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Nature as Database?

Microscope Images' Impact on Visual Cultures of the Natural World

In *Keywords*, Raymond Williams observes, «nature is perhaps the most complex word in the language».[1] Williams explains that not only has the word's meaning changed over the centuries, but also its changes have indicated important trends in ideas: nature is «a word which carries, over a very long period, many of the major variations of human thought – often, in any particular use, only implicitly yet with powerful effect on the character of the argument».[2] Williams here comments on the textual use of «nature»; however, conceptions of nature are not only communicated through words, but also through images. Indeed, images of nature have formed a key component of how cultures have understood the concept of nature; as the editors of this special issue assert in their call for papers, «images of nature serve as important media to construct and perpetuate knowledge of nature». Nowhere is this conveyance of nature via images more relevant than in the sciences such as ecology where nature is one of the objects of knowledge. How «nature» is constructed in scientific images, then, becomes a question to explore to not only understand the specific knowledge of nature that is presented in a given image, but also to investigate the larger, complex frame, «nature», by which that knowledge is made visible.

While Krewani and Schwarz rightly observe that scientific images that show «whole pieces of nature» such as landscapes or biotopes are particularly important, in this essay I would like to focus on another kind of image that I suggest is also important – it also constructs and perpetuates knowledge of nature, albeit at much smaller scales. This other kind of image is common in biology and ecology as well as in fields such as chemistry, physics, and materials science: in fact, seventy of these common images appear in the computer database of ecological research associated with this special journal issue. Examination of these images can also illuminate cultural constructions of nature as well as processes of visualization. How do images of what we cannot see with the naked eye – images of microscopic and nanoscopic phenomena – also construct and perpetuate knowledge of nature? What conceptions of nature do they present?

This article explores these questions while also discussing the effects of technology on constructions of nature through an analysis of some of the traditional and

1 Raymond Williams: *Keywords: A Vocabulary of Culture and Society.* Rev. ed. New York 1976, p. 219.
2 Williams, p. 224.

emerging conventions for visualizing the invisible. My analysis suggests that a view of nature emerges in these images that is influenced not only by traditional conventions of depiction but also by the visualization technologies used to see at those smaller scales as well as what they visualize. This view is one that emphasizes a nature different from that suggested by one of the strongest influences on images of «whole pieces of nature», the landscape tradition. Instead, in microscope images, nature appears to be flat, multiple, and manipulable – similar to a database – as this paper will explore.

Although the version of nature that microscope images present may not align with that found in images within the dominant tradition of landscape portrayal, the images do participate within some trends and conventions that make what they portray worth noting. For one, images of microscopic and nanoscopic phenomena have at various times captivated observers, spreading scientific knowledge to wider groups.[3] Biologist and historian of science Brian J. Ford even claims that conveying microscopical information in image form «was the most startling development of the scientific era».[4] Ford also points out that what is conveyed through these images is important, too: «the revelations offered to the specialist and to the public alike have been influential in almost every sphere of existence».[5] The interest in images of the micro- and nanoscale, as well as the usefulness of the information they convey, have thus also helped circulate particular constructions of nature along with the images.

In addition, microscope images highlight cultural conventions and ideas of what they should depict as much as or perhaps more than other scientific conceptions of nature. This is in part because the process of making these images as well as using them to communicate is complicated by the fact that what microscopes show cannot be confirmed by the unassisted eye.[6] Therefore, researchers must identify what they see not by recognition or even sight of the object alone; instead, they must use additional methods so that they can confirm that what they see is consequential and not a defect in the microscope slide, a fleck of dust, or even the reflection of one of their eyes. In addition, when researchers present their images, they need to convince viewers that their images are not only real, but also that they have scientific merit. Finally, how they exhibit information in image form has parallels with digital images' information organization; as more and more visualization technologies use digital imaging, the dynamics of how images communicate as well as what they convey about nature may become more common. These images can reveal insights

3 For example, in 1665, the publication of Robert Hooke's *Micrographia* generated a large enthusiastic response of the publications among its readers (Fournier 40), which included individuals such as Samuel Pepys, who found it a page-turner (Nicolson 169), as well as scholarly publications, such as the Journal des Scavans, who not only reviewed the book, but reprinted some of its plates (Harwood 119–20). Gerard L'E. Turner also mentions the production of books of microscopy for a popular audience (see 149, for example for a discussion of W.H. Fox Talbot's preparation of microscopical photographs for a popular book).

4 Brian J. Ford: *Images of Science: A History of Scientific Illustration.* New York 1993, p. 167.

5 Ibid.

6 See for example: Gerard L'E Turner: *Essays on the History of the Microscope.* Oxford 1980, p. 141.

into how knowledge of nature – and nature itself – is constructed, which may be useful for other images of larger scale natural phenomena as well.

While detailed studies of specific images are crucial to understanding the fine-grained textures of the historical and cultural milieus in which images exist and are used to communicate, this paper pulls back to take a wider view in order to keep the focus on how aspects of images may serve to construct and communicate knowledge about nature. As conventions of depiction are not entirely determined at the level of the individual image but are collectively shaped and used as elements of communication, a larger view can reveal dynamics shared by images that emerge in a common culture, have been developed using a common process, or exhibit unity of another kind. While the study of such dynamics cannot create a full picture of how particular images communicate, it can inform further studies by illuminating some of the larger trends in which individual images participate. Before turning to how some aspects of microscope images help to construct knowledge of nature, I will expand on how conventions help to articulate the dynamics of imaging; and how the specific qualities of the images as influenced by the visualization technologies and objects of scientific knowledge can affect conventions of depiction.

Imaging the Invisible: Dynamics of Visual Conventions, Visualization Technologies, and Objects of Scientific Knowledge

The images that researchers create of the microscale or nanoscale do not exist by themselves – they are communicative acts and exist within complex cultures. Those who create images of the invisible, like others presenting scientific information in visual form, rely on visual conventions in order to convincingly convey what they find. However, microscope images differ from other kinds of images in that researchers making images from microscopes must rely on conventions of depiction more heavily than those who have the benefit of presenting visual information that can be seen with the naked eye, such as a landscape, for example. Makers of microscope images must therefore concern themselves with decisions about how the information will be presented in image form. Focusing on the conventions used to depict microscopic or nanoscopic phenomena, then, is one way to assess some of the social forces and common practices that shape particular images and reveal collective conceptions of what the images show, such as how nature is articulated.

Rhetoricians Charles Kostelnick and Michael Hassett describe four characteristics of visual conventions in relation to information design that further explain conventions' importance as markers of social change and that can help identify them in scientific microscope images. They first explain that conventions need to «solve information design problems that many users share – *typical* problems, not novel or unique ones».[7] As I will explain further below, researchers face some typical pro-

7 Charles Kostelnick and Michael Hassett: *Shaping Information: The Rhetoric of Visual Conventions.* Carbondale, IL 2003, p. 79.

blems as they use microscopes and create images. Conventions must also circulate in the form of images widely enough to be regularly seen by those within the social group in which they emerge.[8] Third, Kostelnick and Hassett state that conventions must be «reasonably economical to imitate»[9] and, finally, those creating the images must be persuaded to use them instead of other conventions.[10]

This last characteristic also explains what happens when conventions change. As Kostelnick and Hassett assert, factors such as new knowledge and new technologies affect visual conventions;[11] focusing on the dynamics of how researchers have wrestled with depicting microscopic or nanoscopic phenomena in visual conventions can then also show the dynamics of how nature is portrayed. The fact that, as mentioned above, microscale and nanoscale phenomena cannot be seen with the unassisted eye, and so are only visible through mediated means, creates challenges in communicating scientific information about these scales to the viewers of such images. As microscopists rely on conventions, the conventions as well as what is presented in the image shift to accommodate each other, creating the need for further examination. Art historian James Elkins explains the dynamics surrounding the use of conventions to visually convey what is unrepresentable in a way that is also useful for considering the dynamics of presenting microscale and nanoscale phenomena. Elkins writes, «images of unrepresentable objects put a strain on the pictorial conventions they inherit, finally breaking them and becoming different kinds of pictures».[12] His focus on the dynamics between what images attempt to show and conventions, and the resulting possibilities of developing new ways of imaging, presents one way to more closely examine scientific visualization of what is invisible.

Another reason that following the visual conventions used in images can be productive is implied by Elkins' use of the word «finally» in the quote above. As conventions exist at a collective level, they are not replaced quickly or on a whim; instead, they are replaced only when users must do so. As Kostelnick and Hassett explain, even less-than-perfect conventions remain at times even when a better replacement is available due to readers' habits of use.[13] These attributes of conventions suggest that analyzing conventions with attention to researchers' imaging processes with visualization technologies can further illuminate how and what images of the microscale and nanoscale communicate.

Shaping the Image: Landscape Conventions in Microscopy

While the conventional presentation of objects in a three-dimensional space is not the only way that information from microscopes has been presented, this conven-

8 Ibid.
9 Ibid.
10 Ibid.
11 Ibid. p. 43.
12 James Elkins: *The Domain of Images.* New York 1999, p. 44.
13 Kostelnick and Hassett, p. 79.

tion commonly appears in various contexts to convey information about microscale and nanoscale phenomena, including scientific journals, scientific groups' web sites, government documents, and more popular and educational web sites. The visual convention of framing information about the micro- and nanoscale in terms of perspective, which helps viewers recognize objects or at least familiar shapes, performs an organizing function in these images, one which has consequences for understanding how these images function. This framing is by all accounts not new, and as Svetlana Alpers discusses, can be linked to visual practices that have dominated Western definitions of art and images since the fifteenth century (xx). Following some of the key characteristics of this framing helps to explain some aspects of microscope images that make them seem like landscapes or depictions of objects.

This mode of depicting has been called Cartesian perspectivalism by critics such as Martin Jay[14] or has been ascribed to what Alpers terms the Albertian model, based on Leon-Battista Alberti's description of perspectival drawing technique in his 1435 work *De pictura*.[15] Alberti's technique consists of envisioning the drawing surface as a window-like plane out of which the viewer gazes onto the depicted scene. He devised a grid that enables an artist, who immobilizes her or his head and covers one eye, to divide the scene she or he views through the grid into limited, drawable squares, therefore capturing the perspective of what is seen through the entire grid. The resulting drawings show single-point perspective in that they are drawn from one point of view, so that the image's viewer stands in for the artist when viewing the image the artist has produced. This model of perspective has remained the main Western mode of seeing the world and making images.

Perspectival representation's pictorial conventions seem to play a role in some microscope images: examples of microscope images that use conventions of perspective include early images, such as some of Robert Hooke's images, published in 1665 (see, for example, an image of blue mold (plate opposite page 125), which depicts what seem to be a scene of flowers in grass against a dark background). More recent examples include some nanoscale images created with the scanning tunneling microscope that have been included on a web site: one, «Quantum Corral», of quantum states of iron atoms' surface electrons, for example, uses false shadowing and tilting of the horizontal plane to indicate a three-dimensional space.[16] Such details build up an impression of the image as an optical image of an object, or collection of objects, fitting with the Albertian model's view of a representation, which stands in as «an optical substitute for the object itself. [...] It is a facsimile emitting

14 Martin Jay: *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought.* Berkeley 1994, p. 69–70.

15 Svetlana Alpers: *The Art of Describing.* Chicago 1983, p. 41–45.

16 IBM Almaden Research Center Visualization Lab. Quantum Corral. *IBM Almaden Image Gallery.* IBM Almaden Research Center Visualization Lab. www.almaden.ibm.com/vis/stm/corral.html (01.10.09).

the same bundles of light rays that would be reflected by the object if it were there, beyond the picture's frame».[17]

One benefit of using such perspectival conventions is that through their organizing functions, they help researchers convince viewers that what is presented with these conventions are solid, believable objects, similar to objects visible to the unaided eye. Such conventions may help to persuade readers of microscopic or nanoscopic phenomena's existence; however, in presenting objects as in the macroscale, these links do not necessarily present accurate information about phenomena at the microscopic or nanoscopic scales. Perspectival conventions also suggest a certain relationship between viewer and object, which also does not accurately explain what these images actually show, as I will explain further below. Conventions of perspective then do not always help microscope image makers solve typical problems they encounter as they convey information about the micro- or nanoscale; instead, the use of perspectival conventions may reveal more information about societal expectations of nature, or expectations of the audience to whom the microscopist is communicating. As Anne-Julia Zwierlein suggests in her study of the connections between seventeenth- and eighteenth-century science and poetry, in that time when scientists were not yet able to articulate the connections between objects and their microscopic structures, what microscope users saw was mostly a reflection of their collective eye – the world they already lived in but saw repeated «below», in miniature.[18] While the conventions of perspective then do function to help orient viewers and remain a dominant form of depiction, they do not necessarily convey information about the microscale or nanoscale as part of their organization. However, other elements of microscope images suggest that other conventions may solve these problems.

Shaping Conventions: Microscope Visualization Technologies and the Image Form

The question of how images construct nature at the micro- and nanoscale depends in part on how they construct microscopic or nanoscopic objects. How images do so directly affects what is shown and how visual conventions are used to present images as meaningful scientific evidence. Presenting information about the micro- and nanoscales in visual form creates a challenge for micoscopists, whether that form is drawings such those that Robert Hooke created from his observations in the 1660s, photomicrographs such as those in the database associated with this journal issue, or digital images of atoms such as those produced with scanning probe microscopes like the scanning tunneling microscope (STM) and atomic force microscope (AFM). While the images that are produced through these different

17 Ivan Illich: The Scopic Past and the Ethics of the Gaze: A Plea for the Historical Study of Ocular Perception. ournature.org/~novembre/illich (01.10.09).

18 Anne-Julia Zwierlein: Queen Mab Under the Microscope: The Invention of Subvisible Worlds in Early Modern Science and Poetry. In: Joachim Frenk (Hrsg.): *Spatial Change in English Literature.* Trier 2000, p. 89.

media have many unique, important characteristics that merit more detailed examinations of how each functions and how each uses visual conventions, a number of remarks can be made about all of these given their general functions and imaging process in relation to the visualization technologies that helped create them. These general remarks can then point to some common dynamics and so illuminate some visual conventions beyond those associated with perspective that help shape conceptions of nature.

For one, images of microscopic and nanoscopic phenomena do not depict what objects would actually look like at those scales if we were able to see that closely. Indeed, issues in resolving and in illuminating the objects that microscopists encounter make it so that even the most seemingly immediate image of microscopic or nanoscopic phenomena is highly mediated. As Ian Hacking points out about optical and electron microscopes, a microscope image is not a direct, photographic representation. Instead, it forms «a map of interactions between the specimen and the image of radiation», or in other words, charts how light or other radiation reacts with the sample under view (208). The reaction between sample and radiation is not analogous to what happens when we see at the macroscale: as Elkins explains, «the difference between the behavior of light under the microscope and in unaided vision is so great that it can seem as if the microscopic image is an entirely new phenomenon – as different from ordinary seeing as a stock market graph is from a snapshot».[19] In addition, newer microscopes, such as scanning probe microscopes like the STM or AFM, do not even use light to visualize. In these cases, these microscopes also create images out of maps of interactions between the sample and a probe, but instead of light, these microscopes use a tip to which current has been applied (which interacts with the electrons in the sample) in the case of the STM; or a tip which is physically dragged across the surface of the sample in the case of the AFM.

Microscope images then are composed of the map of interactions that the microscopes use to make phenomena visible. Therefore, microscope images do not necessarily represent objects as do more macro-scale drawings or photographs of landscapes or flowers. Instead, microscope images can be more precisely called informatic images, in that what they convey is data arranged in a matrix in the image form. Such images also share characteristics with others designed to present information produced with or without computers such as charts, graphs, diagrams, tables, and maps. What links these diverse images created through disparate production processes is that they present information in a visual, at times nonlinear format, where each point presents a certain value that can be assessed individually or in relation to other points' values.

Presenting information about the microscale and nanoscale in image form affects both form – the image – as well as what is presented in ways that challenge what is communicated as well as how the information is conveyed. In *Ontogeny*

19 James Elkins: *Six Stories from the End of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics, 1980-2000.* Stanford 2008, p. 126.

of Information, Susan Oyama argues that information does not exist a priori but instead co-develops ontogenetically with the form in which it is communicated[20]. What this view suggests is that the presentation of the data in an image not only changes the form, but also the form itself carries a certain number of determinants in its constraints and possibilities, which then shape information choices. As form and information co-develop and interact with each other in the process of formation, both the information as well as how it is presented are affected in this process. On this view, elements of «form» and «information» then are inextricably part of the same process; therefore, what is imaged affects the image form, and so the generation of new knowledge also may help generate variations on the image form. This mutual co-development can lead to changes in what is imaged and changes in the image – which can then lead to changes in or the generation of new visual conventions to depict what is imaged.

Shaping Conventions: The Informatic Image

Microscope images as informatic images, then, may generate their own conventions or alter other conventions already in use in the communities in which the images circulate. A closer look at some of the characteristics of the informatic image can suggest some possible typical aspects of images. These aspects can lead to situations where visual conventions of depicting informatic images can communicate (or the lack of visual conventions can create challenges), following Kostelnick and Hassett's point that one of the features of conventions is that they must solve typical design problems experienced by many users.[21]

One appealing attribute of informatic images is that they condense vast amounts of information into the relatively small spaces of images; this condensation, Edward Tufte notes, aids our ability to visually compare as much as possible in a short time.[22] As Elkins explains, many scientific images condense information by presenting it in multiple, disparate modes within the same image.[23] The database image entitled «Über elektive Vitalfärbungen zweier Drüsen von Daphnia magna Müller» is an example of this: there are two main components of the image, and each shows a different aspect of the same species but uses different stains and different stages – in addition, the photograph contains numbers superimposed to draw attention to part of one of the views.[24]

20 Susan Oyama: *The Ontogeny of Information: Developmental Systems and Evolution*, 2nd ed., rev. and exp. Durham 2000, p. 2.

21 Kostelnick and Hassett, p. 79.

22 Edward Tufte: *Envisioning Information.* Cheshire, CT 1990, p. 168.

23 Elkins *Domain*, p. 36.

24 J. Gicklhorn and R. Keller: Image. Über elektive Vitalfärbungen zweier Drüsen von Daphnia magna Müller. *Bildkulturen ökologischer Forschung.* bildkulturen.online.uni-marburg.de/de/suche/detail/aktuell/40/seite/1/suchart/thesaurus/modus/detail?tsr=methodik&lemma=Mikroskopie&kls=01.01.02.01&lemma=Mikroskopie (01.10.09).

These numbers also point to another way in which informatic images tend to condense information into images: they use the spatial, two-dimensional attributes of a page or screen as an organizing device. The use of this organizing device is one reason why the informatic image at first glance not only forms a coherent whole but also may seem to be similar to more conventional images such as photographs or drawings that may represent an object, for example. Indeed, one of the benefits of arranging information in an image is that viewers can simultaneously see the whole as well as be able to zoom in on particulars.[25] However, the informatic image's ability to present so much complex information also creates some challenges for those making the images and those viewing the images. Makers of informatic images rely on visual conventions in order to communicate their data; readers rely on conventions to understand what the images communicate.

The process of viewing an informatic image differs from viewing an image such as a landscape in part because the viewer often may be looking at an image for specific information or the relationship of certain data to other data, not necessarily for a perception of the image as a whole. For example, in Gicklhorn and Keller's image mentioned above, the import is not on the overall look or feel; instead, the image makers have invited comparison between the data in one part of the image and that in the other part by switching magnification and by showing one at a more advanced stage. Another image in the database, which contains four images within one image, also demonstrates this: «Anleitung zur Untersuchung des Limnoneustons» is not just one image of euglena.[26] Instead, what is important about this image is that it shows the effect of time on a population of euglena through four images between which time has elapsed. This focus on close looking, on comparing, as opposed to perceiving a whole view, helps create an overall feel of surface, of flatness. The spatial relationship between the points becomes important, not the depth of a landscape.

The informatic image functions as an interface as the viewer pores over its parts, and if computer-generated, changes them, saves them, or refreshes the image and so produces a new version. The viewer's eyes are directed to the image's surface, not to objects shown within, and in this way informatic image conventions differ from perspectival conventions such as those functioning to communicate a landscape view. The image series in particular, such as Rylov's image, or others in the database, can be seen as pointing to such a reading process in that they show new versions of the data within one image. This emphasis on change, over in this case manually «refreshed» images, invites readers to move from image to image and in some ways go through the process of viewing along with the experimenter.

25 Tufte, p. 31.

26 W.M. Rylov: Image. Anleitung zur Untersuchung des Limnoneustons. *Bildkulturen ökologischer Forschung.* bildkulturen.online.uni-marburg.de/en/suche/detail/aktuell/59/seite/1/suchart/thesaurus/modus/detail?tsr=methodik&lemma=Mikroskopie&kls=01.01.02.01&lemma=Mikroskopie (01.10.09).

Even in the case of a still image, the informatic images' viewer does not stand in the place of the scene's virtual observer: instead, the viewer contemplates the surface, running her or his eyes over the contours to follow the variations in order to make comparisons between different data points or to understand relationships between them. This close reading, observing the pattern of value differences, is a key characteristic of informatic images. Additionally, in viewing an informatic image on a computer screen, a viewer also can spend time exploring the image's data and so altering the image in response to what she or he sees at first to further determine differences, zooming in on a section, for example. This relationship of viewers to images adds to the extreme alterability of the images: not only do the images' creators manipulate the data, but also so can the viewers as they thread their way through the data, whether through moving from image to image, moving from point to point and so rearranging the data in their reading process, whether or not they literally do so on the screen.

While conventions for reading specific informatic images may vary (for example, conventions for creating and reading graphs differ from those for creating and reading tables, or other charts), one main function for all informatic images is to allow readers to follow the thread of information. Attempts to clarify the differences in the data in the database images manifest through techniques such as distance, which appears in images in ways such as marking the differences on the surface of the image with small numbers, letters, or arrows, mentioned above. In including such marks, microscopists emphasize the image's surface, as opposed to allowing viewers to gaze within. An example of this in the database associated with this journal issue is found in «Epidermis einer Blattspitze von Biota orientalis succinea».[27] In the image, an arrow points to what the author wanted to emphasize in the data, according to the explanation next to the image in the database. Other examples occur in the database as well – and in other times and places; such markings form a fairly typical solution to the problem of directing viewers of microscope images to particular information in an image.

Additionally, color has also been used to differentiate data (although not in the database, as it contains only black and white images). For example, in images made with the scanning tunneling microscope (STM), a color scale is often used to indicate electronic differences. The color is false, as atoms are too small for light to resolve them; however, color serves as a useful way to direct viewers' attention. The color scale can also be altered for different audiences: scientific journal articles tend to include images that use black and white scales, or often a sepia-and-white scale that is the default scale of some commercially produced images, while images that appear on journal covers, on group web sites, or in other electronic or print publications designed for wider audiences tend to use bright color. Such conventions

27 H. von Lengernken: Image. Epidermis einer Blattspitze von Biota orientalis succinea. *Bildkulturen ökologischer Forschung.* bildkulturen.online.uni-marburg.de/en/suche/detail/suchart/thesaurus/modus/detail/?tsr=methodik&kls=01.01.02.01&lemma=Mikroskopie&aktuell=24 (01.10.09).

allow image makers to direct attention to one way (or more) of working through the information, and so the conventions help show readers what is important about the particular images.

These techniques become conventions of depiction, even though their specific manifestations may vary from one image to another. These conventions rely on viewers' close reading along the data points, using color, distance, and other differences that series or time can produce to steer through the information. While the viewer reads these images for what they communicate about the microscale or nanoscale, these informatic conventions can perform the rhetorical work of arrangement by building a frame for understanding the scientific knowledge about the microscale or nanoscale. This frame presents the reader with an overall image that leads into the specific information; the specific data then allow the reader to read closely and interact with it.

Conventions of Demonstrating Objectivity and the Microscope

The interaction with information is also emphasized in the use of the microscope, which adds to the pressure to express information as multiple and manipulable and also shows a conflict with an established scientific convention. This challenge occurs as a tension between the established, common conventions that help to convince viewers that scientific phenomena are being presented objectively and the involvement and manipulation which is part of the process of image production that occurs with microscopes. This process includes the manipulation of samples by researchers to prepare them for microscopy and the actual use of the microscopes including the interactions that produce the informatic images.

Images of the micro- and nanoscale have always involved a degree of a microscope user's involvement and interpretation, from drawing the microscopist's observations, to deciding what to photograph, to shaping data into an image. Microscope users have learned to see by becoming involved with the sample or operation since the microscope's emergence in the seventeenth century: Robert Hooke's unpaginated preface to his 1665 *Micrographia*, which introduced many to what could be seen with the microscope through his detailed engravings, presents a particularly clear case of this as he describes building up a picture over a series of observations of the same object.[28] This involvement with samples over time also shows a certain level of manipulation as the image created is not a direct view of the object, but an aggregate that has been arranged by Hooke's drawing techniques.

The emphasis on the use of the microscope as tool for interacting with objects of study in order to gain knowledge of the natural world also makes it so that the process of imaging becomes part of that tool for interacting – and whether the

28 Also see Ford, Chapter 8, for an intriguing photograph of what Hooke most likely saw through the microscope: comparison with the engravings shows that Hooke's view and Hooke's engravings are quite different.

imaging process is through drawing by pencil or Photoshop, the imaging technology becomes that which the researcher uses to interface with the object under view. The imaging technology then becomes not only what he or she uses to present microscale or nanoscale phenomena to others, but also what he or she uses to see for him- or herself. In order to image the microscale or nanoscale, the researcher not only produces an image, but also in interacting with the image's components at different stages, is able to differentiate one object from another within the context of the sample. This then allows her or him to compose a visual system of what she or he sees and so create a visual language, a visual system of conventions that like a language system generates effects in part because it is citable, and so transferable to other contexts.

As Hacking also points out, given the problems with the microscope, «all but the most expert [observer] would require a ready mounted slide to see *anything*».[29] Instead, seeing with a microscope is composed of learned, practiced actions that include not only looking but also doing. Hacking connects this need for intervention to Berkeley's 1710 *New Theory of Vision*, «according to which we have the three-dimensional vision only after learning what it is like to move around in the world and intervene in it»[30]. Therefore, the microscopist must use both hand and eye as well as practice this fused use in order to build up a capacity for seeing under these circumstances.

And yet, as Evelyn Fox Keller observes, «in scientific discourse, looking is associated with innocence, with the desire to understand, while touching implies intervention, manipulation, and control».[31] Barbara Maria Stafford explains one reason for the downplaying of touch in the eighteenth century, for example: manipulation or manufacture was considered the work of charlatans, not scientists, and so what was prized was seeing an unadulterated specimen. Stafford notes that

> ‹objectivity›, or the honest conduct of the practitioner, was thus synonymous with the absence of any visible sign of manufacture. The rise of objectivity as a scientific ideal in the early modern period was facilitated by the development of measuring and distancing apparatuses. These truly ‹automatic› devices seemed to preclude shady handling and phony gadgetry.[32]

As Lorraine Daston and Peter Galison explore in their study of late-nineteenth and early-twentieth century concepts of objectivity in scientific atlases, scientists continued to turn to mechanically-produced images as a way to eliminate human interpretation of the natural phenomena.

29 Ian Hacking: *Representing and Intervening.* Cambridge 1983, p. 192.

30 Hacking, p. 192.

31 Evelyn Fox Keller: The Biological Gaze. In: George Robertson et al. (Ed.): *FutureNatural: Nature, Science, Culture.* New York 1996, p. 107.

32 Barbara Maria Stafford: *Artful Science: Enlightenment, Entertainment, and the Eclipse of Visual Education.* Cambridge 1994, p. 103.

This convention leads to a tension between following convention to emphasize the visible but not manipulable aspects of microscopy in microscope images and the fact that manipulation is important to the process of not only preparing microscope samples but also of creating microscope images. An example of this tension occurs in the nineteenth century – just as microscopists were adopting photography to help them claim that they presented the world untouched.[33] As Keller observes, biologists were able to use the microscope to help them do their biology: «once the microscope was joined with the manual manipulations of an experimental biology – marking, cutting and dissecting *under* the scope – and the interdependency of hand and eye previously reserved for the naked eye was extended into the microscopic realm, the microscope became a reliable tool for veridical knowledge»[34]. This situation shows how important interaction is in the use of the microscope and shows one of the ways that researchers attempted to solve the problem of showing objectivity – they adopted a new medium that was associated with objectivity to convey their work.

This tension between portraying microscale or nanoscale phenomena as untouched and using the interactive attributes of the visualization technology helps to show the sway of conventions. It also may show the sway of the conventions of perspective as well – when the distance between viewer and object (such as in the Albertian model) is not able to be there, the question arises of how one might know nature if one cannot view it with a distanced perspective. The microscope images answer this question – viewers and microscope users are immersed in a way that does not afford perspective, but rather, close reading of the surfaces. As the photomicrographs in the database show, for example, even though the adoption of photography may have leant microscope images a certain sense of objectivity, elements in microscope images display connections with informatic image conventions that do emphasize the fact that the image does not present nature without the touch of the human hand, such as the inclusion of tiny numbers or letters. In this way, viewers' attention is drawn to the surface as well as to the fact that the images have been marked.

In addition, other microscope images do show the hand of the researcher, such as the more recent scanning tunneling image, «Quantum Corral» mentioned above. This image, of a ring of iron atoms, shows the results of an experiment to position iron atoms in a ring in order to conduct experiments on the electron standing waves «corralled» inside.[35] It is clear that this image could not have been created without the experimenters manipulating the sample of the surface, although it is also interesting that they have relied on creating perspective in this image to emphasize the object that they created.

33 See for example: Turner, p. 147–149.

34 Keller, p. 112.

35 M.F. Crommie, C.P. Lutz and D.M. Eigler: Confinement of Electrons to Quantum Corrals on a Metal Surface. In: *Science* 262, 1993. p. 218-220.

Microscope Imaging Conventions' Effects on Construction of Nature

The visual conventions described above highlight cultural ideas of what they should depict, from the focus on objects that would be found in the macroscale that conventions of perspective highlight, to the focus on objectivity in conventions of presenting what is seen as untouched. The informatic conventions apparent in microscope images, too, highlight cultural ideas of what they should depict, albeit ideas that are not quite as dominant in culture as the first two. As microscope images contribute to scientific knowledge, they also contribute to particular constructions of nature and help form our understanding of the natural world in ways that are less grand, perhaps, than a sweeping view of an ecosystem, but nevertheless important.

The characteristic «close reading» of informatic images that allows readers to make sense of the information presented in them suggests a vision of nature that is perceived from close up, as viewers read from detail to detail, like in a database. The overall view of the image can contain information of its own, but it does not have to in order for the image to communicate; the details – and their proximity to each other – are the important elements of the image. These images are also read through conventions such as distance between image elements, time, and color. Such conventions of depiction guide readers through an understanding of the images, as opposed to, for example, representations of objects themselves.

The vision of nature that is created here is not one guided by an overarching narrative or perspective that organizes all of the details. In this way, the nature that is presented in microscope images corresponds to how Christine Hine describes the organizing function of databases as scientific instruments: as she notes, «instead of imposing its own computer logic, the database provides a focus for specifying and tying together particular natural and social orderings».[36] Nature in microscope images is presented as composed of multiples, awash in associations, like the association of data in a database; the viewer is guided through by the accrual of attention paid to details. The flatness of microscope images as they present a matrix of information becomes a key characteristic, as opposed to the depth of a landscape.

The nature that is constructed through the experience of these details is also a nature that is created through the viewer's participation as he or she interacts with the microscope image to learn what information is conveyed. Informatic microscope images thus portray a nature that is multiple, flat, and manipulable – and experienced through interaction.

36 Christine Hine: Databases as Scientific Instruments and Their Role in the Ordering of Scientific Work Export. In: *Social Studies of Science* Vol. 36, No. 2., 2006. p. 269.

Conclusion

Following the dynamics of visual conventions in microscope images is one way to follow social and technical influences on the construction and shaping of knowledge in microscope images, and so also to address the concepts of nature expressed by these images. These sketches of how imaging conventions are affected by the image form, the objects of scientific knowledge, and the visualization technologies that enable them to be created also hint at some of the cultural complexity that pervades both images and conventions. This analysis merely points to some conventions of depiction and suggests how they may help construct ideas of nature – what is missing from this analysis, of course, is further historical and cultural analysis of specific images to reveal the social, scientific, and historical conditions of a given image's conventions of depiction and so further develop these definitions of nature. While each of the above sketches could be situated within a specific historical and social context in order to develop a fuller picture of the dynamics in play, in aggregate the sketches of conventions can also leave us with a sense of nature depicted in these dynamics. As I hope to have suggested, conventions of depiction influenced by microscope images' qualities as informatic images created by manipulation and interaction do have an impact on the resulting images, and these conventions do help shape an idea of nature as flat, manipulable, and multiple – like a database.

The informatic image has existed throughout the history of microscopy, contributing to scientific understanding ideas of nature that form an alternative to the dominant views of nature as landscape that are inherited from the landscape tradition. Such views of landscapes informed by perspectival conventions have seemed natural in the past: as Elkins remarks, «conventions of computer-generated perspectival scenes in military and scientific simulations, architecture, and commercial games appear ‹natural› or mathematically driven to their designers, even though they can be shown to derive from Western landscape painting of the last two centuries».[37] And yet, they are not the only «natural» ways to view nature, if we pay attention to the conventions of informatic images, as exemplified in microscope images.

Indeed, such conventions and ways of organizing and perceiving the world may be shifting in scientific and in other cultural domains – or at least making such conventions that organize information more visible in other domains. For example, recently Timothy Lenoir has argued that the field of biology shifted to become an «information science» in the mid-1960s. As he further observes, the organization of biology may be affected quite dramatically by this shift.[38] Paying attention, then, to conceptions of nature in microscope images may indeed inform us about other trends and ways of both seeing and seeing nature that have existed in the making of

37 Elkins: *Domain*, p. 9.

38 Timothy Lenoir: Shaping Biomedicine as an Information Science. In: Mary Ellen Bowden et al. (Ed.): *Proceedings of the Conference on the History and Heritage of Science Information Systems.* Medford 1998, p. 27. www.stanford.edu/dept/HPS/TimLenoir/shapingbiomedicine.html (01.10.09)

scientific objects. One could expand Raymond Williams' statement that not only is nature perhaps the most complex word in the language, but that following conceptions of nature in images is also complex, yet equally illuminating.

Works cited

Alpers Svetlana: *The Art of Describing.* Chicago 1983.

Crommie, M. F.. C. P. Lutz and D. M. Eigler: Confinement of Electrons to Quantum Corrals on a Metal Surface. *Science* 262, 1993. pp. 218–220.

Daston, Lorraine and Peter Galison: The Image of Objectivity. *Representations* 40.1, 1992. pp. 81–128.

Elkins, James: *The Domain of Images.* New York 1999.

– *Six Stories from the End of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics, 1980–2000.* Stanford 2008.

Ford, Brian J.: *Images of Science: A History of Scientific Illustration.* New York 1993.

Fournier, Marian: *The Fabric of Life: Microscopy in the Seventeenth Century*. Baltimore 1996.

Gicklhorn, J. and R. Keller: Image. Über elektive Vitalfärbungen zweier Drüsen von Daphnia magna Müller. *Bildkulturen ökologischer Forschung.* bildkulturen.online.uni-marburg.de/de/suche/detail/aktuell/40/seite/1/suchart/thesaurus/modus/detail?tsr=methodik&lemma=Mikroskopie&kls=01.01.02.01&lemma=Mikroskopie (01.10.09).

Hacking, Ian: *Representing and Intervening.* Cambridge 1983.

Harwood, John T: Rhetoric and Graphics in Micrographia. In: Michael Hunter and Simon Schaffer (Ed.): *Robert Hooke: New Studies.* Woodbridge, England 1989, pp. 119–148.

Hine, Christine: Databases as Scientific Instruments and Their Role in the Ordering of Scientific Work Export. In: *Social Studies of Science* Vol. 36, No. 2., 2006. pp. 269–298.

Hooke, Robert: *Micrographia: or some physiological descriptions of minute bodies made by magnifying glasses. With observations and inquiries thereupon.* London 1665.

IBM Almaden Research Center Visualization Lab. Quantum Corral. *IBM Almaden Image Gallery.* IBM Almaden Research Center Visualization Lab. www.almaden.ibm.com/vis/stm/corral.html (01.10.09).

Illich, Ivan: The Scopic Past and the Ethics of the Gaze: A Plea for the Historical Study of Ocular Perception. ournature.org/~novembre/illich (01.10.09).

Jay, Martin: *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought.* Berkeley 1994.

Keller, Evelyn Fox: The Biological Gaze. In: George Robertson, Melinda Mash, Lisa Tickner, Jon Bird, Barry Curtis and Tim Putnam (Ed.): *FutureNatural: Nature, Science, Culture.* New York 1996, pp. 107–121.

Kostelnick, Charles and Michael Hassett: *Shaping Information: The Rhetoric of Visual Conventions.* Carbondale, IL 2003.

Lenoir, Timothy: Shaping Biomedicine as an Information Science. In: Mary Ellen Bowden, Trudi Bellardo Hahn and Robert V. Williams (Ed.): *Proceedings of the Conference on the History and Heritage of Science Information Systems.* Medford 1998, pp. 27–45. www.stanford.edu/dept/HPS/TimLenoir/shapingbiomedicine.html (01.10.09).

Nicolson, Marjorie: *Science and Imagination.* Cornell 1956.

Oyama, Susan: *The Ontogeny of Information: Developmental Systems and Evolution*, 2nd ed., rev. and exp. Durham 2000.

Rylov, W. M.: Image. Anleitung zur Untersuchung des Limnoneustons. *Bildkulturen ökologischer Forschung.* bildkulturen.online.uni-marburg.de/en/suche/detail/aktuell/59/seite/1/suchart/thesaurus/modus/detail?tsr=methodik&lemma=Mikroskopie&kls=01.01.02.01&lemma=Mikroskopie (01.10.09).

Stafford, Barbara Maria: *Artful Science: Enlightenment, Entertainment, and the Eclipse of Visual Education.* Cambridge 1994.

Tufte, Edward: *Envisioning Information.* Cheshire, CT 1990.

Turner, Gerard L'E: *Essays on the History of the Microscope.* Oxford 1980.

Von Lengernken, H.: Image. Epidermis einer Blattspitze von Biota orientalis succinea. *Bildkulturen ökologischer Forschung.* bildkulturen.online.uni-marburg.de/en/suche/detail/suchart/thesaurus/modus/detail/?tsr=methodik&kls=01.01.02.01&lemma=Mikroskopie&aktuell=24 (01.10.09).

Williams, Raymond: *Keywords: A Vocabulary of Culture and Society.* Rev. ed. New York 1976.

Zwierlein, Anne-Julia: Queen Mab Under the Microscope: The Invention of Subvisible Worlds in Early Modern Science and Poetry. In: Joachim Frenk (Ed.): *Spatial Change in English Literature.* Trier 2000. pp. 69–97.