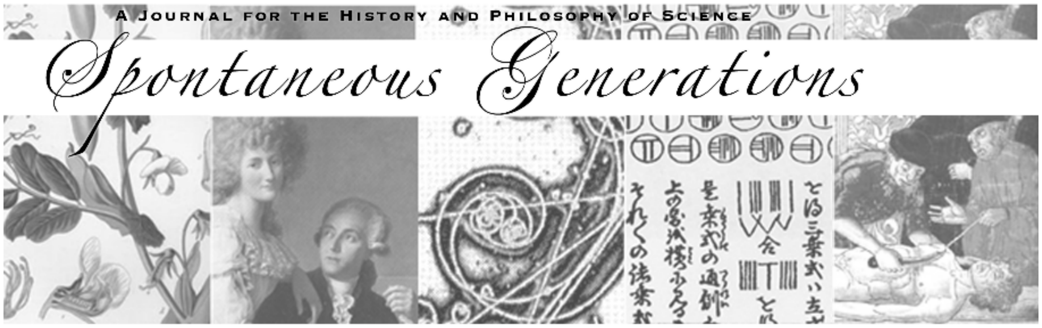

Sound and Vision

Author(s): Edward Jones-Imhotep

Source: *Spontaneous Generations: A Journal for the History and Philosophy of Science*, Vol. 6, No. 1 (2012) 192-202.

Published by: The University of Toronto
DOI: 10.4245/sponge.v6i1.16216

EDITORIAL OFFICES

Institute for the History and Philosophy of Science and Technology
Room 316 Victoria College, 91 Charles Street West
Toronto, Ontario, Canada M5S 1K7
hapsat.society@utoronto.ca

Published online at jps.library.utoronto.ca/index.php/SpontaneousGenerations
ISSN 1913 0465

Sound and Vision*

Edward Jones-Imhotep†

Over the last two decades, Science Studies has produced a fascinating body of literature on visual representation. A crucial part of that literature has explored the materiality of visual representation, primarily the "rendering practices" that make visual representations possible and embody epistemic virtues attached to the scientific self. This essay explores the practices and capacities that support visual representation, but it looks to a seemingly unlikely place for inspiration—the growing literature on the uses of sound in science. My interest here is to see how that literature points us to a view of sound as an epistemic resource that supports the visual. If there is a visual emphasis in modern science, it is made possible by a set of material practices that are only partly visual. As such, this essay suggests how the history of visual representations in science might be bound up with a history of scientific aurality.

Images matter. Over the last two decades, some of the most exciting work in Science Studies has dealt with the dominant place of visual representations in the practice of science.[1] That body of writing has shown us how diagrams,

* Received 9 March 2012.

† Edward Jones-Imhotep is Associate Professor of Science and Technology Studies, and Associate Director of the Institute for Science, Technology and Society at York University. He specializes in the history of modern technology. His publications include: Communicating the North: Representation, Practice and National Identity in Cold-War Canada, Osiris 24(1) (2009): 144-64 (special issue on Science, Technology and National Identity); and Icons and Electronics, Historical Studies in the Natural Sciences 38(3) (Summer 2008): 405-50. His current research project, Reliable Humans, Trustworthy Machines, examines the history of technological reliability as a history of the technological self.

[1] The literature on visual representation is vast. A few representative works include: M.J. Rudwick, The Emergence of a Visual Language for Geological Science 1760-1840, *History of Science* 14 (1976):149-95; M.J. Rudwick, *Scenes From Deep Time: Early Pictorial Representations of the Prehistoric World*, (Chicago: University of Chicago Press, 1992); B. Latour and S. Woolgar, *Laboratory Life: The Social Construction of Scientific Facts*, (Princeton: Princeton University Press, 1979): B. Latour, Drawing things together, In *Representation in Scientific Practice*, eds. M. Lynch and S. Woolgar, (Cambridge: MIT Press, 1988); B. Latour, How to be iconophilic in art, science, and religion, In *Picturing Science, Producing* Art, eds. P. Galison and C.A. Jones. (New York: Routledge, 1998); B. Baigrie, *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, (Toronto: University of Toronto Press, 1996); M. Lynch, Discipline and the Material Form of Images: An Analysis of Scientific Visibility, *Social Studies of Science* 15(1) (1985): 37-66; M. Lynch, The Externalized Retina: Selection and Mathematization in the Visual Documentation of Objects in the Life Sciences. *Human Studies* 11(2/3) (1988): 201-34; M. Lynch and S. Woolgar,. *Representation in Scientific Practice*, (Cambridge, MA: MIT

pictures, drawings, and graphs, to name a few, help shape theories, certify authority, and convince publics. Pushing further, that work has inspired us to ask about the material practices that surround visual representations: the crafted tools, the prepared specimens, and the often laborious techniques that go into producing scientific images. Those "rendering practices" allow representations to stand in for the natural (Lynch 1985). They permit scientists to measure, to point to, and to argue over graphs and pictures in place of natural objects; and in doing so they help shape virtues that stand at the core of the scientific self.[2]

Exploring those conditions of production is what interests me here. What are the practices and capacities that generate and support the visual? Much of the best work on visual representations has seen the production of images as involving the work of the eye and the hand, as well as the instruments that mechanize and coordinate their behaviour.[3] Rendering natural phenomena visually, on this view, is about seeing and marking, and about the tools, material processes, and dispositions that make certain types of sight and certain kinds of marks possible. More recently, authors have pushed into explorations of the kinds of people that certain images presuppose, the ways of seeing, the epistemic virtues that images embody, and the techniques that are necessary to produce everything from botanical drawings to lunar photographs (Daston and Galison 2007). Here, I would like to explore one way that we might push those investigations further still. What has been missing from our accounts are observations of how rendering objects and phenomena visually, how stabilizing graphic properties in the first place, involves a broader and richer idea of the capacities and practices that make it possible. I am interested in how the history of visual representations in science might be more than a history of the eye, the hand, and the materials they organize and shape.

One place to look for that expanded exploration is in the recent literature on sound. As an object of scientific inquiry, sound has been one prominent focus of the drive towards visualization.[4] Etienne Jules Marey's attempts to render

---

Press, 1990); P. Galison and C.A. Jones, *Picturing Science, Producing Art*, (New York: Routledge, 1998); K. Anderson, Looking at the sky: The visual context of Victorian meteorology, *The British Journal for the History of Science* 36 (3) (2003): 301-32; D. Kaiser, *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics*, (Chicago: University of Chicago Press, 2005); and L. Pauwels, *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication*, (Lebanon, NH: University of New England, 2006).

[2] On how images stand in for natural objects, see Latour (1988); on the place of representations in instantiating and forming the scientific self, see Daston and Galison (2007).

[3] See, for instance, Lynch (1985, 43) on marking, constituting graphic space, etc.; on the material practices surrounding visual representations, see Latour and Woolgar (1979).

[4] See, for example, Brain (1997); A. Voskuhl, Humans, Machines, and Conversations: An

spoken language graphically in Third Empire Paris turned the visualization of sound into a powerful weapon in the battle between French linguistics and German philology, instantiating the linguistic nation and securing the leverage of the metropolis against the provinces and their patois (Brain 1997). His work signalled a general tendency towards visualization within sciences that take sound as their object of study. [5] As a subject of scholarly attention, on the other hand, sound has provided an occasion to extend our studies into the detailed material practices of science.[6] Here, sound has been juxtaposed as a kind of analytical counterbalance to the predominance of the visual within our own investigations. Labs, this literature suggests, may be inscription factories; but they are also full of sounds—discussions, negotiations, arguments, the hum and click of instruments and electronics, and the numerous ambient noises that surround the work that goes on there. "If the visual dimension is part of material practice then so too is the world of sound" (Pinch and Bijsterveld 2004, 637). And if we want to faithfully represent scientific practice in these spaces, this literature suggests, we have to be prepared to listen.

Both those perspectives—sound as object and as subject—are fascinating. My interest here is slightly different, though. What I find fascinating is how this emerging literature points us to a view of sound that is neither the object of a visualizing paradigm, nor its competitor, but rather an epistemic resource (Mody 2005, 177).[7] How is sound part of the knowledge that gets made in the lab? How is it part of the material processes that are at work there and, specifically, how is it part of the crucial work of seeing and visualization? Scientific practice goes beyond the work of the hand and the eye, and visual representations are themselves often the product, not of a pure visual experience, but of a multifaceted one involving the other senses. If there is a visual emphasis in modern science, it is made possible by a set of material practices that are only partly visual. Implicated in the manipulation of instruments, the coordination of actions, and the dispositions of the body, sounds are also woven into experimental practice and into its crucial acts of looking and seeing (Mody 2005,

---

Ethnographic Study of the Making of Automatic Speech Recognition Technologies, *Social Studies of Science* 34(3) (2004): 393-421; E. Thompson, Dead Rooms and Live Wires: Harvard, Hollywood, and the Deconstruction of Architectural Acoustics, 1900-1930. *Isis* 88(4) (1997): 597-626; Pinch and Bijsterveld (2004); and T. Pinch and F. Trocco, 2004. *Analog Days: The Invention and Impact of the Moog Synthesizer*, (Cambridge, MA: Harvard University Press, 2004).

[5] Cyrus Mody (2005) says that in the sciences that treat sound as an object of study, the attempt is to constantly turn sound into an inscription.

[6] See, in particular, the edited volume by Pinch and Bijsterveld (2004).

[7] Marc Perlman has written about epistemic authority and the ear in the context of audiophilia; see M. Perlman, Golden Ears and Meter Readers: The Contest for Epistemic Authority in Audiophilia, *Social Studies of Science* 34(5) (2004): 783-807.

176-77). How does the auditory help generate and support the visual? How does sound form part of the practices that help make the visual possible in the first place? And how do those works point us towards a history of scientific aurality?

Historically, the places of experiment have been full of sounds, and the work that goes on there has been deeply shaped by them. Noises have long threatened to intrude on the work of science, disturbing delicate experiments and shaping where and when scientific work takes place. In the modern lab, sounds provide yet another source of possible contamination (Mody 2005, 177). The physical architecture of labs is designed partly to create sonic environments that control or eliminate those intrusions, making them fit for science; the considered positioning of labs and field stations within the larger soundscapes of campuses, landscapes, and cities works to situate—socially, culturally, geographically—the work carried out there.[8]

But sound functions as more than backdrop and disturbance. Fields from animal behaviour to kinematics have made use of sound as a resource in producing their results.[9] Galileo's famous experiments with the inclined plane, the trials that helped him derive his famous law of fall, provide one example. Around the time Galileo accepted the professorship of mathematics at Pisa in 1589 and began his studies of motion, his father, Vincenzo Galilei, was embroiled in a tense dispute over what precisely produced the harmony of specific musical intervals like the octave. His rival, Gioseffo Zarlino, appealed to numerical ratios as the cause; Vincenzo disagreed, and set out to prove it with a series of experiments (Drake 1970, 495-96). Galileo was likely involved in those trials and his own later work on falling bodies drew on a broad immersion in the experience and contemplation of music, particularly on the importance of the trained ear. Hailing from a family of accomplished musicians, including his father and brother, Galileo was himself an accomplished lute player. In need of a way to mark small and precise units of time in his motion studies, Galileo turned to the testimony of the ear. He tied movable gut frets around an inclined plane, in the same way they would be tied around the neck of a late-Renaissance lute. As the polished marble or metal balls rolled down the plane, they struck the frets and produced a staccato. With the plane and ball now forming a kind of metronome, Galileo would sing a favourite song at the correct tempo and adjust the frets until the sound of the ball striking them produced the proper beat—something Galileo's trained musical ear could determine to within 1/64 of a second (Drake 1975, 101; Torretti 1999, 24). He then measured the successive distances that the ball had travelled in equal time intervals (given by the spacing

[8] The boundary between noise and signals, however, is not stable. The points at which certain sounds become irritants, the way they are managed in the production of results, with time and contexts. See K. Bijsterveld, *Mechanical Sound: Technology, Culture, and Public Problems of Noise in the Twentieth Century*, (Cambridge, MA: The MIT Press, 2008).

[9] On this larger role of sound, see Pinch and Bijsterveld (2004, 638).

between adjacent frets) and used these in working out his law of fall.

The example of Galileo points us to the rich intersections that existed around music and science in the late sixteenth century.[10] It also points us to the crucial practice of listening in the broader history of science. Recent studies have suggested how that practice has also played a role in the related history of visualization. Two examples—one from medicine, one from microscopy—illustrate the point.

One of the medical practices that has become emblematic over the last two centuries is auscultation—the use of the stethoscope to listen to the sounds of the body, particularly of the heart and lungs.[11] Auscultation arose within a very specific context. The large Parisian hospital system where it was developed around 1816 required a way to quickly and effectively manage large numbers of patients; patients in turn acted as research subjects in exchange for free care (Lachmund 1999, 423). The inventor of the method, René Theophile Laennec, sought to define diseases through anatomical pathology rather than etiology. Consumption, for instance, was defined not according to its causes, but solely by the presence of tubercles—the small nodular legions in tissue that we now associate with tuberculosis. His classification for diseases of the chest drew exclusively on a detailed depiction of the visual properties revealed through dissection (Lachmund 1999, 424). Laennec, however, also assumed a direct causal relationship between the pathologies revealed visually and the sounds that could be heard in the body (Lachmund 1999, 425). Through techniques of percussion—tapping the chest—and auscultation, he sought sound indicators of these pathological states so that they might be identified in living patients at the bedside. In order for those sounds to be codified and communicable, Laennec drew on visual imagery and the surrounding soundscape to give them meaning and precision. His catalogue of sounds and their mental images mixed urban and rural, domestic and public, the theatre, the military, and the hospital. The range and character of comparisons is astonishing:

> The voice of Policinelle, the ventriloquist; high voices; silvery

[10] Those connections extend beyond Galileo's context. For the historical relations between science and music, see Pinch and Bijsterveld (2004, 638); A. Johns, Music and Science During the Scientific Revolution, *Perspectives on Science* 9(1) (2001): 106-115; P. Gouk, The Role of Acoustics and Music Theory in the Scientific Work of Robert Hooke, *Annals of Science* 37(5) (1980): 573-605; P. Gouk, Performance practice: Music, Medicine and Natural Philosophy in Interregnum Oxford, *The British Journal for the History of Science* 29(3) (1996): 257-88; P. Gouk, *Music, Science, and Natural Magic in Seventeenth-Century England* (New Haven, CT: Yale University Press, 1999); H.F. Cohen, *Quantifying Music: The Science of Music at the First Stage of the Scientific Revolution, 1580-1650*, (Dordrecht: D. Reidel, 2010); and P. Pesic, Hearing the Irrational: Music and the Development of the Modern Concept of Number, *Isis* 10(3) (2010): 501-30.

[11] I draw here on Jens Lachmund's fascinating study (1999).

> voices; trembling voices; the voice of a sheep; a voice transmitted through a metal trumpet; the bleating of a goat; the chirp of small birds; the coo of pigeons; the whistle of the wind in the lock of the door; the steady rustle of the sea; the noise of a coach rolling over the pavement; the tinkle of weapons during military exercises; the jingle of a small valve; the crackle of salt being dissolved in a bowl of warm water; the snoring of a sleeping man; the rattle of the dying; the sound produced by a piece of healthy lung-tissue filled with air, which one presses between ones fingers; the crepitation of a dry bladder which is being inflated; the rumble of a drum; the sound produced when a string of bass is beaten with a finger; the vibration of a metallic string which is rubbed with the tip of the finger. (Lachmund 1999, 425)[12]

Philosophers sometimes distinguish between the pictorial—the material representations that take the form of pictures, graphs, and charts—and the visual, the full range of perceptual, pictorial, verbal and conceptual images through which we make sense of the world.[13] That distinction is useful here as well. For Laennec, the auditory was enlisted in generating an image of the body, one that was informed by the testimonies of the eye through dissections, drawings and medical atlases (Lachmund 1999, 428; Taylor and Blum 1991). As such, auditory signs were still certified by reference to signs seen in the body: "One can only give an idea [of them] by comparing the perceptions given by the sense of the ear with those which would be given by sight" (Laennec [1826] 1837, 1:123). But once certified in this way, the auditory was not opposed to the visual or subordinated to it.[14] Laennec's work involved a deep consonance, if not a complete symmetry, between the eye and the ear. Spread spatially across the sick ward and the dissection room, Laennec's work involved two simultaneous and complementary projects: one narrowly visual, located in the dissection room and focused on the deceased body; the other broadly visual and auditory, occupying the spaces around the sick-bed and the living body of the diseased. Schematizing only slightly, we might say that, within the Parisian hospitals of the early Bourbon Restoration, Laennec proposed to produce images of the sick body by listening to the living and looking at the dead.

The blind spot in our explorations of visual representation, then, has not been to focus on the visual or on seeing, but to imagine that seeing has only

[12] Jens Lachmund provides these examples, taken from the second edition of Laennec's treatise on auscultation. See Laennec ([1826] 1837, 1:48-148; 2:1-158).

[13] On the issue of imagery, see W.J. T. Mitchell, *Iconology: Image, Text, Ideology*, (Chicago: University of Chicago Press, 1986).

[14] Lachmund (1999, 440) suggests that we systematically consider how these two elements reinforce each other in the history of science.

to do with sight. In one of the most fascinating philosophical discussions of experimental practice we have, Ian Hacking explores what seeing means in the case of microscopy. Hacking is interested in two principal questions: do we "see" through a microscope? And do we have warrant to believe that the entities we observe with the instrument are real? His primary target is a set of anti-realist claims about microscopic vision. Leaving aside that larger debate, Hacking's examination is useful here for demonstrating how seeing has only partly to do with the eye. He leads us through a now-familiar narrative: that seeing through a microscope is never simply a question of looking; that we have to learn to see with instruments; and that most of the advances in what we have seen with microscopes came about because of developments in allied technologies like aniline dyes, microtomes, pure light sources, and screw micrometers rather than improvements in the optics of the instrument (Hacking 1983, 192). But crucially for Hacking, seeing is also about doing. Drawing on the work of Bishop Berkeley, he explains that we *acquire* three-dimensional vision; we learn to see in specific ways only after learning how to move around in the world and intervene in it (Hacking 1983, 189). Against the claims of inescapable theory-ladenness, Hacking (1983, 191) suggests that seeing requires not theory but practice—doing, not just looking. That intervention provides not only one of the most powerful arguments for how we come to see, but also for how we come to believe in the reality of what we see and therefore in the authority of its representations. We generally see *with* microscopes, not through them (Hacking 1983, 207). What convinces us of the reality of microscopic phenomena is not some overarching theory regarding the specimen or the instrument, but rather a rich collocation of interlocking low-level generalizations through which we can control and create phenomena in the viewfinder or on the monitor (Hacking 1983, 209).

Hacking emphasizes only the visual side of those interlocking generalizations. But there is nothing in his argument that keeps them there. What allows us to "see" is the ability to create a rich correspondence—a map—between the specimen and the image of radiations (Hacking 1983, 208). Sound is a crucial resource in generating those maps, often as a medium of intervention, sometimes as a complementary medium of representation, and therefore a key part of that complex of capacities that help us see and represent, sorting out signal from noise as we go.[15]

Transmission electron microscopy provides a particularly rich example of this, as Cyrus Mody has shown. The instruments used here are exceedingly precise, focusing on objects sometimes as small as a few angstroms. Dirt and dust combine with ambient sounds to potentially intrude on the images produced (Mody 2005, 179). The human body is just one particularly persistent

[15] For Hacking (1983, 209), discarding aberrations is a crucial part of "seeing" and realism in microscopy.

source of this. And just as there are techniques of the self developed historically to restrain the intrusion of the scientist into visual representations, there are self-directed techniques meant to control the researcher's effects on delicate instruments and mental work (Knorr-Cetina 1996). In certain kinds of electron microscopy, for instance, scientists "must constantly be aware of their bodily habitus—how they position themselves, when they address each other, how they move—so as not to produce sounds or vibrations that might disturb the instrument by talking too loudly at the wrong time or accidentally bumping the microscope console" (Mody 2005, 179).

But sounds also function as a way of certifying the microscope as a working instrument, as something that allows us to see. The ability to intervene in what the instrument displays, to disturb it through noises like stomping and clapping, is taken as an indication of its proper functioning, establishing the background against which signals can emerge (Mody 2005, 187). For microscopists, sound further provides immersion in the instrument (just as auscultation provides immersion in the body). In certain cases, hearing is even privileged above sight. Researchers, for instance, often prefer listening when trying to detect periodicity in phenomena (Mody 2005, 188). Perhaps most tellingly, some researchers even convert the microscope's electrical signal—the one generally used to produce only the visual image—into an audio output, allowing them to listen to the operation of the device at the same time as they watch the display.[16] The reason, they explain, is that certain instrument malfunctions are more easily heard than seen. Using sound in this way, they not only monitor the instrument through hearing, but they make adjustments and interventions based on what they hear (Mody 2005, 189). Aesthetic sensibilities develop around these sounds, as does a relationship between listening and temporality. As Mody notes, the auditory dominates when the instrument has to be monitored or manipulated over an extended period; the visual (understood narrowly) dominates when its output has to be in the form of static images for publication or circulation (2005, 190). But before the publications and their circulation, researchers rely on sound to determine whether they are "seeing" with the instrument, and whether there is something worth looking at in the first place.

As the cases of auscultation and microscopy suggest, our studies of the epistemic function of sound have been predominantly synchronic until now—taking sounds in certain places and contexts and understanding the way they inform the local practice of science, including visual representations. But in doing their careful and fascinating work, they raise the inevitable question about the diachronic: what role has sound played in the longer-term transformations in scientific culture, including visualization, through which we

[16] "Sonification" of this kind is a more general approach within the sciences. See Pinch and Bijsterveld (2004, 638).

understand our subject? Architectural modernism provides one inspiration here. For a long time, modernity in architecture was treated as a visual phenomenon characterized by, for instance, transparent construction, absence of decorative elements, use of modern materials like steel, concrete, and glass, and so on. With Emily Thompson's work we see how the experience of modernity involved a crucial aural dimension as well, characterized particularly by the elimination of reverberation and the separation of sounds from the spaces of their production (2004, 7). Those changes were part of a larger transformation in hearing and listening between 1900 and 1933, in the sounds produced and in how those sounds were given value and meaning during a crucial period of the "Machine Age." The visual is no longer enough to understand the experience of modernity in the early twentieth century, not even its purportedly visual elements.

That insight suggests that our investigations of visual representation are implicated in a history of scientific aurality that we have only begun to explore. The large-scale transformations in the sciences of the eye have always rested on a set of material practices that are only partly visual. In the introduction to their wonderful book, *Objectivity*, Lorraine Daston and Peter Galison invoke a history of listening. "You can play an eighteenth-century clavichord at any time after the instrument's revival around 1900," the authors write, "but you cannot hear it after two intervening centuries of the pianoforte in the way it was heard in 1700" (2007, 19). There is an analogy with the history of scientific sight, they suggest. Successive epistemic virtues like truth-to-nature and objectivity, virtues that attached to images as well as to the scientific selves that produced them, formed dynamic configurations with earlier virtues rather than replacing them outright. Our recent studies on sound suggest that we could push further than analogy here, and into explorations of how calibrating the eye also depended on teaching people what they ought to hear and how they ought to understand it. The ear, to paraphrase Bourdieu, is also a product of history (1984, 10).[17] Given the role of sound in seeing and given the rich, varied, and profound changes in the visual cultures of science over its history, we need to explore how transformations in the experience and culture of sound combined with and supported new ways of looking and seeing in science and how certain ways of hearing counted as virtuous, and in that way underwrote the fuller formations of the scientific self.

[17] A number of historical works explore the larger history of sound and listening. See J.H. Johnson, *Listening in Paris: A Cultural History*, (Berkeley, CA: University of California Press, 1996); J. Sterne, *The Audible Past: Cultural Origins of Sound Reproduction*, (Durham, NC: Duke University Press, 2003); T. Day, *A Century of Recorded Music: Listening to Musical History*, (New Haven, CT: Yale University Press, 2002); A. Corbin, *Time, Desire and Horror: Towards a History of the Senses*, (Cambridge, MA: Polity Press, 1995); and A. Corbin, *Village Bells: Sound and Meaning in the 19th-Century French Countryside*, (New York: Columbia University Press, 1998).

Edward Jones-Imhotep
Science and Technology Studies
Bethune College 218
York University
4700 Keele Street
Toronto, ON L6J 2M3
Canada
imhotep@yorku.ca

References

Bourdieu, Pierre. 1984. *Distinction: A Social Critique of the Judgement of Taste.* Cambridge, MA: Harvard University Press.

Brain, Robert. 1997. *Standards and semiotics. In Inscribing Science: Scientific Texts and the Materiality of Communication*, ed. Timothy Lenoir, 249-284. Palo Alto, CA: Stanford University Press.

Daston, Lorraine, J. and Peter L. Galison. 2007. *Objectivity*. New York: Zone.

Drake, Stillman. 1970. Renaissance music and experimental science. *Journal of the History of Ideas* 31(4): 483-500.

Drake, Stillman. 1975. The Role of Music in Galileo's Experiments. *Scientific American* 232(6): 98-104.

Hacking, Ian. 1983. *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science.* Cambridge: Cambridge University Press.

Knorr-Cetina, Karin. 1996. The Care of the Self and Blind Variation: The Disunity of Two Leading Sciences. In *The Disunity of Science: Boundaries, Contexts, and Power*, eds. Peter Galison and David Stump. Stanford, CA: Stanford University Press.

Lachmund, Jens. 1999. Making Sense of Sound: Auscultation and Lung Sound Codification in Nineteenth-Century French and German Medicine. *Science, Technology, & Human Values* 24(4): 419-50.

Laennec, René Theophile. [1826] 1837. *Traité de l'auscultation mediate et des maladies des Poumons et du coeur*. 3 vols. Paris: Chaudé. Quoted in Lachmund, Jens. Making Sense of Sound: Auscultation and Lung Sound Codification in Nineteenth-Century French and German Medicine (*Science, Technology, & Human Values* 24 [4]: 419-50, 1999).

Lynch, Michael. 1985. Discipline and the Material Form of Images: An Analysis of Scientific Visibility. *Social Studies of Science* 15(1): 37-66.

Mody, Cyrus C. M. 2005. The Sounds of Science: Listening to Laboratory Practice. *Science, Technology, & Human Values* 30(2): 175-98.

Pinch, Trevor, and Karin Bijsterveld. 2004. Sound Studies: New Technologies and Music. *Social Studies of Science* 34(5): 635-48.

Taylor, Peter, and Ann Blum. 1991. Pictorial Representation in Biology. *Biology and Philosophy* 6(2): 125-34.

Thompson, Emily. 2004. *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933.* Cambridge, MA: MIT Press.

Torretti, Roberto. 1999. *The Philosophy of Physics*. New York: Cambridge University Press.