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 disci-

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plines, 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

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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.

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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 (see the samples on the next page).[41]

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 (illustrations on the second and third page following).[42]

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

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Texte interprétatif de la norme | **Interpretation of the standard**

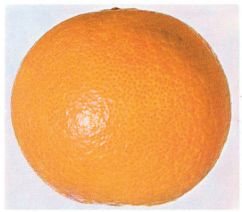
ATTEINTES CICATRISÉES DUES A UN TRAUMATISME (suite)

Meurtrissures (Dommages causés par choc ou pression sans rupture de l'épiderme)(Variété Navel)

Bruises (Damage caused by shock or pressure without the skin being broken) (Navel variety)

Catégorie «Extra»

"Extra" Class

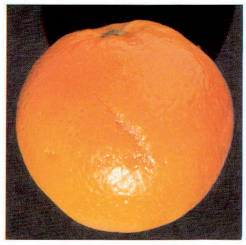


Catégorie I

— légère
— superficielle
— non étendue

Class I

— slight
— superficial
— not extensive



Limite admise — Limit allowed

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

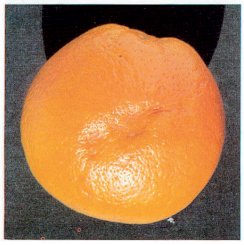
Class II

— 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**



Texte interprétatif de la norme | **Interpretation of the standard**

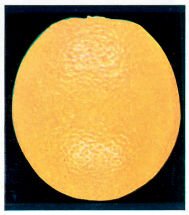
ATTEINTES CICATRISÉES DUES A UN TRAUMATISME

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

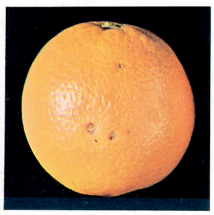


Catégorie I

— légères

Class I

— slight



Limite admise — Limit allowed

Texte interprétatif de la norme | **Interpretation of the standard**

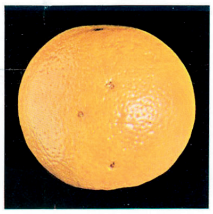
HEALED INJURIES DUE TO ACCIDENTS

Catégorie II

— assez légères

Class II

— fairly slight



Limite admise — Limit allowed

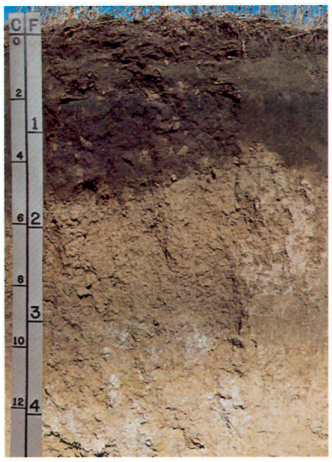
Admis dans les tolérances de la catégorie **II**

Allowed within the tolerances for Class **II**

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 (see illustration on page 49).[43]

Irrigated corn on level Hall soils. In the Great Plains most of the corn grown for grain is irrigated. Many Hall soils in the uplands have buried soil, as seen in the profile below. The soil to a depth of 80 cm is in a more recent deposit of loess. Hall soils often receive extra water from adjacent slopes. This soil profile picture also illustrates the color differences between dry and moist soils.

HALL SOILS



Ap 0–20 cm (0–8 in.). Grayish brown silt loam, very dark grayish brown, moist; slightly acid.

A12 20–45 cm (8–18 in.). Dark grayish brown silt loam, very dark brown, moist; weak fine granules; neutral.

B2t 45–80 cm (18–31 in.). Brown silty clay loam, dark brown, moist; moderate medium blocks; clay skins on peds; firm; neutral.

A1b 80–110 cm (31–43 in.). Dark grayish brown silt loam, very dark brown moist; weak medium subangular blocks; friable; neutral.

C1ca 110–130 cm (43–51 in.). Grayish brown silt loam; massive; friable; few gray limy masses, calcareous.

C1 130–150 cm (51–59 in.). Light brownish gray silt loam; massive; calcareous.

Geography: Central Nebraska and north-central Kansas. 183

Soil Family Classification

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

Fine, montmorillonitic, mesic Typic Argiustolls

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

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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.

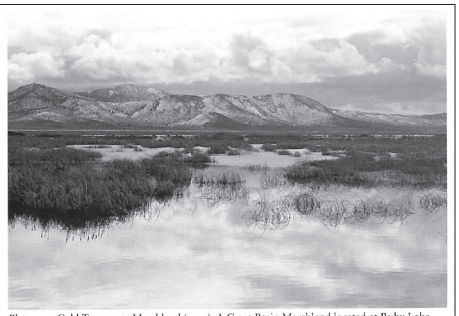

Plate 109. Cold Temperate Marshland (242.). A Great Basin Marshland located at Ruby Lake, Elko County, Nevada. The principal marsh emergents are roundstem bulrush (*Scirpus acutus*) and cattail (*Typha latifolia*). Photo by D. E. Brown.

Plate 113. Warm Temperate Strand (253.) represented by California Maritime Strand at Scammon's Lagoon, Baja California Norte, Mexico. This sparsely vegetated community on a mud substrate, although a true wetland, is reminiscent of, and analogous to, the desertland formation of upland vegetation. A stand of cordgrass (*Spartina* sp.) forms a marshland in the background. Photo by D. E. Brown.

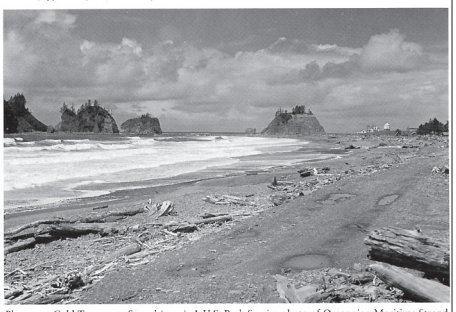

Plate 112. Cold Temperate Strand (252.). A U.S. Park Service photo of Oregonian Maritime Strand taken in February 1961 by Louis G. Kirk at Rialto Beach, Olympic National Park, Washington.

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

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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

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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.

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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

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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

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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?

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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. The most through work on the subject is beeing done by Elizabeth Kessler, whose work I found, unfortunately, just after this MS went to press. Her interviews with astronomers are very illuminating for the questions I raise here.

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).

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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 (as in n. 21).

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

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[33] See www.nanotechnology.hu, and Márk Géza, I. Biro, P. László, and Philippe Lambin, "Calculating of Axial Charge Spreading in Carbon Nanotubes and Nanotube Y-Junctions During STM Measurement," *Physical Review* B 70 (2004); and see the preprint at www.mfa.kfki.hu/int/nano/reprint/prb_70_115423_3d.pdf.

[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.*

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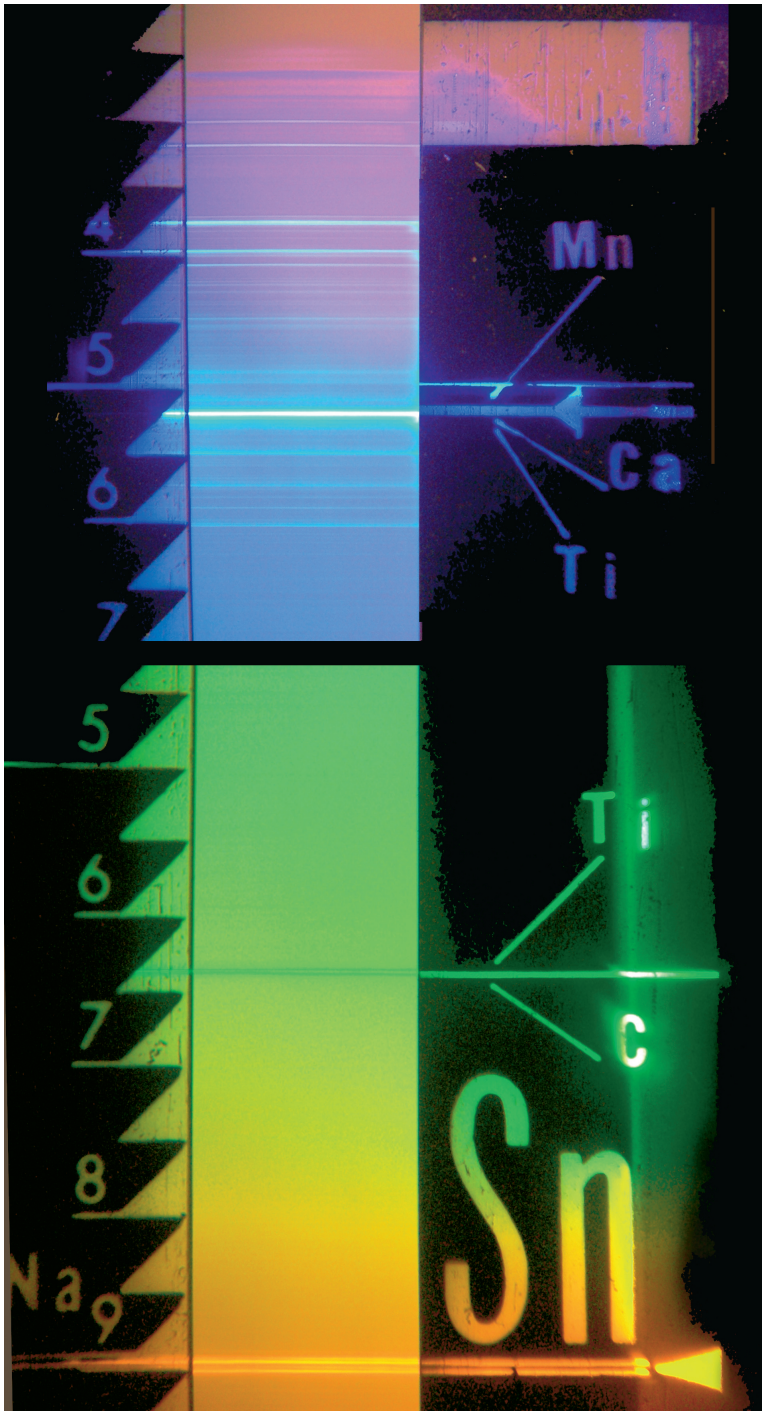
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