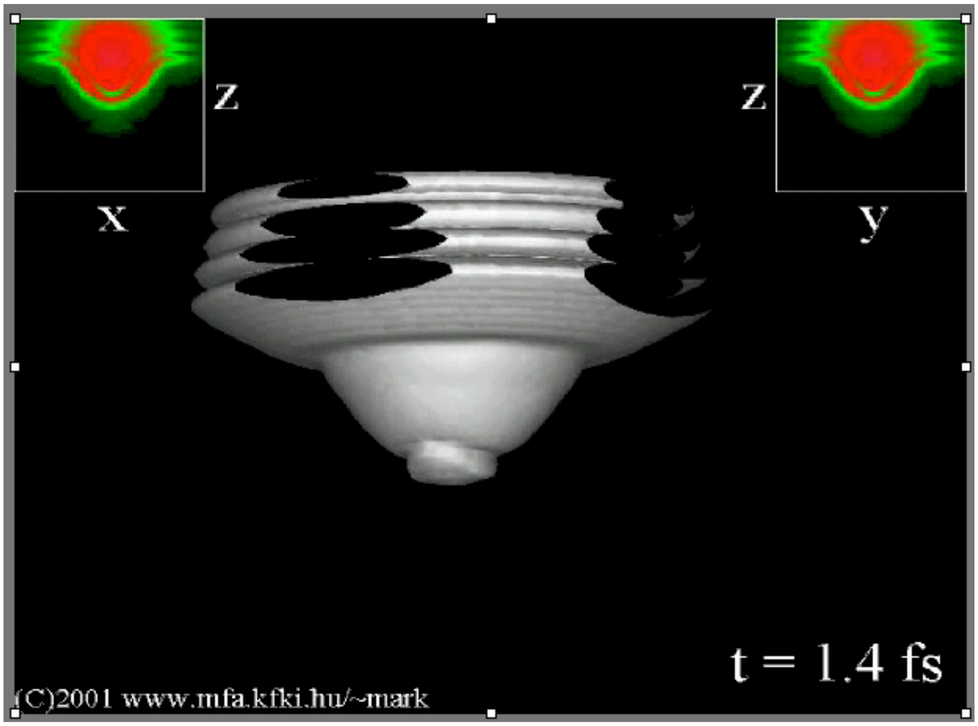
By *forced visualization* I mean the habit of making pictures of objects that are non-visual because they are multidimensional or not susceptible to illumination. Quantum mechanics is the twentieth century's pre-eminent example. The objects it describes are famously outside of ordinary human experience and possibly of all spatial intuition. Paul Dirac, one of the most acute theorists of quantum mechanics, is often quoted for his mistrust of images and his injunction to physicists to just "follow the mathematics" no matter how strange it might seem.[30] On the other hand there are specialists in quantum physics who do the opposite: they go on making pictures of quantum phenomena, despite the fact that they have to bend pictorial conventions to uses they had never had.[31] Bernd Thaller is the best example I know; he has written books and computer programs, and produced CDs of his visualizations. He makes pictures and movies of quantum effects, showing how particles exhibit wavelike behavior when they encounter objects (plate 15).

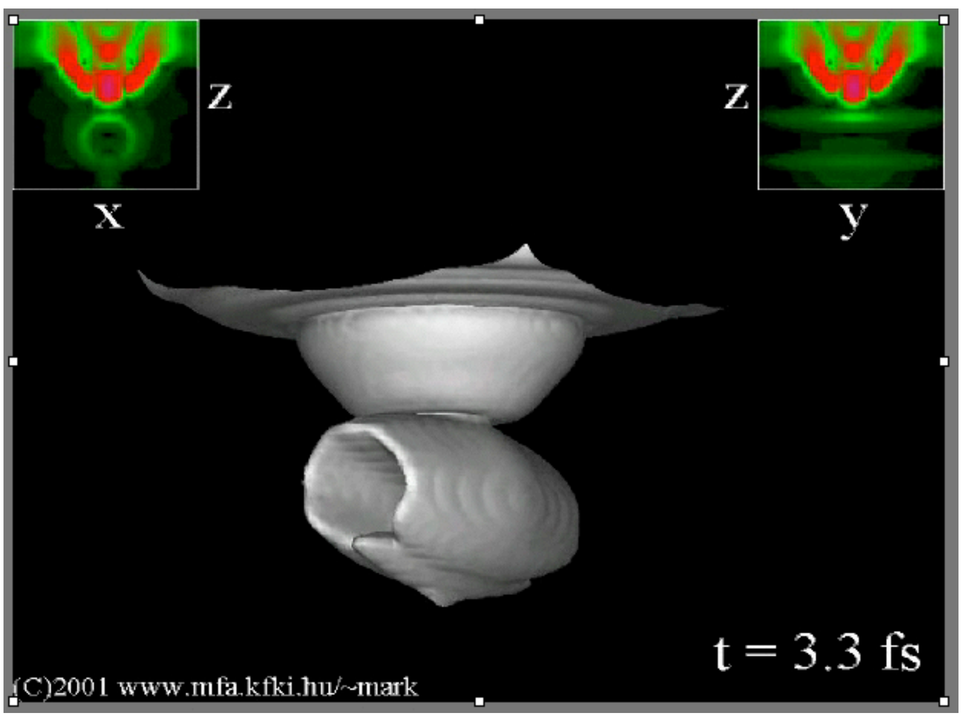


His images are colorful because he symbolizes the phase of the wave equation by colors assigned to the complex plane: a positive real component is red, decreasing in chroma in proportion to its distance form the origin, a positive imaginary component is yellow-green, and so forth. I mention this for readers who may be interested; the salient point is that the colors are only one of several properties of the particle's wave equation. Other properties have to go unvisualized because it simply isn't possible to put them all into a picture or a movie. Most fundamentally, the wavelike objects Thaller visualizes aren't waves, but probabilities, in accord with quantum mechanics, and that basic difference is one of the reasons some quantum physicists eschew pictorial representation altogether. Everything about such pictures, it could be said, is a misleading analogy based on familiar, human-scale phenomena. Thaller is an optimist about representation, a complement to Dirac's pessimism. He is very inventive at bending the usual functions of pictures to make them express the maximum amount about the unimaginable objects described by the mathematics. He "forces" the conventions of pictures to express properties of objects that can never be seen—much less seen as waves or as color.

Useless visualization. In 1999 I visited a laboratory at the University of North Carolina at Chapel Hill, where a scientist named Richard Superfine was investigating carbon nanotubes.[32] He had several atomic force microscopes set up in the lab, trained on microscopic samples of the nanotubes. Sitting at a monitor, I saw a flat surface in perspective, with a wobbly form lying on it like a bent pipe. At my right, in front of the monitor, was a pen, attached by a series of bars and joints to the desktop. As I moved the pen, a cursor on the screen moved. The idea was that I could actually push the nanotube around on the substrate, and that when I made contact, the pen would push back, representing the force required to move the nanotube. The universal joint attached to the pen would provide force-feedback, giving me a kinetic sense of the object's tensile properties and the forces binding it to the substrate. Superfine's laboratory had several such microscopes, which they used to investigate the ways nanotubes bend, roll, and stack — the ultimate aim being to build structures with them, possibly even nanodevices such as nanobots. I asked for some scientific papers that set out discoveries made with the atomic force microscopes, and Superfine said there weren't any — that his results came from other experiments. That surprised me, and I asked what the force-feedback devices taught them. He said they kept a list of "aha!" moments, in which people in his lab had found unexpected properties of the nanotubes by pushing them around, but that none of those "aha!" moments had made it into a scientific publication. The microscopes were wonderful, he said, for getting a feel for the objects, and they were also popular with school tours. They helped publicize and promote the lab's activities, and they gave an intuitive grasp of the objects, but they did not produce science. The science came from more controlled experiments, in which properties such as tensile strength and compressibility could be quantitatively measured.

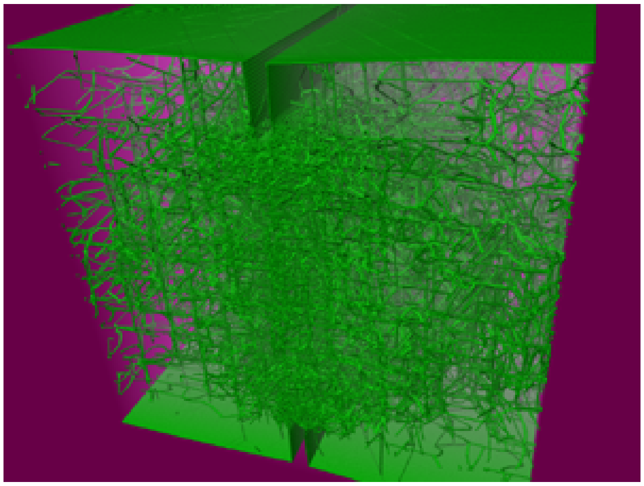
A "useless" image, in science, can be defined as an image that cannot be used to calculate, because it has nothing quantitative in it. Superfine's force-feedback setups are useless in that sense. There are also images that have quantitative information, but the experiments choose not to extract it. Instead the people who make the images are interested in them as visual examples of what their equations would look like. There are some spectacular examples in recent science. A Hungarian team produced a short film of a scanning tunneling microscope tip hovering over a carbon nanotube, just the kind of arrangement that Superfine's laboratory had.[33] In scanning tunneling microscopes, a sharp tip (the inverted cone at the top) senses the object, in this case a carbon nanotube (the hollow tube at the bottom). In practice, such a microscope would be used to produce a picture of the object—the nanotube—as if it were seen from above, and that is the way I observed nanotubes in Superfine's lab. In the Hungarian scientists' movie, what's under study is the microscope itself. The carbon nanotube is modeled as a cylinder 0.5 nanometers in diameter, and time is measured in femtoseconds. As the viewer watches, a slippery-looking sheet comes down over the tip and envelops the nanotube, as if it were a dessert being covered with liquid white chocolate (plates 16, 17).

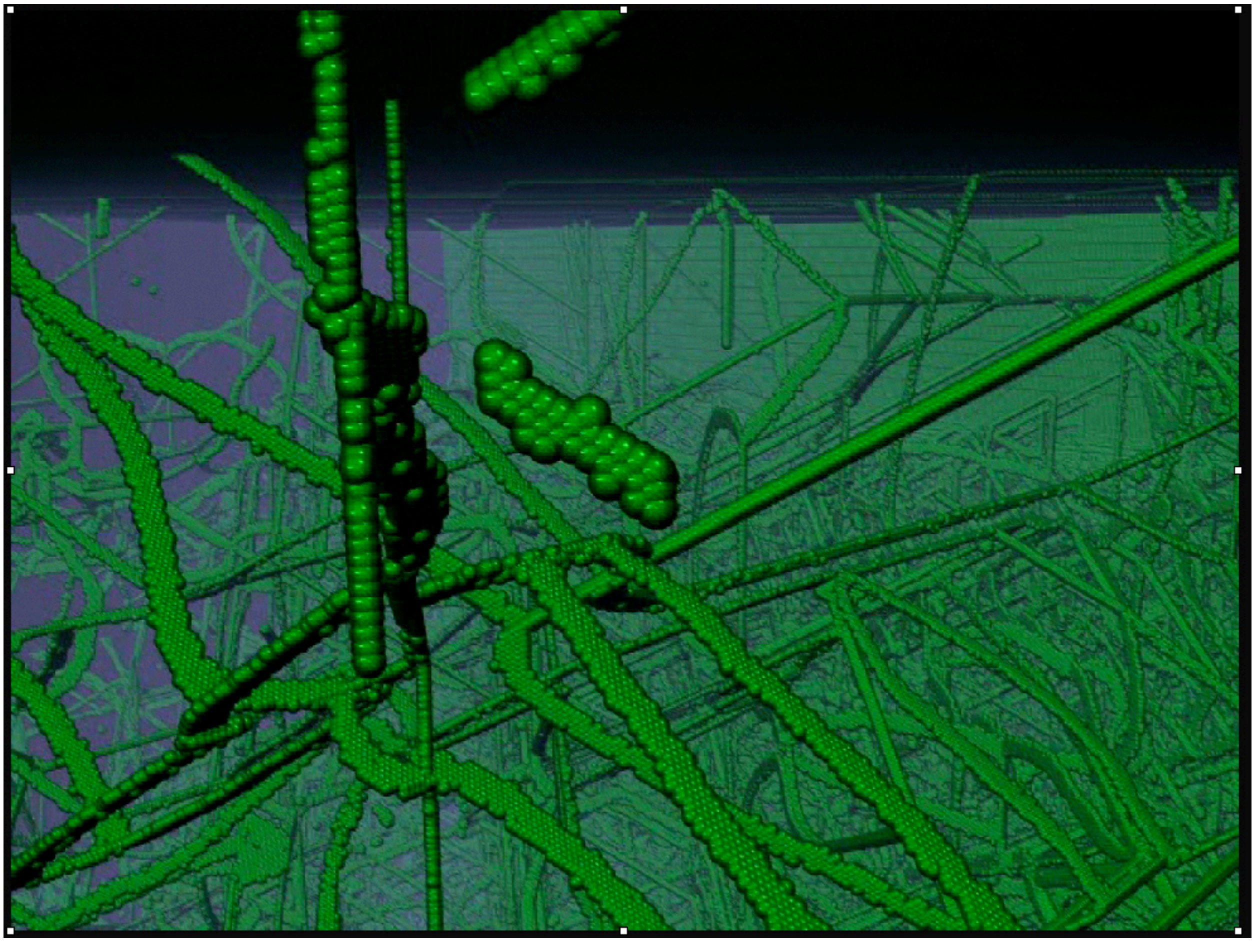




The white goo is the constant-probability surface of a Gaussian wave packet. It is an amazing visualization, and the mathematics behind it are pertinent for the design of such microscopes — but the film itself does not provide the analysis, only the visualization.

An even more impressive example is Farid Abraham's simulation of the motion of 1 billion atoms in a block of copper.[34] It is a film made to show the effects of putting copper under stress but not breaking it: the atoms shear against one another, producing dislocations throughout the block. The film includes several fly-throughs of the block, and viewers can watch as the dislocations spread like tendrils throughout the mass of copper (plate 18).





(Atoms are only drawn if they are dislocated by the pressure: the film actually represents a solid block of a billion atoms, but the only ones shown are along shear lines.) Interesting as the film is, it only gives a qualitative idea of the tangle of dislocations; the science is elsewhere. It is useless, strictly speaking, because it serves more to capture viewers' imaginations than to disclose new properties of copper.

It might be said that the "abused" images in these four categories aren't "useless" at all, because they serve political ends. They help laboratories and scientists advertise themselves, and they spark conversations about the work that may lead in new directions. That is true; the images are only "useless" in the sense that they themselves are not the proof or evidence of whatever scientific claims the laboratory is making. They are, instead, ornaments on the more fundamental work of experiment or mathematics. I called this theme "abuses of the visual" rather than, say, "images that are only political" because the word "politics" flattens the images' different relations to scientific truth and utility. The politics of publicity, grants, careers, and publications certainly contributes to the production of "useless" and other "abused" images, but politics isn't the whole story. In the humanities, and especially in visual studies, the politics of an image is nominally its most fruitful and constitutive property. Politics is taken to go, as Nietzsche said, "all the way down," and analyses can begin and end with the politics of image-making and image interpretation. In the sciences, politics plays a crucial role but it is not what the enterprise is all about. The idea of thinking about "abuses of the visual" is to shift the conversation a little so that these images cannot be so quickly explained as politically expedient.

A salient fact here is that the sciences, unlike the humanities, produce enormous numbers of images they do not directly use. To some degree these "useless" images are evidence that people associate truth with images, so that an image is a proof of veracity even when it is does not, strictly speaking, prove anything. It makes sense, I suppose, that such images are common in the sciences than in the humanities, where veracity and truth are so much to the point. It might be fruitful to study these "abused" images from this perspective, as remnants of the idea that images are truth. (One could ask, for example, what about each image seems to capture something true, even though that truth cannot be quantified or linked to the mathematics or the experimental data.)

Images that are made and discarded, made but not used, made but not valued, are ubiquitous, and one of the cardinal dangers of any study that emphasizes images is not noticing when the objects of study aren't valued by the people who make them. The field of visual studies, and in particular those scholars, centers, and departments interested in non-art images, are liable to make too much of what they study, and not to notice when the objects are eclipsed or forgotten. "Abused" images are also a reminder that it is easy to overvalue the objects of one's attention. Many of the pictures in this book are simply not important to the fields that produce them.

3. *What counts as a picture?* I have mentioned the fact that some images in this book look like naturalistic pictures, but aren't. The images in Chapter 12, for example, are "velocity graphs." In a normal, naturalistic picture of something — say, a galaxy — an object higher in the picture would be "higher" in space (perhaps in declination, to use the astronomical term), and an object to the right in the picture would be "to the right" in space (in right ascension, say). In Chapter 12, the two axes of the pictures do not represent position, but speed. The images look like ordinary photographs of astronomical objects, but they aren't.

Should such images be counted as pictures, or would it be better to call them graphs or—following the three-part division in *Domain of Images*—notations? Sonograms are another example. The song of the Canyon Wren reproduced in Chapter 8 looks like a picture of the bird's song, but of course it isn't: it's a graph of the pitch of the song as it changes through time. Readers accustomed to music notation will be able to "read" the graph in a general way, and see how the song drops down in pitch. It's the kind of song that people call "sad" or "plaintive." The sonograms of human speech reproduced in the same Chapter are harder to "read" but they are constructed the same way. It would probably be stretching the concept to call these pictures, but it would also be appropriate because they are constructed to look a bit like pictures. It often helps scientists to have images that behave *a little* like ordinary naturalistic photographs.

That extraordinary fact opens a new way of talking about such images. They are *picturelike,* and the right language for interpreting them should probably not be too far removed from the language that is used to interpret naturalistic images. If they were simply or purely graphs or notations they might well be arranged differently: without glowing colors, for example, and without higher tones being higher on the image. Those are pictorial conventions, borrowed from ordinary picturemaking. All sorts of different conventions would be available to imagemakers who did not want to keep the residue, the hint, of ordinary pictures.

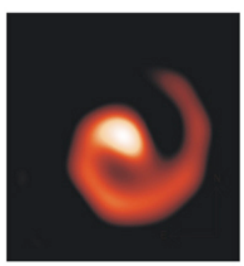
It is possible to distinguish several different kinds of images that are not quite pictures:

Picturelike graphs. The examples I have given so far substitute things like pitch, time, and velocity for the usual dimension of space. (A photograph is a space-space representation, to put it abstractly. A sonogram is a pitch-time representation, and the images of the galactic center are velocity-velocity representations.) Even the spectrum that opens Chapter 1 is picture-like. Its vertical axis indexes wavelength, and its horizontal axis is meaningless. (Aside from the film strips at the right and left, which are used for measuring.)

Multidimensional images. Chapter 16 reports on an aerial survey of Cork done with a specialized camera, like one later flown on a mission to Mars. The camera gathered a mass of data, which was used to produce aerial photographs that look just like old-fashioned aerial photographs taken with simple cameras. But those familiar-looking images were *extracted* from the mass of data the camera gathered, which could be used to generate all sorts of other images. The team that flew the camera over Cork used the fuller data set to study the height of buildings and to make a simulation of the flooding of the city. The data could also be used to identify specific crops, or distinguish fallow fields from planted ones, or to survey tree cover — there is a large potential range of agricultural, geological, engineering, and city planning applications. The aerial photographs are thin slices of a larger data set.

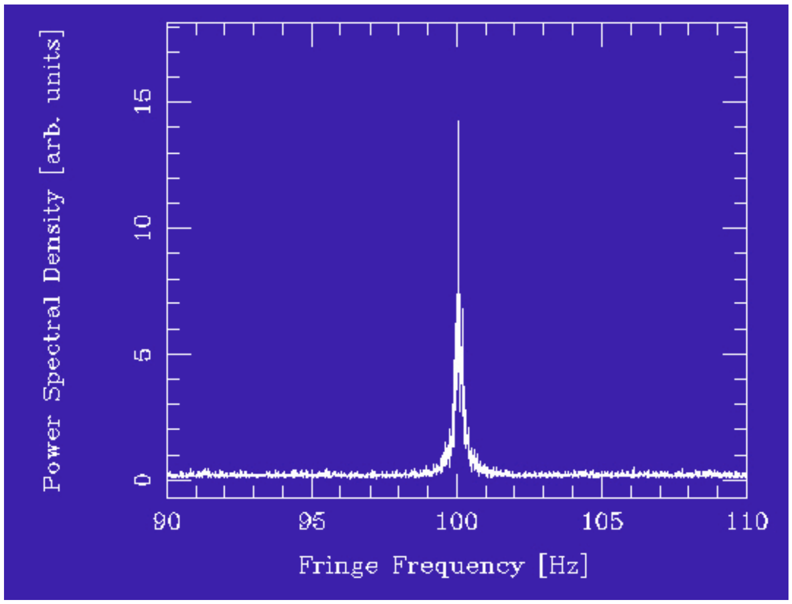
The same could be said of the 3-D laser surveys of inscribed stones described in Chapter 22, or even the encyclopedic map of the geology of southwest Ireland shown in Chapter 14. Both result in pictures that are only samples of the available data. This kind of thing rarely happens in the arts and humanities. The *Mona Lisa* is not an extract from some larger bank of images, except in the abstract sense that it has a history and a context, like any image. Artworks tend to display or contain the sum total of their information, but scientific images are sometimes just tiny portions of a larger invisible or unvisualized whole.

Frankenstein pictures. Then there are images cobbled together from many different sources, not all of them visual. A curious example is a film of the binary star system named Wolf-Rayet 104 (the name identifies one of the two stars in the system). The system, WR104, has been widely reproduced as a short film loop because of the very unusual fact that it looks like a pinwheel (plate 19).

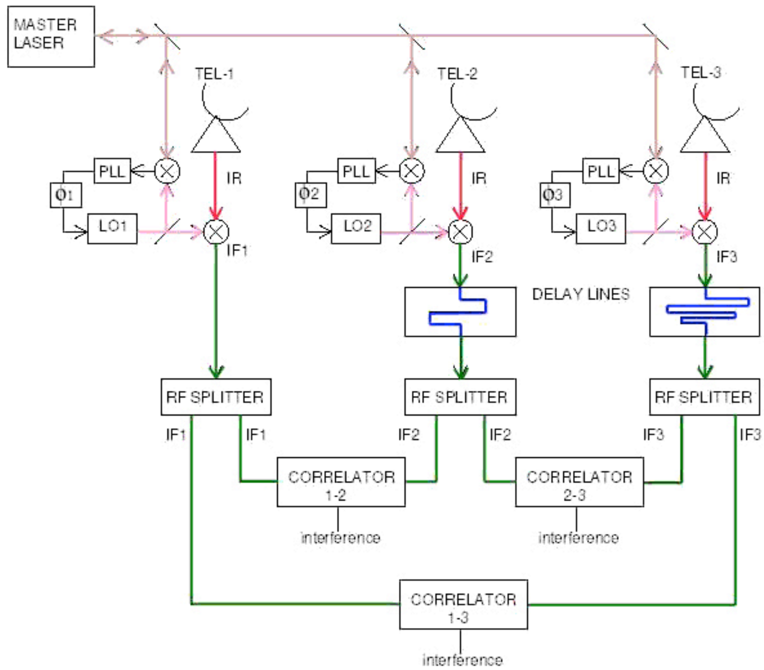


In the film, the spiral spins. The effect is caused by hot gases being thrown off of one of the stars in the pair. (Neither star is directly visible in the image.) The popularity of the film must be due in part to the surprise of discovering that somewhere in the constellation of Sagittarius there is a little pinwheel spinning.

Yet the film is really very distant from a movie of a pinwheel-shaped object. First, its “hot” red color is false.[35] Actually, it was imaged in the infrared, so this particular shape would be invisible to the naked eye. Second, this was never seen from a single telescope. It is an image constructed from three telescopes situated a small distance from one another in a field. Third (and most counter-intuitive), none of the three telescopes produced an image on its own. They each saw just one point of light at a time, and their signals were combined using interferometry. The combination of the signals of two of the three is shown in plate 20; that is a stage in the construction of the pinwheel image.



Fourth, the signals processed to make the image underwent a change known as *heterodyne reduction:* they were each combined with laser light, producing a single wave of a much longer frequency, which was then carried as a *radio* signal in wires. Fifth, the reduction was necessary because the signals have to reach the computer that analyzes them at the exact same time, and the telescope at one end of the field is actually a tiny bit father from the star than one at the other end of the field. To compensate, the signal from the closer telescope is sent through a longer wire. It seems implausible, but in this way the three telescopes are effectively exactly the same distance from their object (plate 21).

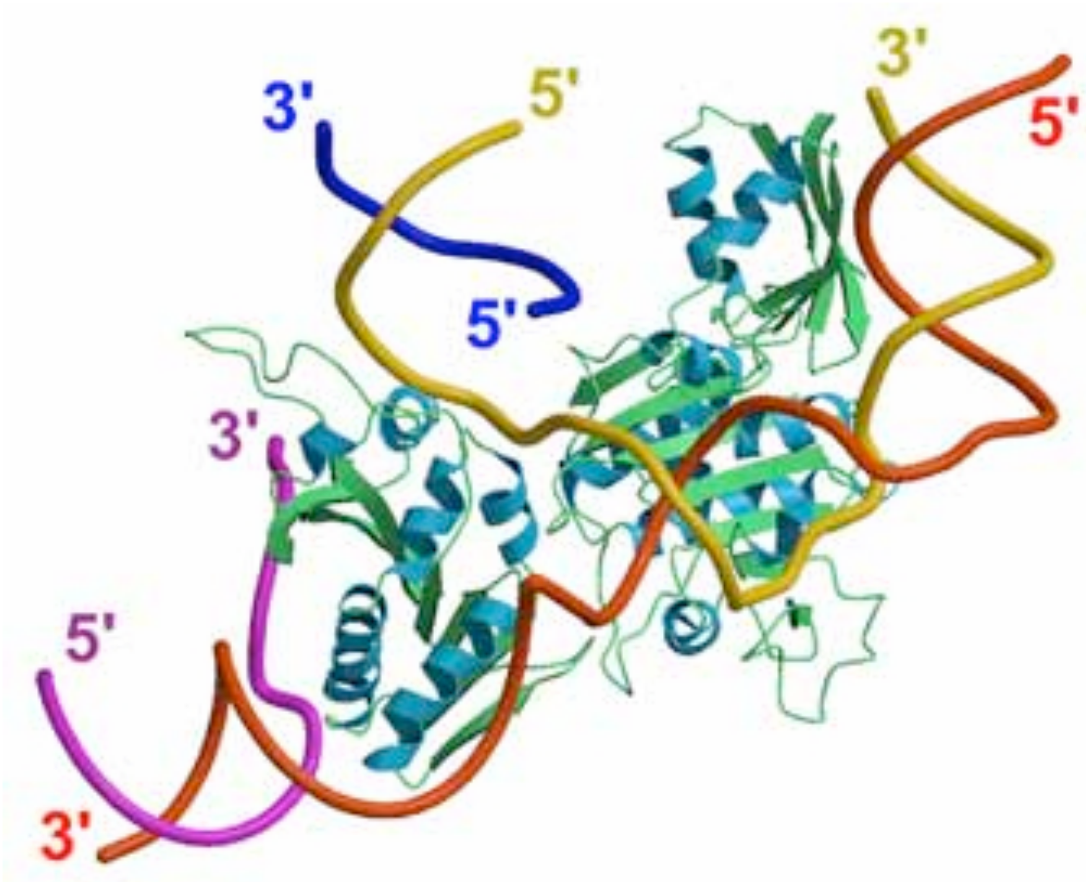


The pinwheel image was therefore built out of the signals from three telescopes, by heterodyne reduction, signal delay, interferometry, and false color: hardly an ordinary way to make an image.

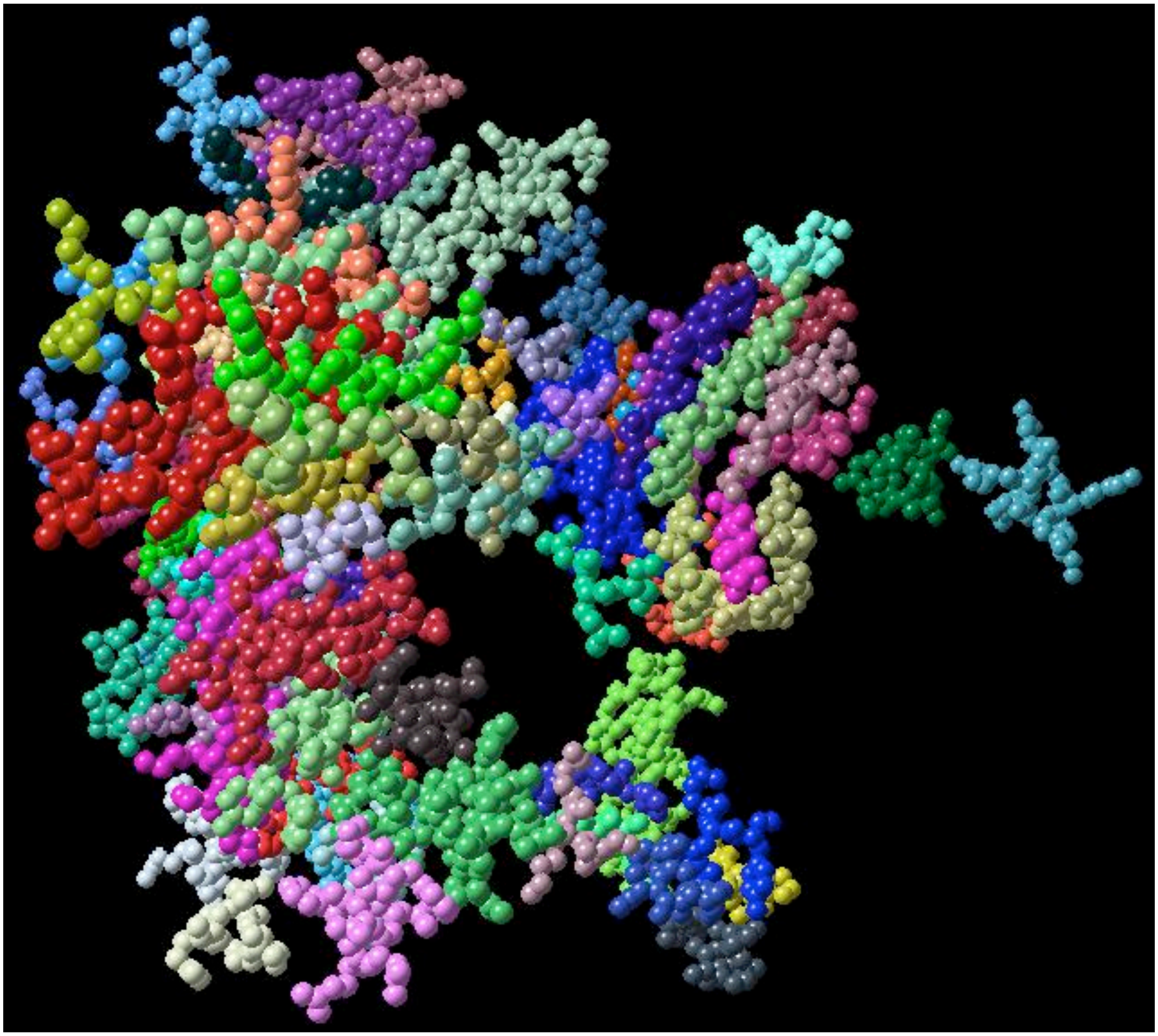
Interferometry of this kind, which generates 2-D images, is both counter-intuitive and complicated, and although I have tried I cannot understand it in full. The deceptively familiar-looking pinwheel is a Frankenstein creation, made of disparate parts. There is nothing quite so elaborate in this book, although the images of inscribed stones in Chapter 22 are roughly equivalent. They begin as "point clouds" (sets of 3-D data points recording the shapes of the stones) and end, after many layers of processing, as apparently naturalistic images that are actually composites of surface corrections, 3-D manipulations, lighting routines, false color, and texture mapping. They seem to raise the same issues of realism as the computer-generated monsters in Hollywood movies — except that the images of inscribed stones, and the film of WR104, began with observations of real objects.

Picturelike graphs, multidimensional images, and Frankenstein pictures are examples of things that aren't really pictures or films in the conventional senses of those words. The aerial photograph in Chapter 16 is only a conventional picture if its matrix is ignored: really, it's a sliver of something larger, like the portion of a multidimensional geometrical object that can be represented on a piece of paper. The Wolf-Rayet star, velocity graphs (Chapter 12) and speech sonograms (Chapter 8) are picture *mimics:* they work, in part, because the mimic pictures.

4. *The thicket of representation.* This is a phrase coined by the biologist and philosopher William Wimsatt to describe the problem of making pictures of genes.[36] There are a half-dozen different conventions for making pictures of complex organic molecules, and no one of them is adequate by itself. Each gives a particular kind of information, and works at a certain level of detail. Ribbon diagrams of molecules, for example, do not quite reach to the level of atoms (plate 22),



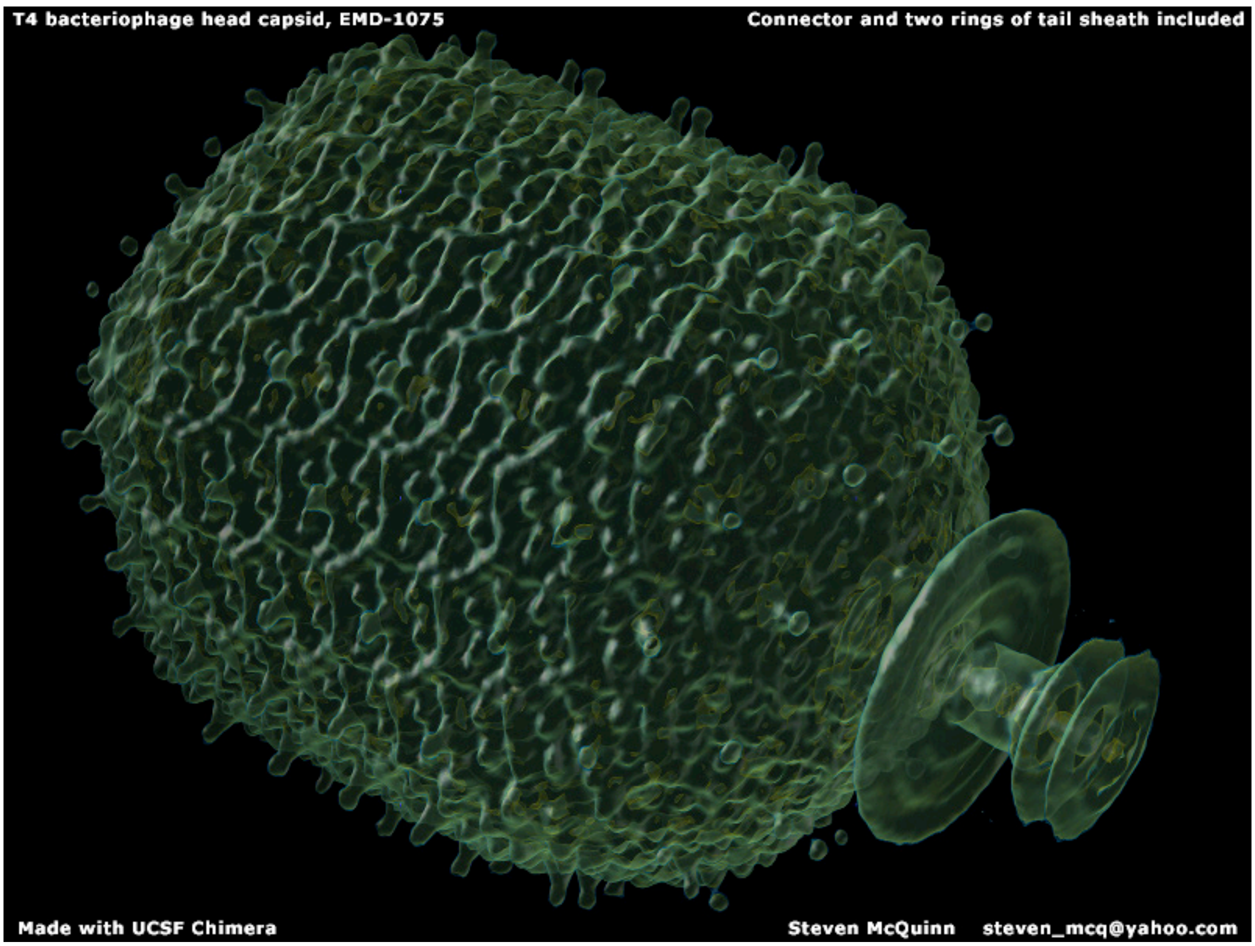
but ball-and-stick models do (plate 23).[37]



These two images cannot be combined into one image because they use different imaging conventions; it would be like trying to paste a picture of your house onto a map of your town. In scientific software these two conventional representations can be "toggled," but they can't be fused into one kind of picture.

This is another theme that is largely unknown in the humanities. A close parallel might be the existence of a painting and a drawing for the painting: the two can't be combined, but they have to be considered together in order to get the fullest idea of the artist's conception. The flaw in that parallel is that in most cases, the painting was intended to be the self-sufficient and authoritative version of the object; in science, all the kinds of representation in the thicket need to be considered together. The authoritative version of the object is not any one visual representation, but a conceptualization that involves a number of different kinds of images.

In this book, a good example is the visualization of bacteriophages in Chapter 27. The Chapter lists eight different ways of making pictures of bacteriophages. They vary tremendously, from ordinary close-up photography of Petri dishes to complicated graphics of individual atoms. More could be added to the list. I have mentioned Hybrid Medical Animation's dramatic movies (see plate 3). Another is Steven McQuinn's 3-D renderings of the head capsids of a bacteriophage; he uses translucent surfaces to make the subtlest structures visible (plate 24). (In Steven's case, the idea isn't to do science, but to tweak the scientists' assumptions about what subatomic objects might "look like." He intentionally uses translucent surfaces and ray tracing to make the viruses look like plastic bottles.[38])



There are also a few scanning electron microscope images of bacteriophages, and I could add life-cycle diagrams (a common feature of biology textbooks for at least fifty years), and even spectrographs.[39] On a rough count that is thirteen ways of looking at bacteriophages, although the number is arbitrary because most kinds subdivide into different types. A typical scientist might use a half-dozen in different combinations, toggling back and forth to compare them, and printing several side by side in scientific papers. The thicket cannot be cleared: it can only be negotiated.

In this book, you can explore the thicket of representation in most of the chapters. The exceptions are subjects where just one kind of image is optimal (Chapters 7, 17) or where images really aren't the point (Chapter 24). The arts, again, are the odd man out: Chapters 15 and 26 on fine art do not have competing images. Even archaeology, among the humanities, has a ferociously complicated repertoire of imaging types, many of which are used together to describe archaeological sites (Chapter 13). The thicket is the norm, and the isolated image of fine art is the rarity.

5. *Image quantification.* If there is a general, underlying expectation of images in the sciences it is that they contain what I call *propositional content.* It is expected that data can be extracted from them, that they contain measurable forms. A bar graph can be read immediately for its information, and so can the kind of supply-demand graph used in economics (Chapter 4). Other images have to be measured before information can be extracted from them; an example is astronomical images, which are read pixel by pixel to extract quantitative information. The analogue in the humanities would be images that are also writing, so they can be read as well as seen, as in Chapters 5 and 29. It is normal in the sciences to analyze an image in order to extract information, and anything that is left over is considered heuristic, decorative, "aesthetic," or "beautiful." A striking image can be a good thing, if it helps the image attract attention, but what matters is the content, stuff that can be used to calculate. It is more or less the opposite in the humanities, where propositional content in an artwork—themes, ideas—would normally be seen as an interesting part of the work, but by no means its central quality. The lack of interest in propositional content explains why art historians (I was one of them) were impatient with David Hockney's and Charles Falco's explanations of the perspective and geometry of paintings: it wasn't that Hockney was wrong, exactly, but that his observations were beside the point.[40] John Heartfield's political collages, studied in Chapter 26, are not valued because of what they say about Hitler — many other people during the Weimar Republic accused the Nazis of similar things — but because of their visual form. It is the extra, what is taken as the visual contribution, that matters in fine art.

It is interesting to study how scientists, lawyers, doctors, and engineers search for propositional content. Often the tool is image-analysis software, which can outline objects of specified shapes, sizes, or colors. The geologist Pat Meere uses software to find the outlines of grains embedded in rocks (Chapter 23). The biologist Emer Rogan uses software to find the outlines of the fins of whales and dolphins (Chapter 25), and Marc Shorten uses similar software to trace the outlines of the wings of ducks and other birds (Chapter 18). All three outlining routines are different. Image-analysis software is ubiquitous in this book. It can also color-code objects of interest, such as frequencies in sonograms (Chapter 10) or crops in a field (Chapter 16). It can count objects, and even produce equations for their shapes (Chapter 23). In the humanities, there really isn't such a thing: it is only the sciences and allied fields where the quantification of images is important. Image-analysis software is a big and largely unstudied field; the major software packages, such as Exbem, NIH Image, and ImageJ, are virtually unknown outside the sciences. (Photoshop, the image manipulation software of choice in the arts, has only very limited image analysis capabilities.) Scientific image analysis software packages are the equivalent of the exotic kinds of diggers that are used in large-scale strip mining: they are the most efficient way to strip away the "aesthetic" and get at the informational.

It is fascinating that some image-making practices outside the arts continue to resist quantification. An example is mammography, which despite all efforts to automate it continues to require expertise and, as a necessary correlate, to be considered less than wholly reliable. In the mid-twentieth century the same was true of the diagnosis of chest X-Rays for signs of tuberculosis. Having been tutored in how to read X-Rays, I can say that it is definitely an art (that is, a skill that cannot be wholly taught) to spot the small white smudges that are the first signs of tubercular infection. They are hard to see, and hard to distinguish from vessels seen end-on. Experts in chest X-Rays and mammograms tend to be people who have practiced for years.

In this book the preeminent example is the physician Nollaig Parfrey's discussion of kidney diseases (Chapter 21). Parfrey is an expert on membranous glomerulopathy, a condition that is not easy to diagnose. It requires a series of images made using different image technologies — it's an example of the thicket of representation. Each image needs to be analyzed for qualitative, rather than quantitative, signs. The relative abundance of some forms, or the relative thickness of capillary walls, are clues. Only a few of the signs Parfrey looks for are unambiguous forms that are either present or absent. Medical semiotics, I think, is the best example of a discipline that seeks to extract propositional content from images, but cannot always do so. Its images are qualitative, but they are studied for quantitative information.

Image quantification, and the search for propositional content, is terra incognita for the humanities. A visual studies scholar, looking at these examples, might be interested in the human interactions that result from Parfrey's analyses (some of which require biopsies), or in the reasons some scientists *want* to measure with such sweeping techniques and such obsessive precision. Visual studies might be good on the politics, the sociology, the psychology of image analysis: but it remains the case that image analysis itself is an enormous advance in the interpretation of images, made within the last twenty years, and it has been virtually ignored by scholars interested in the uses and meanings of the visual.

Those five themes—deciding how much of the world can be pictured, cataloging abuses of the visual, wondering what counts as a picture, exploring the thicket of representation, and learning about image quantification—structure this book. They do not make these chapters into a unity, because that would play false with the diversity of imaging practices, but they should be kept in mind as you read. Other themes—I'll mention a few more below—could easily be found; that's why it's a wonderful subject.

The Idea of a University-Wide Course

In 2006, I supervised a course called "Visual Practices Across the University," with guest lecturers from the exhibition. It was the first of its kind in Ireland and the UK, because it was open to all students, in all faculties of the university, and at all levels. It was intended to test the possibility that images might be a way of introducing students and faculty to the full range of disciplines in the university.

One issue we mulled over was how many kinds of image production, or image interpretation, there are. If there are as many kinds as there are departments, then studying visual practices across the university would just be studying as many examples as feasible in a given time. There would be no possibility of ever getting a sense of the whole, and possibly no way to achieve a satisfactory articulation of themes like the five I have just enumerated. But as we worked through the material, the ways of making images and the ways of interpreting them started to fall into groups.

The first, and perhaps most apparent, distinction is between disciplines whose image-making practices are technical and those that appear not to be. Nominally, all departments in a university practice and represent a *discipline,* with all that word implies. Given that disciplinarity has its own ideology, and that it often privileges technical knowledge that cannot easily be gained by other disciplines, it is to be expected that most of the examples in this book, and in the class, required preparatory study. But not all of them. Bernadette Sweeney's practice of documenting performance art and theater is non-technical in the sense that the problems it raises can be set out fairly quickly. In Chapter 2, Sweeney outlines the problematics of documenting transitory art forms like theater, and she briefly mentions the literature in which critics have said that "time arts" (such as film and performance) require a new sense of documentation, and a new kind of art criticism. That literature is large, and so is the literature on the technical, philosophic, and political aspects of documentation. But Sweeney's practice can be shown relatively easily, and it does not present itself as technical. The questions it raises (Is this an adequate document of the performance? Is it biased in some way?) can be pondered by any viewer.

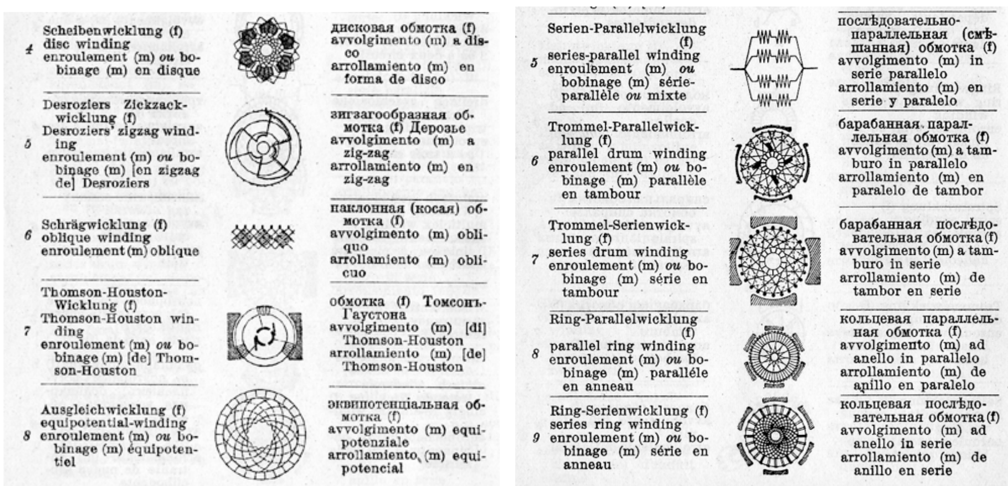
Likewise the contributions by the Departments of Occupational Therapy (Chapter 9) and Applied Social Studies (Chapter 20) have no technical language. The former is an exercise to help children become socialized by making art; and the latter is a workshop on social identity, in which participants make and wear masks of themselves. In both cases a technical exposition would be inappropriate because the purpose of the work is to create new social bonds among people who are not members of any particular discipline. The same observation could be made of Chapter 7, in which a lawyer reports on the use of a "virtual-reality" system to help witnesses recall what happened during an event in which a number of people were killed. Anything technical in the system would have put off the witnesses, and it would not have been helpful to the tribunal, which was trying to find the maximum amount of information about the event.

Two chapters display the non-technical side of science. In Chapter 3, the geologist Bettie Higgs shows what can be deduced by just looking at weathered sandstone rocks found on a seashore. Higgs brought rocks into the class and had people lift them — some were fairly heavy — and consider their properties and their age without prior information and without magnifying lenses. She considers that kind of preliminary inspection an integral part of geology. She calls it "artistic" as opposed to "scientific," but I would prefer to say simply "non-technical" and "technical," because the "scientific" examination requires technical knowledge. (She also brought a polarizing microscope into class, so students could see birefringence phenomena; but analyzing those phenomena requires technical knowledge.) Chapter 11 is probably the oddest thing in this book: it is a discussion of the colors of porcelain teeth by two experts in restorative dentistry. It was a popular display in the exhibition, because visitors were invited to learn the system and then look in a mirror and classify their own teeth. (Those of us who gave tours to the public suggested that people learn the color nomenclature of their own teeth, and then surprise their dentists by asking for specific colors.) There is real color science in Chapter 11, because it turns out that teeth come in all the hues of the rainbow, but the colors are reduced to subtle shades of off-white, so they are extremely difficult to spot. But even the color science is not technical, and the end purpose is an "aesthetic" match, meaning in this case a feeling, on the part of the patient, that the porcelain tooth matches perfectly.

So a first look at visual practices suggests they might divide between those that depend on technical information known only in certain disciplines and those that employ non-technical or non-disciplinary words to describe images. I have not pursued that distinction, for two reasons. Most apparently, it depends on dubious senses of what is technical: people in the humanities say the sciences are technical, but the same can be said about some of the humanities because it isn't clear what counts as technical language. More importantly, the distinction has to make use of an ideology of disciplines according to which the sciences and medicine are safely walled enclaves of the obscure.

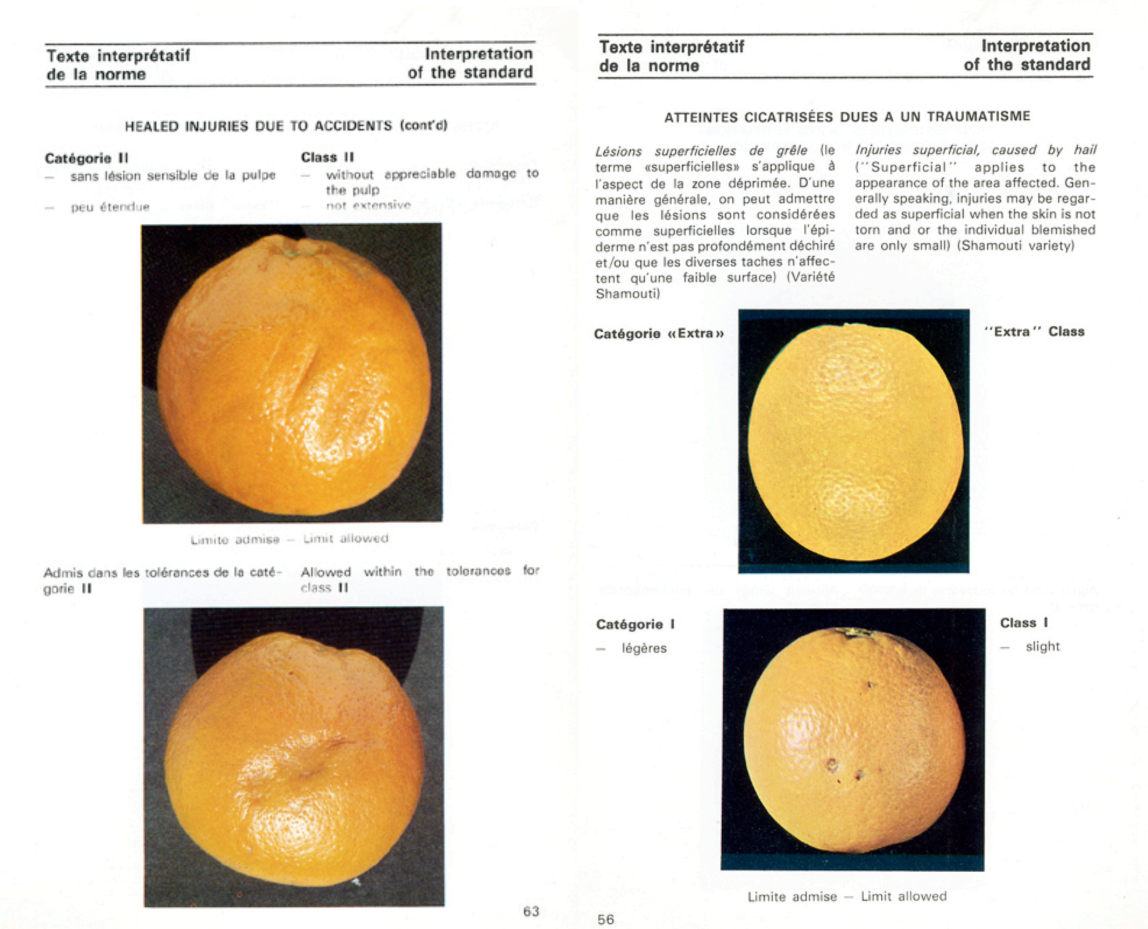
More promising groupings began to appear as soon as the planning for the exhibition was underway. Optical microscopy, for example, formed a group across several disciplines, including polarized-light microscopy (in geology), fluorescence (in biology and medicine), phase contrast, and interference contrast (in biology). They comprise a kind of group, in the sense that a person who knows one can pick up the others.

My electrical engineering encyclopedia has many examples of images, and kinds of images, that fall into such groups. About ten pages, for example, are devoted to the ways wire is wrapped in coils to make motors (plate 25).



I have no doubt that if I applied myself, I would soon be able to tell the difference between "parallel-drum winding" and "series drum winding," and if I worked at it, I would eventually be able to name all fifty or so windings.

The motor windings portion of the electrical encyclopedia is like a little treatise, separate from the other 2,050 pages of the book. I want to draw some parallels between circumscribed subjects like these and the visual practices in this book, but first let me add a few examples. First is a lovely little book I found called *Argumes / Citrus Fruit,* published by an international committee for the standardization of citrus (plates 26, 27).[41]


Texte interprétatif de la norme — Interpretation of the standard

HEALED INJURIES DUE TO ACCIDENTS (cont'd)

Catégorie II
- sans lésion sensible de la pulpe
- peu étendue

Class II
- without appreciable damage to the pulp
- not extensive

Limite admise — Limit allowed

Admis dans les tolérances de la catégorie II

Allowed within the tolerances for class II

63

Texte interprétatif de la norme — Interpretation of the standard

ATTEINTES CICATRISÉES DUES A UN TRAUMATISME

Lésions superficielles de grêle (le terme «superficielles» s'applique à l'aspect de la zone déprimée. D'une manière générale, on peut admettre que les lésions sont considérées comme superficielles lorsque l'épiderme n'est pas profondément déchiré et/ou que les diverses taches n'affectent qu'une faible surface) (Variété Shamouti)

Injuries superficial, caused by hail ("Superficial" applies to the appearance of the area affected. Generally speaking, injuries may be regarded as superficial when the skin is not torn and or the individual blemished are only small) (Shamouti variety)

Catégorie «Extra» — **"Extra" Class**

Catégorie I
- légères

Class I
- slight

Limite admise — Limit allowed

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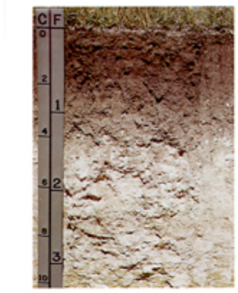
The pamphlet offers just a few criteria to help wholesale grocers and farmers distinguish between Second Class, First Class, and "Extra" Class lemons and oranges. The pamphlet does not go into the hundreds of varieties of citrus, and the technical nomenclature is minimal. The conceptual difficulty here is distinguishing what is meant by "light" damage as opposed to "heavy," or what is "superficial" as opposed to "deep." The number of terms is minimal, but they are slippery.

Andrew Aandahl's *Soils of the Great Plains* (1982) is an atlas of about a hundred soil types in central North America (plates 28, 29).[42]



Native vegetation and tame broomgrass pastures on undulating slopes. Native grasses include big bluestem, little bluestem, sideoats grama, switchgrass, and blue grama. Few level slopes of Campus soils are used to grow winter wheat. Note the liminess in the road ditch.

CAMPUS SOILS

A1 0–20 cm (0–8 in.). Dark grayish brown loam, moderate fine and medium granules; friable; calcareous.

B2 20–40 cm (8–16 in.). Grayish brown loam; moderate medium granules; friable; numerous small limy concretions; strongly calcareous.

C1ca 40–90 cm (16–35 in.). White loam; massive; about 25 percent hard caliche plus an additional 15 percent soft limy masses; strongly calcareous; wavy boundary.

C2 90–125 cm (35–49 in.). Light yellowish brown and gray loam; massive; few vertical and horizontal white streaks of lime.

Geography: West-central Kansas.

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Soil Family Classification
Fine-loamy, mixed, mesic Typic Calciustolls

Sorghum and winter wheat on level Harney soils. Large grain elevator in the background. These are common in the Great Plains and usually one is in sight wherever there is considerable acreage of cropland. A few tracts of these soils have native vegetation consisting of little bluestem, sideoats grama, buffalograss, and blue grama.

HARNEY SOILS

A1 0–25 cm (0–10 in.). Dark grayish brown silt loam; moderate medium granules; firm; neutral.

B21t 25–45 cm (10–18 in.). Grayish brown silty clay; strong medium and coarse blocks; firm; mildly alkaline.

B22t 45–60 cm (18–24 in.). Pale brown silty clay; strong, medium and coarse blocks; very firm, moderately alkaline.

B31ca 60–112 cm (24–44 in.). Light yellowish brown silty clay loam; moderate coarse blocks; firm; few small masses of soft lime and limy coatings on peds, calcareous.

IIB32b 112–155 cm (44–61 in.). Brown silty clay loam; weak coarse subangular blocks; firm; few small limy masses; calcareous. (This horizon is part of a buried soil formed in an older loess with a reddish tint. Buried soils are common below Harney soils, but they are not always present.)

Geography: West-central Kansas.

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Soil Family Classification

Each page has a sunny photo of a landscape, and a photograph of a cut-away section of the soil, and a technical analysis of the soil layers. The right-hand portion of each cut-away section has been smoothed with the back of the shovel, so it reflects light differently. The purpose of the atlas is to enable farmers to identify their soil types, ideally without having to cut cross-sections. If I were to study this book while I drove around the Midwest in the United States, I would eventually be able to make a guess about soil types without needing to do any digging. There is a technical vocabulary to be learned here, and a list of a hundred soil types to be memorized, but if this were the subject of a class, it could be done in, say, a few weeks. *A Classification of North American Biotic Communities* (1998) is different because the criteria for identifying each biotic community is much less well defined (plates 30-33).[43]

Plate 108. Arctic-Boreal Marshland (241.). A tiny sedge-populated *cienéga* of Rocky Mountain Subalpine Marshland located at 2740 m (9000 ft) atop the Pinaleño Mountains, Graham County, Arizona. Photo by D. E. Brown.

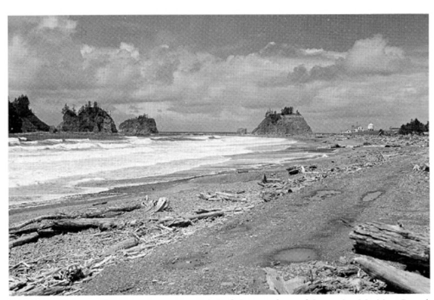

Plate 112. Cold Temperate Strand (252.). A U.S. Park Service photo of Oregonian Maritime Strand taken in February 1961 by Louis G. Kirk at Rialto Beach, Olympic National Park, Washington.

Plate 109. Cold Temperate Marshland (242.). A Great Basin Marshland located at Ruby Lake, Elko County, Nevada. The principal marsh emergents are roundstem bulrush (*Scirpus acutus*) and cattail (*Typha latifolia*). Photo by D. E. Brown.

Plate 92. Central American Thornscrub (134.6) near Comayagua, Honduras. The shrubbery is punctuated by a columnar cactus, a cholla, and an arboreal prickly-pear, as well as numerous small trees. Photo by D. E. Brown.

Each caption names only a few plants that are typical of the community: for "Central American Thornscrub," for example, we are told only that "the shrubbery is punctuated by a columnar cactus, a cholla, and an arboreal prickly-pear, as well as numerous small trees." Elsewhere in the book the listings are expanded, but there are no definitive or comprehensive enumerations of the plants that are typical of each biotic community. Such a listing would be open-ended, because biotic communities overlap, and it would be too long to put in a book. So to identify the biotic communities, a reader needs to note where the community is (the book is accompanied by a map), and then get a "feel" for it. My response to this book varies depending on whether or not I am already familiar with the kind of landscape in the photo. I know "Arctic Boreal Marshland," and I recognize the feel or the look of the place. If I have ever walked through "Central American Thornscrub," I am unaware of it, and it seems only faintly familiar, as any arid hillscape might be. This is a more difficult subject than the Midwest soils, which are in turn more difficult than the citrus guide, and all three are harder than the listings of motor windings.

I am suggesting that these are subjects that are similar in complexity to the image-making practices in this book. I think it helps to imagine these four books, and the individual Chapters of this book, as if they were languages, either in Wittgenstein's sense of toy languages (imaginary languages with just a few words) or in the ordinary sense. I do not mean anything especially profound by this. In particular I am not implying anything about underlying structures, as in Chomsky or Jerry Fodor. Nor do I mean to suggest that these languages have some relation to differing epistemologies of the world, as in Benjamin Whorf's work, or even to different kinds of intelligence, as Howard Gardner has argued. And I am not saying these are languages in a philosophic sense, in Nelson Goodman's or Quine's sense.

I mean something more prosaic and practical: like languages, these subjects can be learned to a reasonable degree of proficiency in a reasonable amount of time. The time required is keyed to the structure of university disciplines, so that it takes a year or two, sometimes three, to become adequately proficient at most of the visual practices in this book. That time scale allows students to shift subjects, and add areas of expertise, within the frame provided by the university. (Of the four books I have mentioned, only the last two are difficult: I imagine learning motor windings and grades of citrus would take only a semester.)

The university scale of the time it takes to learn the visual practices in this book is the first analogy with languages. The other is that the visual practices in this book occur in groups, as I suggested in the case of light microscopy. Like languages, they come in families. For a person who understands phase contrast microscopy, interference contrast microscopy will already be partly intelligible. A person who knows interference contrast microscopy will know some of the fundamentals of polarized light microscopy. The same affinities occur in natural languages. A person who knows Danish will be able to understand Norwegian and parts of Swedish, but such a person will not be able to follow spoken Finnish or Estonian, because they belong to different language families. In the university, the language families of visual practices cluster in related departments.

Provisionally, then, the language families of the *construction* of images include the following: (a) optical microscopy, comprising about five languages; (b) image analysis software (NIH Image, ImageJ, Exbem, Photoshop); (c) digital video editing; (d) mapmaking and surveying in archaeology and civil engineering; (e) electron microscopy, including transmission, scanning, and atomic force microscopy, all of them represented in this book. There are perhaps a dozen others: my claim would be that the number of "language families" is not the same as the number of disciplines or departments in a university, but is a significantly smaller number. That is crucial to this project, because it means that visual practices can be studied across the entire university. If there is a preeminent language family of image construction, analogous to Indo-European among natural languages in Europe, it is not fine art but scientific and technical image manipulation: another reason to say the humanities are in the minority when it comes to images.

These "languages" can also be enumerated from the side of image *interpretation*, in which case I might list: (a) X-Rays and mammograms, (b) histology, (c) cognitive psychology and the neurobiology of vision, and (d) the history of art, which has about a dozen named languages in this sense including psychoanalytic art criticism, deconstruction, semiotics, and feminisms. Again there would be about a dozen more, all told. There is an often implicit claim among visual studies scholars that image interpretation is theorized mainly in the humanities, but if there is a preeminent language family here it would be medical semiotics. The kinds of interpretations of histological material given in Chapter 21 represent an enormous set of practices with a long history, stretching back to ancient divination using animal organs. By contrast the humanities own only a small number of ways of interpreting images.

(This enumeration of language families, both in image construction and interpretation, may be compared to the much larger sample in the book *Bild und Erkenntnis,* edited by Andreas Beyer and Markus Lohoff.[44] Their book surveys many more technologies, and groups them according to an eclectic glossary of "visualization techniques" such as "Modell," "Notationssystem," "Objektklassendiagramm," "Phasendiagramm," "Piktogramm," "Prototyp," and "Radardiagramm." I find their book interesting as a resource, but I am more optimistic about organizing the material into a smaller number of conceptual units.)

In outline this is how I would defend the idea that visual practices can be studied all together, and that they can be learned to a workable degree of detail in, say, a year-long course. Such a course would have several advantages over existing introductions to the visual world. It would be *specific,* and need not rely on general observations about image production and dissemination. Existing introductory classes on visual studies or visual appreciation stay mainly within the fine arts, because the sciences, medicine, law, engineering, and other fields are out of reach unless students are introduced to their actual, day-to-day discourses, in detail and without undue generalization. (Students would have to learn some mathematics and physics, for example, in order to understand the images of carbon nanotubes I mentioned. That is impractical but not at all impossible, providing the instructors are available.) I think the existing first-year classes on visuality and visual culture are more rewarding for students who go on to study in the humanities than they are for students who study the sciences, because the level of detail of the art examples is so much higher than the detail accorded to the few non-art examples. A student majoring in chemistry, for example, will probably not think back on her first-year visual studies class when she is busy with molecular imaging: but she would if she had the experience of encountering molecular imaging in her first year in college, in the context of imaging done in other fields.

A second advantage of a year-long course on visual practices is that it does some justice to the commonplace that ours is a visual culture, where learning is increasingly done through images. There is a large literature arguing that visuality is the preeminent medium of our experience of the world, but universities continue to pursue text-based and mathematics-based education. This class would put visuality on the table in the first year of college as a subject and a central vehicle for understanding the world.

A final reason I am interested in using materials like the ones in this book for a university-wide course is that it could provide the beginnings — the first impetus — for university-wide conversations. The visual can be an informal *lingua franca* for the university, allowing people who would not normally stray outside of, say, inorganic chemistry, to consider starting conversations with people in, say, Asian studies.

Despite the interest in interdisciplinarity, universities are not usually unified in more than name. Students begin to specialize in their first few years, and by the time they are ready to begin graduate study they are already focused on just a portion of one subject in one Department. In the Irish and UK systems, it is normal for students reading medicine to have no arts courses at all, and vice versa. Many initiatives are being developed to prevent that, but it is inevitable given the degree requirements of different fields. The Law Faculty might as well be in a different city from the Agriculture Faculty or the Engineering Faculty. In the US it is said that "distribution requirements" and "core requirements" compel students to take classes outside their major fields, and that is true, but the number of courses is small, and the selection is narrow. In a typical case a student in Arts may have to take one science course and one social science course. In that mix Dentistry, Medicine, Food Processing, Pharmacology, Business, and any number of other subjects are omitted. The university is still unified in name only.

I do not think that this book could be a panacea for the fragmented life of the contemporary university. Even if it were two hundred chapters long, accommodating every department and named subspecialty in a large university, it would still only be a provisional cross-section, a sampler like my 2,100-page encyclopedia of electrical engineering. But I am convinced that this is a way to discover whether the university is a single thing, or just a collection of buildings in which people speak mutually unintelligible languages.

The literature on the unity of the university is itself based in the humanities, and biased toward them. (It is also a very non-visual literature: not a single book I have seen is illustrated.) Like Cardinal Henry Newman's *Idea of a University* (1852), Jaroslav Pelikan's book of the same name (1992) has next to nothing to say about the sciences. Henry Hutchins, one of the principal theorists of the University of Chicago, argued in *The University of Utopia* (1964) that nothing should be taught in the university except philosophy. Other books, from Clark Kerr's *Uses of the University* (1963) and Kenneth Minogue's *Concept of a University* (1973) to Bill Readings's *University in Ruins* (1996) and Jacques Derrida's essays collected in *Eyes of the University* (2004), are similar in their emphasis on philosophic "rights" and philosophic analysis. Ultimately they all owe that emphasis to Kant, whose theorization stressed the importance of the Faculty of Philosophy over the "vocational" Faculties of Law, Medicine, and Theology. The fairly enormous literature on the idea of the university is strongly biased to the humanities, and exclusively non-visual. I'd like to think this book is a small step toward a different theorization.

I would also like to distinguish this book from certain parts of the current interest in interdisciplinarity. Traditionally, the idea of interdisciplinarity is traced to Wilhelm von Humboldt, whose ideal of the university has gone through many transformations. An excellent book by R. D. Anderson, *European Universities from the Enlightenment to 1914* (2004), distinguishes Humboldt's ideas from the notion of them held in the nineteenth century, and the different notions attributed to him in the twentieth century.[45] In the nineteenth century it was still remembered that the purpose of studying all subjects together was to reveal *Wissenschaft,* properly signifying the unity of all knowledge. That Romantic ideal, which I suspect few people believe today, was the original rationale for what is now known as interdisciplinarity. By the twentieth century, the Humboldtian ideal was held to be the research university, which was conflated with the Romantic idea of interdisciplinary work. Many university systems in the United States are said to be derived from the German university system, meaning the Berlin University and specifically Humboldt, even though we have long forgotten the Romantic ideal of unified knowledge and we have misinterpreted Humboldt's interest in research (which was always tied to teaching).

Today, with the Humboldtian heritage forgotten, there seem to be several other reasons for promoting interdisciplinarity. In Europe, interdisciplinary initiatives are sometimes said to be done in emulation of the US. Interdisciplinarity is also said to enable universities to be more economically efficient. A university financial officer in Ireland once told me that interdisciplinarity in the European Union is modeled on the success of "big science" such as the Manhattan Project and CERN. Interdisciplinarity has been a byword in the humanities since the spread of poststructuralism, although it is not clear to me whether the humanities' sense of interdisciplinarity has influenced the current worldwide interest in interdisciplinarity, or has just happened to coincide with it. It is interesting that those three explanations for interdisciplinarity—emulation of the US, efficiency modeled on big science, and the influence of poststructuralism—are different and even mutually contradictory.

My own interest in exploring interdisciplinarity came partly from talk about interdisciplinarity in the humanities. Visual studies claims itself to be interdisciplinary in a new and interesting fashion, creating a new form of knowledge that is more than the simple juxtaposition of its component disciplines. It is still hard to tell whether or not that is happening, but it is likely that visual studies is an amalgam of disciplines and that each one is retaining much of its original nature.[46] There is at any rate no evidence of a radical, self-transforming interdisciplinarity in the Chapters of this book. The Chapter with the largest number of specialties involved is Chapter 22, on the laser scanning of inscribed stones. It involves a physicist, a computer scientist, and people with expertise in epigraphy, church history, Latin, Irish, literary theory, and education. But it is collaborative rather than transformative: each person contributes expertise to a project whose ultimate purpose is the preservation of cultural heritage. I suspect that the epistemologically challenging interdisciplinarity (or "transdisciplinarity" or "subdisciplinarity") sought in visual studies is not something that most interdisciplinary ventures outside the humanities would seek even if they knew about it.

I do not know what sense of interdisciplinarity is enacted by this book. Given that theorizations of the university are still done from within the humanities, that the original impetus for interdisciplinarity has long been forgotten, that the reasons now given for it are so diverse and mutually contradictory, and that the utopian transformative interdisciplinarity envisaged by visual studies may not exist — given all that, it is probably best to avoid the subject for the time being. For the duration of this book, at least, let us just listen to how images are talked about in their own disciplines, and contemplate the possibility that they might coalesce just enough to make a constellation, as Mallarmé says in *Un Coup de dés* — something new, that may have a meaning we can only just glimpse. I think what is lost by spending some time with these occasionally arcane, particulate practices is more than repaid by the sheer expanse of the view outside the confines of fine art and visual studies. And in any case what reasons do we have, aside the many habits of art, to keep our distance from so much of the visual world?

Notes

[1] The main set of papers in the conference, with contributions by W.J.T. Mitchell, Barbara Stafford, Jonathan Crary, and others, will appear as *Visual Literacy,* edited by James Elkins (New York: Routledge, 2007); a second set of papers on the subject of the histories of individual nations and their attitudes to visuality and literacy, will be forthcoming as *Visual Cultures.*

[2] eb.mit.edu/i-m/intro.htm. My review of the 2001 conference is “Who Owns Images: Science or Art?” *Circa* 97 (2001): 36-37, online at recirca.com/backissues/c97/elkins.shtml.

[3] web.mit.edu/felicef/.

[4] In this context I am only giving the outline of the argument: an example is discussed in detail in my *Domain of Images* (Ithaca NY: Cornell University Press, 1999).

[5] Hester, quoted in Frankel, “Sightings,” *American Scientist* (September-October 2004): 463.

[6] Try www.thomaskinkade.com; there are many other sites and stores.

[7] Smock, “Picture This!” in *California Monthly* (March/April 2005), pp. 16-27.

[8] www.dna11.com, accessed March 2006. I thank Curtis Bohlen for drawing my attention to this.

[9] Thomas Rossing and Christopher Chiaverina, *Light Science: Physics and the Visual Arts* (New York: Springer, 1999). See the review by Henry Stroke in *Physics Today* (May 2001): 60; Stroke notes the asymmetry of the book, which concentrates on the influence of science on art, and notes that artists sometimes influence science. His example is Leopold Godowsky, Jr., and Leopold Mannes, who invented the Kodachrome process; but Stroke observes they both also had physics degrees.

[10] His website glosses his book by claiming that “despite what appear to be irreconcilable differences, there is one fundamental feature that solidly connects… evolutionary art and visionary physics. [They] are both investigations into the nature of reality. Roy Lichtenstein, the pop artist of the 1960s, declared, ‘Organized perception is what art is all about.’ Sir Isaac Newton might have said as much for physics.” It would be extremely difficult to find another artist who says that, and just as hard to define what it might mean. What art is made from “disorganized perception”? And what is “evolutionary art” anyway? Shlain, at www.artandphysics.com.

[11] Gilardoni, *X-Rays in Art: Physics, Technique, Applications* (Mandello Lario, Italy: Gilardoni, 1977); Latham, *Art After Physics,* exhibition catalog, Museum of Modern Art, Oxford, 1991 (Oxford: The Museum, 1991); Shlain, *Art and Physics: Parallel Visions in Space, Time, and Light* (New York: Morrow, 1991).

[12] The most promising project along these lines is John Onians’s research at the World Art Studies Centre at the University of East Anglia, which is a patient and systematic search for things that particular branches of science—especially neurology—can say about art.

[13] Notably David Stork and Charles Falco. My responses are a review of David Hockney, *Secret Knowledge* (New York: Viking, 2001), on the College Art Association review site at www.caareviews.org/hockney.html, and a review of the NYU conference in *Circa* 99 (spring 2002): 38-39; online at recirca.com/backissues/c99/elkins.shtml. The paper I delivered at the conference is at webexhibits.org/hockneyoptics/post/elkins.html. I have also rehearsed these argument in "Aesthetics and the Two Cultures: Why Art and Science Should be Allowed to Go Their Separate Ways," in *Rediscovering Aesthetics,* edited by Tony O'Connor, Frances Halsall, and Julia Jansen (New York: Columbia University Press, forthcoming).

[14] Winner, "Art History Can Trade Insights With the Sciences," *Chronicle Review* (*Chronicle of Higher Education)* 50 no. 43 (July 2, 2004): B10, accessed online at chronicle.com, November 2004.

[15] webexhibits.org/hockneyoptics.

[16] I am not criticizing all technologically-oriented art; my main target is the perception of the mainstream art world. For a full argument see my "Preface" to Eduardo Kac, *Telepresence and Bio Art: Networking Humans, Rabbits, and Robots* (Ann Arbor MI: University of Michigan Press, 2005).

[17] This point is elaborated in my review of Martin Kemp, *The Science of Art* (Yale, 1990), *Zeitschrift für Kunstgeschichte* 54 no. 4 (1991): 597-601, and later in *The Domain of Images*.

[18] *The Domain of Images* (Ithaca NY: Cornell University Press, 1999).

[19] *How to Use Your Eyes* (New York: Routledge, 2000).

[20] The argument I am alluding to here is given in my *Visual Studies: A Skeptical Introduction* (New York: Routledge, 2003).

[21] One more project needs to be added to this sequence. From 1998 to 2002 I worked a book called *Six Stories from the End of Representation,* which will appear roughly at the same time as this book. It considers six fields, two in the arts and four in the sciences, and studies them in six separate chapters. (*Six Stories from the End of Representation: Painting, Photography, Astrophysics, Microscopy, Particle Physics, Quantum Physics* [Stanford: Stanford University Press, forthcoming]. I make no connections at all between the six fields, and I do not present any over-arching theme. The idea is to let each discipline speak in its own words, in full technical detail, and not to popularize anything. *Six Stories From the End of Representation* is a kind of reductio ad absurdum of this book: it goes at great length into just six fields, instead of sampling thirty fields, and it declines all opportunities to make connections, whereas here I entertain whatever possibilities present themselves. *Six Stories* is intended to display the weaknesses of popularizing and abbreviating, and to pay whatever cost may be entailed in terms of readability.

[22] *Die Elektrotchnik,* vol. 2 of *Schlomann-Oldenburg Illustrierte Technische Wörterbücher,* edited by Alfred Schlomann (Munich and Berlin: R. Oldenburg, n.d.).

[23] See the demonstration of different parameters by James Holton, at ucxray.berkeley.edu/~jamesh/.

[24] Two examples: Kay Hamacher's animation of protein-ligand docking at www.kay-hamacher.de (which is very suggestive, and would have delighted the Surrealists), and the high-speed snakelike folding of a 64-residue protein done by the Process Systems Engineering team at the University of California at Davis, www.chms.ucdavis.edu/research/web/pse/research_areas/protein_folding_dynamics/protein_dynamics.php.

[25] Eric Sorin et al., "Does Native State Topology Determine the RNA Folding Mechanism"? *Journal of Molecular Biology* 337 (2004), with online supplement, including a very complex animation, at folding.stanford.edu/tRNA/.

[26] See the IBM research page "Imaging Atoms at Sub-Angstrom Resolution with a Corrected Electron Microscope," at domino.research.ibm.com/Comm/bios.nsf/pages/sub-a.html, accessed February 2006. "[W]hen two of them approach, they feel an attractive force. As they approach closer, this attractive force turns into a repulsive force. This can be seen in real time: summarized by the frames labeled by time. In this case, two atoms approach, circling one another (indicated by the arrows). Then one of the atoms moves rapidly away to a spot about 0.5 nanometers distance away. Finally the other atom follows."

[27] Jan-Olov "Bob" Bovin: bob.materialkemi.lth.se/. I discuss these images at length in my *Six Stories from the End of Representation,* forthcoming.

[28] See especially the films of oxidation on the surface of a Platinum-group metal by Bastiaan Lambertus Martinus Hendriksen at www.physics.leidenuniv.nl/sections/cm/ip, which reports on Hendricksen, "Model Catalysts in Action: High-Pressure Scanning Tunneling Microscopy," PhD thesis, University of Leiden, 2003.

[29] Electrophoretograms are discussed in my *Domain of Images,* chapter 3, in reference to a study by Karin Knorr–Cetina and Klaus Amann, "Image Dissection in Natural Scientific Inquiry," *Science, Technology, and Human Values* 15 no. 3 (1990): 259–83.

[30] Dirac: "one can tinker with one's physical or philosophical ideas to adapt them to fit the mathematics," he said, "but the mathematics cannot be tinkered with. It is subject to completely rigid rules and is harshly restricted by strict logic." Dirac, "The Mathematical Foundations of Quantum Theory," in *Mathematical Foundations of Quantum Theory,* edited by A. R. Marlow (New York: Academic Press, 1978), 2.

[31] "On Some Useless Images [in Physics]," *Visual Resources* 17 (2001): 147-63; I will discuss the subject at length in *Six Stories From the End of Representation,* forthcoming.

[32] See for example www.rpi.edu/~huangh/workshoppdf/03LectureByDonaldBrenner.pdf.

[33] Nanostructures laboratory, KFKI MFA Budapest;
see www.mfa.kfki.hu/int/nano/online/kirchberg2001/.

[34] Farid Abraham of IBM Almaden Research, in collaboration with LLNL personnel Mark Duchaineau and Tomas Diaz De La Rubia; www.llnl.gov/largevis/atoms/ductile-failure/.

[35] The following is from isi.ssl.berkeley.edu/system_overview.htm#optics.

[36] This is discussed in my *Domain of Images,* together with further references.

[37] For the ribbon diagram see www.stjude.org/structural-biology/0,2540,432_2059_11435,00.html; for the ball-and-stick model, see www.ticam.utexas.edu/CCV/gallery/molecular-images/.

[38] McQuinn informs me that his ironies have been somewhat lost on scientists. Part of the problem is that the optimism about visualization is ubiquitous, and working scientists adopt rendering routines developed for Hollywood and for design. See for example the field ion microscope image of atoms in a tungsten needle, rendered as if the atoms were raspberries covered in syrup: www.aip.org/png/2006/264.htm.

[39] For spectroscopy of bacteriophages see nmrresource.ucsd.edu/posters/thiriot02.html.

[40] Hockney, *Secret Knowledge.* In addition to the essays I mention above (loc. cit.), there is a longer discussion in my *Visual Studies.*

[41] *Agrumes / Citrus Fruit,* in the series *Normalisation internationale des fruits et légumes / International Standardization of Fruit and Vegetables* (Paris: Organisation de Coopération et de Développement Économiques, 1980).

[42] Andrew Aandahl, *Soils of the Great Plains* (Lincoln NE: University of Nebraska Press, 1982).

[43] David Brown et al., A Classification of North American Biotic Communities (Salt Lake City: University of Utah Press, 1998).

[44] *Bild und Erkenntnis: Formen und Funktionen des Bildes in Wissenschaft und Technik,* edited by Beyer and Lohoff (Munich: Deutscher Kunstverlag, 2006); the glossary is on pp. 467-538.

[45] R. D. Anderson, *European Universities from the Enlightenment to 1914* (Oxford: Oxford University Press, 2004).

[46] This is discussed at length in my *Visual Studies.*