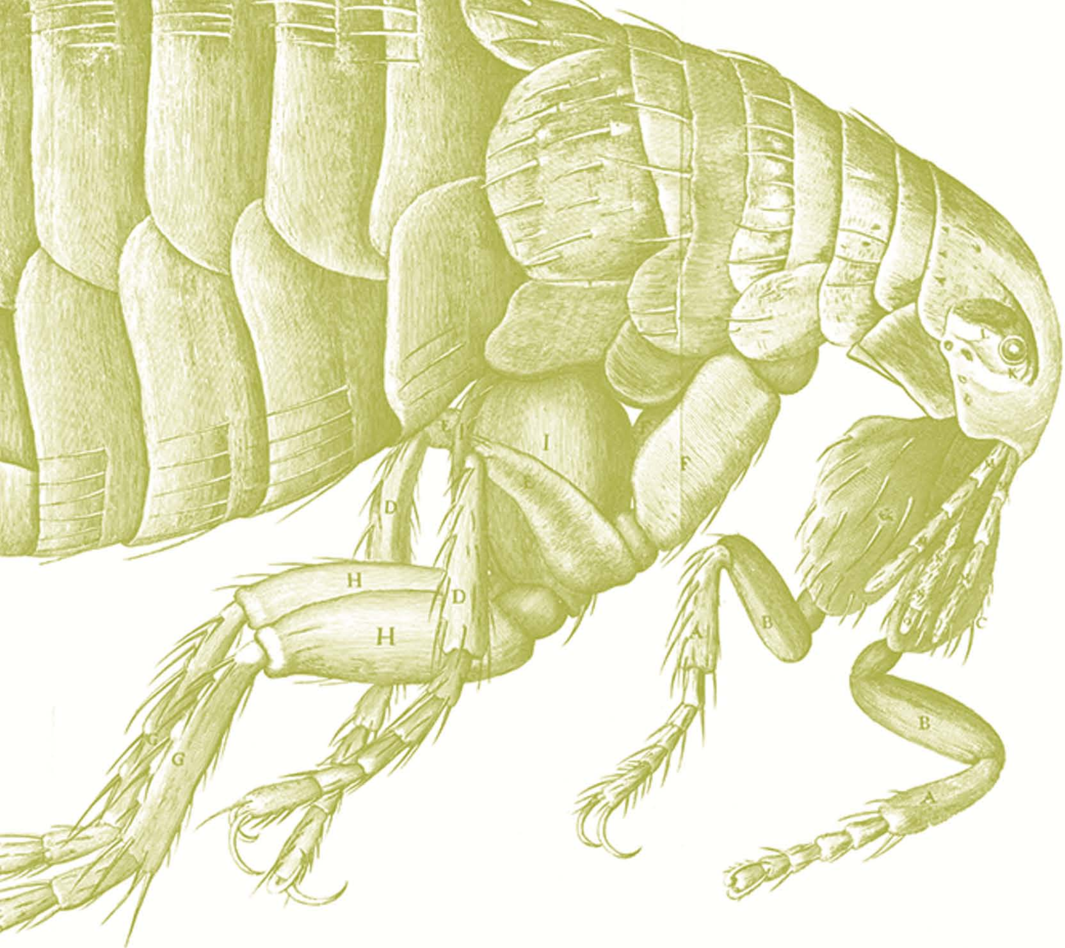
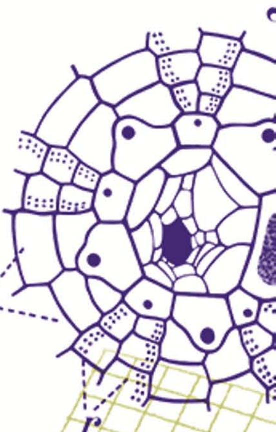




The Technical Image

A History of Styles in Scientific Imagery

Edited by Horst Bredekamp, Vera Dünkel, and Birgit Schneider

The TECHNICAL IMAGE

A HISTORY OF STYLES IN SCIENTIFIC IMAGERY

EDITED BY HORST BREDEKAMP, VERA DÜNKEL, AND BIRGIT SCHNEIDER

In science and technology, the images used to depict ideas, data, and reactions can be as striking and explosive as the concepts and processes they embody—both works of art and generative forces in their own right. Drawing on a close dialogue between the histories of art, science, and technology, *The Technical Image* explores these images not as mere illustrations or examples, but as productive agents and distinctive, multilayered elements of the process of generating knowledge. Using beautifully reproduced visuals, this book not only reveals how scientific images play a constructive role in shaping the findings and insights they illustrate, but also—however mechanical or detached from individual researchers' choices their appearances may be—how they come to embody the styles of a period, a mindset, a research collective, or a device.

Opening with a set of key questions about artistic representation in science, technology, and medicine, *The Technical Image* then investigates historical case studies focusing on specific images, such as James Watson's models of genes, drawings of Darwin's finches, and images of early modern musical automata. These case studies in turn are used to illustrate broad themes ranging from "Digital Images" to "Objectivity and Evidence" and to define and elaborate upon fundamental terms in the field. Taken as a whole, this collection will provide analytical tools for the interpretation and application of scientific and technological imagery.

Horst Bredekamp is professor of art history at the Humboldt University of Berlin and a permanent fellow of the Institute for Advanced Study in Berlin. **Vera Dünkel** is a scholarly assistant with the "Das Technische Bild" research project. **Birgit Schneider** is the Dilthey Fellow of the Fritz Thyssen Foundation at the Institute for Arts and Media, University of Potsdam.

208 pages | 93 color plates, 92 halftones | 8 ½ x 11

ISBN-13: 978-0-226-25884-3

Publication Date: March 2015

Cloth $50.00/£35.00

Copublished with the Bard Graduate Center

For a review copy or other publicity inquiries, please contact:

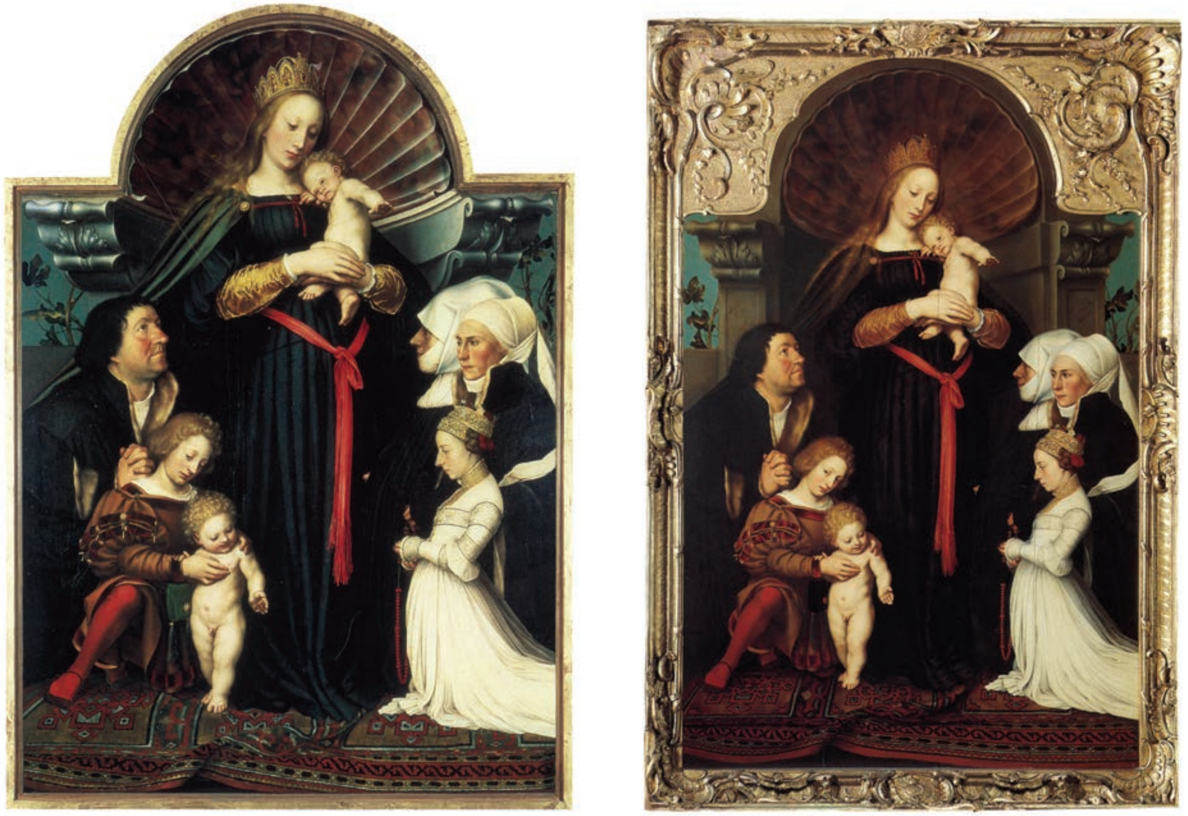
Nicholas Lilly,
Promotions Manager,

University of Chicago Press,
1427 East 60th St, Chicago IL 60637.

Email: nlilly@press.uchicago.edu;
Telephone: 773-702-7490;
Fax: 773-702-9756.

To place orders in the United States or Canada, please contact your local University of Chicago Press sales representative or contact the University of Chicago Press by phone at 1-800-621-2736 or by fax at 1-800-621-8476.

Methods



FIGS. 1a, 1b: *Darmstadt Madonna* (*Madonna* of Jakob Meyer zum Hasen) by Hans Holbein, 1526, 146.5 × 102 cm, Städelsches Kunstinstitut Frankfurt am Main, and a copy of Holbein's *Madonna* by Bartholomäus Sarburgh, 1635/1637, 158.9 × 103 cm, Gemäldegalerie Alter Meister, Dresden. For a long time, the painting on display in the Dresden Gemäldegalerie (right) was regarded as a product of the hand of Hans Holbein. In the nineteenth century, a painting with the same motifs and composition was discovered (left), and a dispute about the authenticity of the Dresden version broke out. Public comparison and discussion of the two paintings during an exhibition in 1871 decided the dispute in favor of the second picture. Direct comparison made a strictly formal and precise comparison of styles possible. An empirical procedure was established that based its findings on the examination of details, the individual characteristics of the artist's hand, painterly methods, techniques, and color materials. This procedure has since become an integral element of art-historical methodology. Oskar Bätschmann and Pascal Griener, *Hans Holbein the Younger: Die Darmstädter Madonna* (Frankfurt am Main: Fischer-Taschenbuch-Verlag, 1998). Fig. 1a: © Hans Holbein d. J. Madonna des Bürgermeisters Jacob Meyer zum Hasen, 1525/26 und 1528 (Öl auf Nadelholz, 146.5 × 102 cm), Würth Collection, Inv. 14910, Photographer: Philipp Schönborn, München. Fig. 1b: © Bartholomäus Sarburgh (Kopie nach Hans Holbein d. J.): Die Madonna des Basler Bürgermeisters Jakob Meyer zum Hasen, Gal. Nr. 1892. Gemäldegalerie Alte Meister, Staatliche Kunstsammlungen Dresden, Photographer: Hans-Peter Klut.

COMPARING IMAGES

Generally, comparison can be described as a fundamental method that orients people in their environment so that they can distinguish (differentiate) and categorize (classify) what they see and experience. More specifically, it is an intellectual technique used in various scientific disciplines and performed and evaluated in many different ways (Lutz et al. 2006; Elkins 2007). While texts, verbal imagery, patterns of behavior, styles of thinking, and cultures are compared in cultural and literary studies, art history deals explicitly with the comparison of images. In art history, comparative visual analysis is one of the central methodological paradigms of analysis and argumentation. As such, it serves to order works of art historically into schools and eras, to identify unknown masters, and to identify authentic and inauthentic, genuine and counterfeit works (Wölfflin 1932; Friedländer 1930; Gombrich 1960; figs. 1a and 1b). At the same time, comparative visual analysis plays a fundamental role as a basis for argumentation in presenting such findings in publications and slide lectures.

One reason for the difficulties in theorizing comparative visual analysis seems to lie in the double role

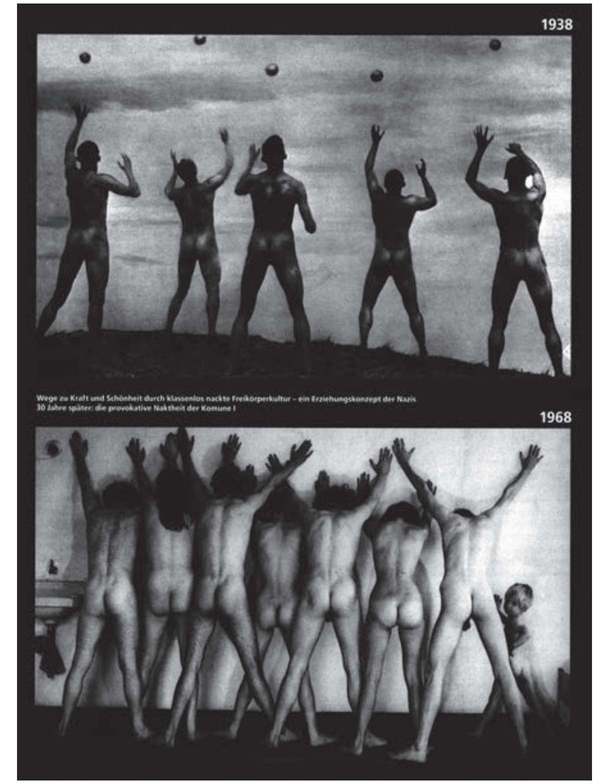
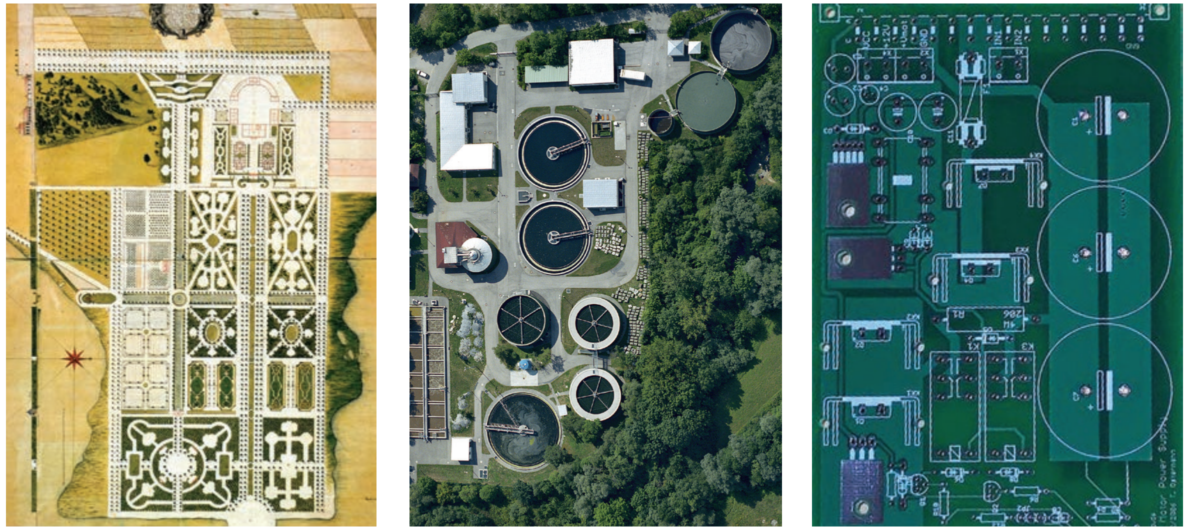


FIG. 2: A page from the March 2008 issue of *Cicero: Magazin für politische Kultur*. These two photographs were compared in the context of an article by the German historian Götz Aly. The essay argues for the existence of direct parallels between the rise of the Nazis in the 1930s and the student revolts of 1968 in Germany and Berlin. According to Aly, both were "young" movements with a "totalitarian language" and a "tendency towards violent activism" that pursued a "takeover of power." The two images are supposed to convey this connection; at first glance, the similarities in their composition and subjects are striking. Yet the question is whether, beyond the formal similarities of the images, the differences do not in fact predominate. The people in the upper image are men involved in a ballgame in the open air, with raised heads and outstretched arms. In the lower photo, by contrast, men, women, and a child pose in a confined space, their heads lowered, arms and legs rigidly spread along a wall; the arrangement would seem to quote the scene of an arrest. Criticizing the *Cicero* article, the daily newspaper *Die Tageszeitung* (*Taz*) was able to show in an article entitled "Nackerte Tatsachen" ("Bare Facts") that the presentation of the pictures obscured or falsified their contexts and the dates on which they were made. The second photograph, of Kommune I, was taken by Thomas Hesterberg after the shah's visit to Germany in 1967; the other is a still from Wilhelm Prager's 1924 film *Wege zu Kraft und Schönheit*, which seeks to portray the rebirth of the body from the spirit of antiquity. The comparison seems evocative and persuasive enough at first glance but on closer inspection turns out to be not only formally but also historically untenable. Götz Aly, "Unser Kampf: 1968," *Cicero*, March 2008, 105 and © akg-images and © Hesterberg, Thomas / Süddeutsche Zeitung Photo..

that comparison plays in this discipline as an instrument of analysis *and* argumentation. Comparative visual analysis was part of the implicit basic know-how or "tacit knowledge" (Michael Polanyi) of art-historical writing long before art history was established as an academic discipline in the nineteenth century (Friedländer 1942). Even today, it forms a self-evident and largely unquestioned part of the discipline as a means of acquiring knowledge, of analyzing and describing images. This may explain why comparative practices have only rarely been investigated as a problem in their own right.

Based on the German art historian Heinrich Dilly's seminal research, art history scholars have more recently carried out studies that have investigated the meaning and scope of comparison as a method in the development of art history as an academic discipline; in particular, they traced the history of the material foundations of comparison, which were laid by the emergence of new reproductive media such as photography and their connections with science (Dilly 1975; Wenk 1999; Nelson 2000; Ratzeburg 2002; Reichle 2002; Bader 2007). At the same time, art history has repeatedly reproached itself for not adequately substantiating the comparisons it makes: with the help of apparently "evident" visual comparisons, relationships between images are more implicitly asserted than verbally or contextually deduced. The objection that there are images that simply cannot be compared implies the accusation that relations are claimed where divergence—indeed, irreconcilable difference, regarded as essential—is the strikingly predominant observation (Geimer 2006). It is a rhetorical quality of comparative presentation that showing two images in juxtaposition tends to suggest relationships more than



FIGS. 3a–3c: Baroque garden (a), sewage treatment plant (b), and circuit board (c). The *tertium comparationis* for the comparison of these three images lies not in a shared time horizon, nor in the subject or context. Comparability is derived here solely from the formal level of order and structure. In all three images, round, square, and diamond-shaped elements are linked by thin lines as in a labyrinth; lines are laid straight, diagonally or slightly bent across the surface. In all images, the structures seem to follow well-ordered and ornamental laws and logic. This comparability is supported and largely made possible by the bird's-eye perspective common to the three images and their unified size. Only seeing these objects as images allows a microchip to resemble a baroque garden. But can such similarities increase knowledge, and is there a shared basis for these structures? To answer this question, we would have to study the issue of the overarching requirements on the planning of a coherent networked system. In all three cases, planners were faced with the task of arranging several functions rationally and symmetrically on a surface, optimally positioning paths and guidance systems. The formal resemblance is a symbol of functional networking. But while the ornamental structures of the gardens of Versailles reflect the ideal of a tamed nature, the sewage treatment plant and the microchip produce symmetries in the quest for optimum planning in a technical sense. Fig. 3a: Adrian von Buttlar and Nargita Marion Meyer, eds., *Historische Gärten in Schleswig-Holstein* (Heide: Boyens, 1996), 118. © Cecilia Heisser, Nationalmuseum, Stockholm. Fig. 3b: © FOTAG Luftbild München. Fig. 3c: http://www.mechapro.de/shop/images/product_images/popup_images/132_0.jpg (accessed November 2013).

distinctions, just as positioning two or more images on a surface or in a space seems to suggest a certain direction in which to "read" them. In consequence, the danger can arise of generating "accidental similarities" (Geimer 2010; fig. 2).

It should be noted, however, that it is initially a fundamentally open question what a juxtaposition of images—particularly during research—is supposed to express. The visual confrontation of two objects is inherently capable of both revealing relationships and emphasizing difference and specificity more sharply; it can distinguish more clearly or bring closer together, as the art historian Otto Pächt explained in *The Practice of Art History* (Pächt 1999, 87–104). To this must be added the potential of montage to create something new beyond the individual images from which it is composed, as the French art historian Georges Didi-Huberman has pointed out (Didi-Huberman 2010).

Pächt emphasized that what is compared is oriented toward what the comparison is supposed to achieve. The collating of images is carried out based on decisions and in accordance with epistemic interests that may vary widely. For example, in an attempt to initially view and classify visual material, comparison can provide a first orientation and then sharpen the eye, leading to an understanding of the particularity of a work or a group of works. We might say that every comparison serves to elucidate an image by drawing on other images. Following Pächt, the distance between the objects compared in a first step must be as short as possible (Pächt 1999, 87). But it does not follow that comparability simply results from formal congruities. In fact, comparability is constituted by at least one constant, which, as the *tertium comparationis*, forms its basic precondition, and formal similarity is just one such criterion among many. Comparability can also be based on a *tertium comparationis* that is not present at the visible level of the image but is, for example, established by a shared context. Further bases for comparison in this sense might be a shared time or place of origin, a shared theme or subject, or the same design purpose. In such cases, two images may be juxtaposed that show two completely different outcomes even though they were, for example, created to achieve the same end.

With regard to technical images, the spectrum of comparison criteria is expanded by the scientific contexts from which the images come, the functions they serve in these contexts, and the imaging technology used to generate them. A particular challenge is posed by comparisons of artistic and non-artistic images and the investigation of migrating imagery that diffuses through various disciplines. Here, too, comparison must always be made based on an awareness of the epistemic interests and deliberately selected criteria. For instance, when similar images are brought together with a particular interest in the transmission and adoption of forms, such comparison should be undertaken, on the one hand, with an awareness of the possible difference between individual associations, the viewer's own visual memory, and that of the creator of the image. On the other hand, formal proximity must be continually related to other criteria such as function, context, and the conditions under which the images were produced. It is then just as possible for a comparison to fail to produce useful knowledge as it is for it to visibly provide associative, productive cause for thought and initiate new investigations (figs. 3a–3c). Whether a comparison is useful can only be determined in the course of further research and a detailed investigation of the objects brought together as well as in the discussion following a public presentation of comparisons. In this process, the relative significance of equivalences and differences should be subject to ongoing critical revision. The legitimacy of a presented comparison can only be determined by the verbal argumentation that accompanies it. This also means that the respective interests in it must be disclosed and made transparent. —VD

LITERATURE

Bader, Lena. "Imaging Imagery: On the Visuality of Iconic Criticism and the Early Media of Visual Studies in Their Current Meaning." In *Image-Problem? Medienkunst und Performance im Kontext der Bilddiskussion*, ed. Slavko Kacunko and Dawn Leach, 67–86. Berlin: Logos-Verlag, 2007.

Baxandall, Michael. *Patterns of Intention: On the Historical Explanation of Pictures.* New Haven: Yale University Press, 1985.

Didi-Huberman, Georges. "Was zwischen zwei Bildern passiert: Anachronie, Montage, Allegorie, Pathos." In *Vergleichendes Sehen*, ed. Lena Bader, Martin Gaier, and Falk Wolf, 537–72. Munich: Fink, 2010.

Dilly, Heinrich. "Lichtbildprojektion: Prothese der Kunstbetrachtung." In *Kunstwissenschaft und Kunstvermittlung*, ed. Irene Below, 153–72. Giessen: Anabas-Verlag, 1975.

Elkins, James. *Visual Practices Across the University*. München: Wilhelm Fink Verlag, 2007.

Friedländer, Max J. *Genuine and Counterfeit: Experiences of a Connoisseur*. New York: A. and C. Boni, 1930.

Friedländer, Max J. *On Art and Connoisseurship*. Boston: Beacon Press, 1942.

Geimer, Peter. "Unwillkürliche Kunstgeschichte: Peter Geimer im Gespräch
mit Texte zur Kunst." *Texte zur Kunst*, no. 62 (June 2006): 56–71.

Geimer, Peter. "Vergleichendes Sehen oder Gleichheit aus Versehen? Analogie und Differenz in kunsthistorischen Bildvergleichen." In *Vergleichendes Sehen*, ed. Lena Bader, Martin Gaier, and Falk Wolf, 45–69. Munich: Fink, 2010.

Ginzburg, Carlo. "Morelli, Freud and Sherlock Holmes: Clues and Scientific Method." *History Workshop*. (1980): 5–36.

Gombrich, E.H. *Art and Illusion: A Study in the Psychology of Pictorial Representation*. New York: Pantheon Books, 1960.

Klonk, Charlotte, and Michael Hatt. *Art History: A Critical Introduction to Its Methods*. Manchester: Manchester University Press, 2006.

Lutz, Helga, Jan-Friedrich Missfelder, and Tilo Renz, eds. *Äpfel und Birnen: Illegitimes Vergleichen in den Kulturwissenschaften*. Bielefeld: Transcript, 2006.

Nelson, Robert S. "The Slide Lecture, or the Work of Art 'History' in the Age of Mechanical Reproduction." *Critical Inquiry* 26, 3 (2000): 414–434.

Pächt, Otto. *The Practice of Art History: Reflections on Method*. New York: Harvey Miller, 1999.

Ratzeburg, Wiebke. "Mediendiskussion im 19. Jahrhundert: Wie die Kunstgeschichte ihre wissenschaftliche Grundlage in der Fotografie fand."

Wölfflin, Heinrich. Principles of Art History: The Problem of the Development of Style in Later Art [1915], trans. M.D. Hottinger. New York: Dover Publications, 1932. Kritische Berichte, no. 1 (2002): 22–39.

Reichle, Ingeborg. "Medienbrüche." *Kritische Berichte*, no. 1 (2002): 40–56.

Wenk, Silke. "Zeigen und Schweigen: Der Kunsthistorische Diskurs und die Diaprojektion." In *Konfigurationen: Zwischen Kunst und Medien*, ed. Sigrid Schade and Georg Christoph Tholen, 292–305. Munich: Fink, 1999.

Wölfflin, Heinrich. *Principles of Art History: The Problem of the Development of Style in Later Art* [1915], trans. M.D. Hottinger. New York: Dover Publications, 1932.

FIG. 1: Wilhelm Conrad Röntgen, X-ray image of his wife Bertha's hand, December 1895. Picture from a series of prints that Röntgen sent to colleagues on January 1, 1896. Archive of the Deutsches Röntgen-Museum Remscheid-Lennep, Germany. © Deutsches Röntgen-Museum, Remscheid-Lennep.

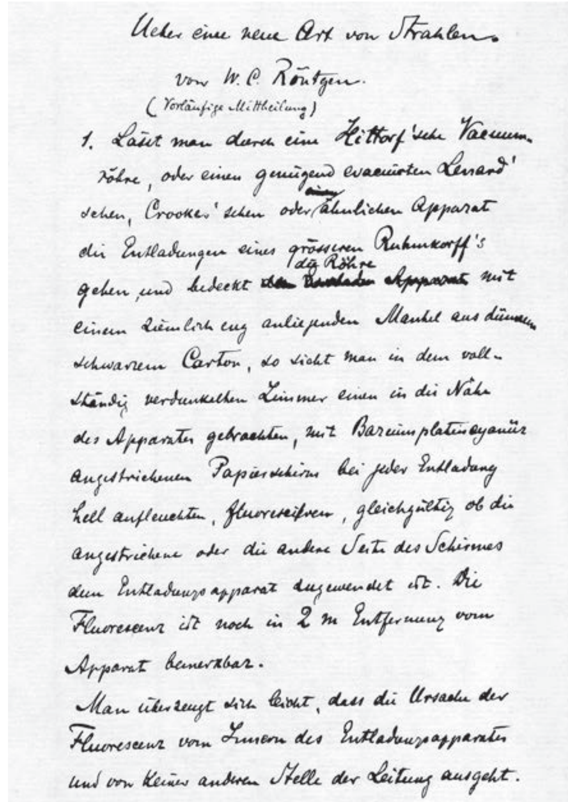

Ueber eine neue Art von Strahlen
von W.C. Röntgen.
(Vorläufige Mittheilung)
1. Lässt man durch eine Hittorf'sche Vacuum-
röhre, oder einen genügend evacuirten Lenard'
schen, Crookes'schen oder einen ähnlichen Apparat
die Entladungen eines grösseren Ruhmkorff's
gehen und bedeckt die Röhre mit
einem ziemlich eng anliegenden Mantel aus dünnem,
schwarzem Carton, so sieht man in dem voll-
ständig verdunkelten Zimmer einen in die Nähe
des Apparates gebrachten, mit Bariumplatincyanür
angestrichenen Papierschirm bei jeder Entladung
hell aufleuchten, fluoresciren, gleichgültig ob die
angestrichene oder die andere Seite des Schirmes
dem Entladungsapparat zugewendet ist. Die
Fluorescenz ist noch in 2 m Entfernung vom
Apparat bemerkbar.
Man überzeugt sich leicht, dass die Ursache der
Fluorescenz vom Innern des Entladungsapparates
und von keiner anderen Stelle der Leitung ausgeht.

FIG. 2: Röntgen's manuscript "Über eine neue Art von Strahlen" ("On a New Kind of Rays"), sent to the publisher in late 1895, in which he describes his experimental set-up for the first time. Archive of the Deutsches Röntgen-Museum Remscheid-Lennep, Germany. © Deutsches Röntgen-Museum, Remscheid-Lennep.

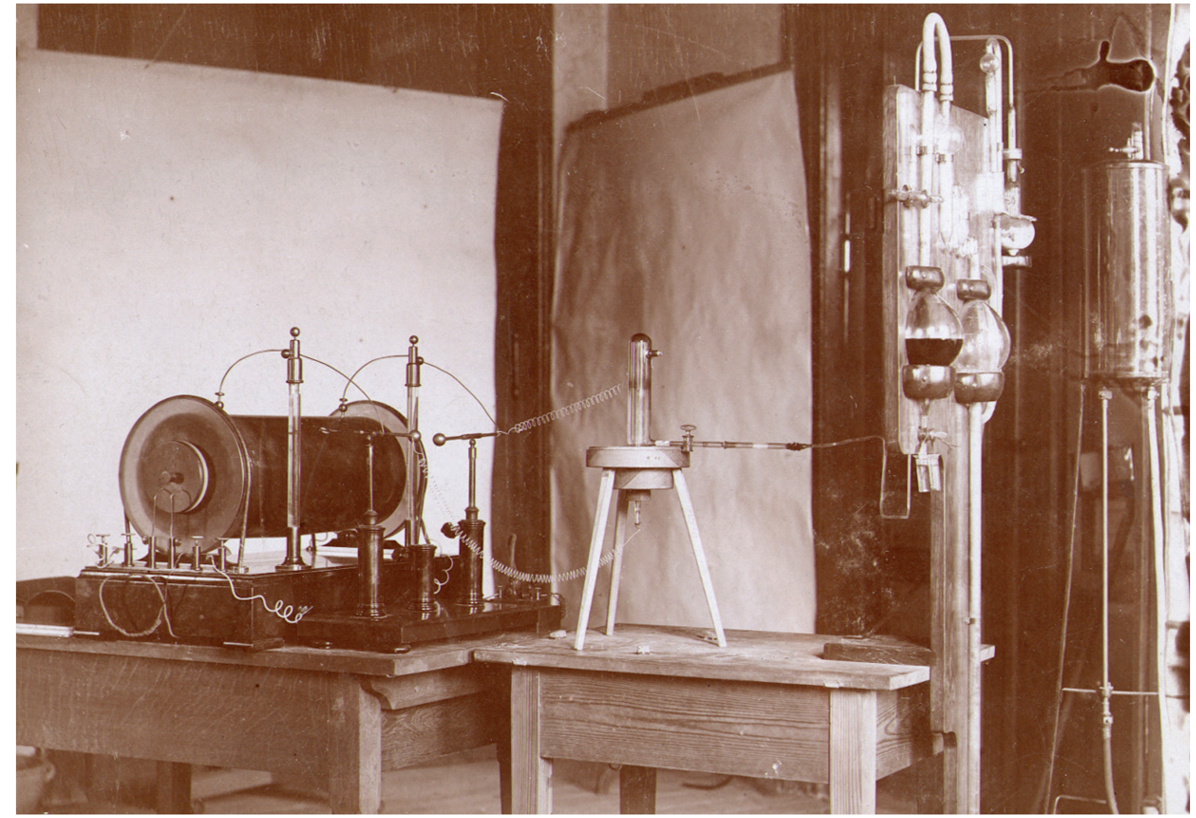


FIG. 3: The laboratory and devices Röntgen used to research the rays; photo taken in Würzburg in May 1923, showing the spark inductor, X-ray tube, and vacuum pump (from left). Archive of the Deutsches Röntgen-Museum Remscheid-Lennep, Germany. © Deutsches Röntgen-Museum, Remscheid-Lennep.

ICONOLOGICAL ANALYSIS

The term *iconological analysis* designates the art-historical method that seeks to complement the method of iconography, which identifies and interprets subjects and motifs. Iconological analysis synthesizes the precise description of a work with studies of its contexts. This synthesis guides the interpretation of the work (Warnke 1980; Schmidt 1993; Warburg 1999). Although the method is central to the work of the German art historian Aby Warburg (1866–1929), his student Erwin Panofsky was the first to develop and publish a three-stage model of iconological analysis; he called the third stage of this model "iconological interpretation" (Panofsky 1970 and 1981; Holly 1984). Since then, iconological analysis has been taken to refer to the step-by-step interpretation of pictorial artifacts within their cultural and historical contexts (Elsner et al. 2012; Mitchell 1986).

According to Panofsky's model, interpretation begins with a formal description (first stage), proceeds to an iconographic analysis of content (second stage), and then determines the meaning of the work of art (third stage). This last phase analyzes the period in which the work was created and the prevailing social, political, philosophical, and religious attitudes of the era or nation that influenced its creation. The work as a product of these attitudes thus appears as paradigmatic or symptomatic of an epoch or, in the context of the history of ideas, as a historical document of ideas, opinions, and views. Beyond such symptomatic qualities, the extent to which the work itself actively participated in forming these ideas, opinions, and views requires scrutiny as well.

Iconological analysis seeks to reconstruct traditions and reveal layers of meaning by critically investigating literary sources of various provenances, including documents from everyday culture and superstition as well as other artifacts related to the work of art. Such meaning may not be apparent to the observer at first glance, nor was it necessarily intended by the producer or commissioner of the work. Iconology as practiced by Panofsky, especially in the concluding phase of the interpretation, seeks to place a work in a wider context of meaning. The interpreter's profound and broad knowledge of the cultural and historical context of the work serves as a corrective to his "personal psychology" or "worldview."

In 1912, Aby Warburg described iconological analysis in the conclusion to his lecture on the frescoes in the Palazzo Schifanoia, Ferrara, as a method "that can range freely, with no fear of border guards, and can treat the ancient, medieval and modern worlds as a coherent historical unity." He proposed that art historians examine "the purest and the most utilitarian of arts as equivalent documents of expression" (Warburg 1999), overcome evaluative categories such as "high" and "low," transcend disciplinary boundaries, and proceed by covering various periods, occasionally anachronistically, when searching for correlations among traditional forms of representation and motifs (Beyer 1992).

The underlying assumption that every form is a historical phenomenon and has a history of its own must therefore also apply to the interpretation of technical and scientific images and be the starting point of their iconological analysis. The latter takes into account first of all the image's specific scientific context; in so doing, it relies on knowledge from other disciplines. To decode the ways in which scientific and technical images create meaning, iconological analysis examines their functions within productive and epistemic processes and attempts to identify the formal properties of images by examining the interplay of technological conditions, design inter-

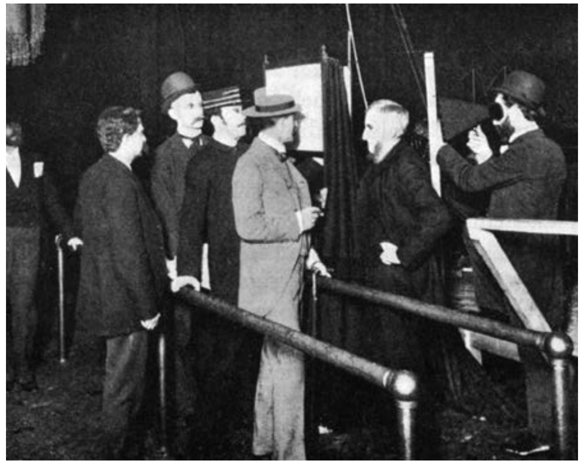
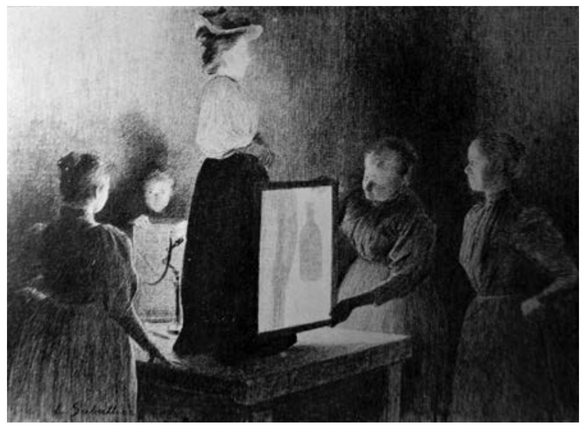


FIG. 4 (left): Demonstration of radiographic screening during the special exhibition organized by Thomas Alva Edison about X-rays as part of the *Electric Light Exhibition* in New York, May 1896. One after another, visitors were invited to hold their hands behind the fluorescent screen. Otto Glasser, *Wilhelm Conrad Röntgen und die Geschichte der Röntgenstrahlen* (Berlin, Göttingen, Heidelberg: Springer, 1959 [1931]), 204. Edward P. Thompson, *Roentgen Rays and Phenomena of the Anode and Cathode*, published in 1896 by the D. Van Nostrand company in New York.

FIG. 5 (bottom left): Medical examination using X-rays, around 1900. Advertising for the Parisian X-ray laboratory of the instrument maker Arthur Radiguet, who made his machines available to doctors. *La Nature. Science et Progrès* (Paris 1897).

FIG. 6 (bottom right): Smuggler caught by customs officials with the help of X-rays. Popular illustration, 1897. *L'Illustration*, no. 2836, July 3, 1897, 7.



ventions, and scientific convictions. In light of the ideas proposed by the Polish philosopher of science Ludwik Fleck, then, the aim is to reveal the extent to which social and psychological aspects influence the creation of scientific images that develop in what Fleck called a "communication of ideas" among the scientists. He investigated this process under the headings "thought style" and "thought collective" (Fleck 1979). The method of iconological analysis also focuses on the productive interventions of scientists and apparatuses and their impact on the aesthetics and visual effects of the images.

In order to examine the diverse purposes and claims of scientific and technical images, iconological analysis also relies on contemporary texts such as scientific reports and papers. It inquires into possible references to scientific discourses and into models and traditions of representation within and outside specific disciplines. The transfer of images to the public sphere, their popular reception, and the repercussions in science must also be part of such an analysis, as must the attempt to position scientific and technical images in an overall history of forms of visual representation. Such classification creates a cultural context that does not efface the distinction between the scientific and the popular, between art and non-art, but provides insight into the exchanges, interactions, and interconnectedness of these areas. The challenge of an iconology of scientific imagery, then, is to establish a balance between this integration into a broader history of images and the attention to specific scientific and technological contexts.

Early X-ray images, which, apart from their medical purposes, made it possible actually to see through a wide range of objects, are an exemplary field for such iconological analysis. Once described and historically classified, they may be interpreted as an expression of the voyeuristic curiosity and widespread mania for translucency typical of fin de siècle culture. That culture expanded around 1900 into diverse scientific and popular areas and still affects the visualization strategies of today's medical imaging processes. (figs. 1–8)

Collections of drawings by sixteenth-century natural philosophers in which traditional representations of monsters and mythical creatures are presented on an equal footing next to images documenting individual observations are another example. This juxtaposition is virtually incomprehensible in the perspective of today's understanding of taxonomy. Yet the iconological method reveals, for example, the pictorial traditions inherent in the discourse on natural philosophy in Aldrovandi's picture collection and the concept of nature that is expressed in the composition of such a collection.
—VS/VD

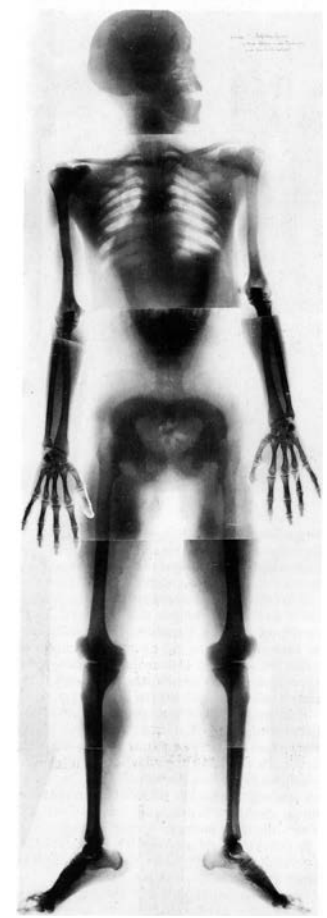


FIG. 7 (left): X-ray image of the human body, a collage of six images of three men, made by the physicist Ludwig Zehnder and photographer Karl Ernst Kempke in the summer of 1896. Height: approximately 1.84 m. Michel Frizot, ed., *Neue Geschichte der Fotografie* (Cologne: Könemann 1998), 281. © Foto Deutsches Museum, BN01755.

FIG. 8 (right): Magnetic resonance tomography image from an article in *Die Zeit*, 2004. The popular reception of new imaging techniques such as computer tomography (CT) and magnetic resonance tomography (MRT) shows a fascination with the technology similar to that elicited by early X-ray images; note, for instance, that—as the article reports—people in the United States even undergo full-body imaging in shopping malls as a precaution. The medical benefits, meanwhile, are of secondary importance, and the debate over the widespread application of this image sectioning procedure is controversial. Some argue that full-body MRT scanning offers preventative health benefits, while others point to the possibility of erroneous results and the difficulties in interpreting the images. *Die Zeit*, January 15, 2004, 28. © Tobias Beck.

LITERATURE

Beyer, Andreas, ed. *Die Lesbarkeit der Kunst: Zur Geistes-Gegenwart der Ikonologie*. Berlin: Wagenbach, 1992.

Elsner, Jaś, and Katharina Lorenz. "The Genesis of Iconology." *Critical Inquiry* 38, 3 (2012): 483-512.

Fleck, Ludwik. *Genesis and Development of a Scientific Fact* [1935]. Chicago: University of Chicago Press, 1979.

Holly, Michael Ann. *Panofsky and the Foundations of Art History*. Ithaca, N.Y: Cornell University Press, 1984.

Jordanova, L J. *Sexual Visions: Images of Gender in Science and Medicine between the Eighteenth and Twentieth Centuries*. Madison, Wis: University of Wisconsin Press, 1989.

Kaemmerling, Ekkehard, ed. *Ikonographie und Ikonologie: Theorien, Entwicklung, Probleme*. Cologne: DuMont, 1979.

Mitchell, W J. T. *Iconology: Image, Text, Ideology*. Chicago: University of Chicago Press, 1986.

Panofsky, Erwin, "The Concept of Artistic Volition" [1920], trans. Kenneth J. Northcott, and Joel Snyder. *Critical Inquiry*. 8.1 (1981): 17–33.

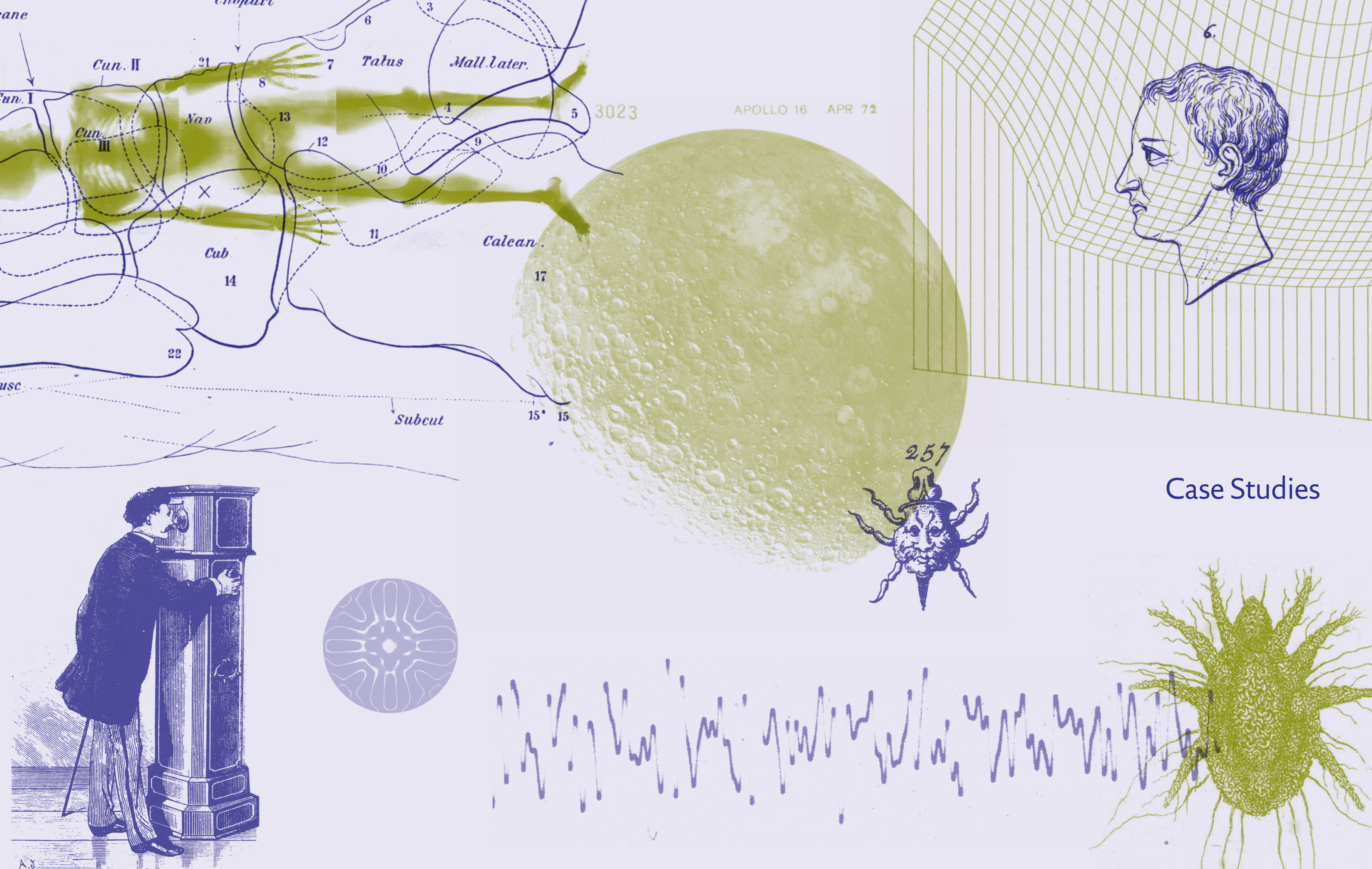
Panofsky, Erwin. "Introduction: The History of Art as a Humanistic Discipline" and "Iconography and Iconology: An Introduction to the Study of Renaissance Art." In *Meaning in the Visual Arts*, 23–50 and 51–81. Harmondsworth: Penguin Books, 1970.

Panofsky, Erwin. *Studies in Iconology: Humanistic Themes in the Art of the Renaissance*. New York: Oxford University Press, 1939.

Schmidt, Peter. *Warburg und die Ikonologie: Mit einem Auszug unbekannter Quellen zur Geschichte der Internationalen Gesellschaft für Ikonographische Studien von Dieter Wuttke*. Wiesbaden: Harrassowitz, 1993.

Warburg, Aby. "Italian Art and International Astrology in the Palazzo Schifanoia, Ferrara (1912)." In *The Renewal of Pagan Antiquity: Contributions to the Cultural History of the European Renaissance*, 563–91. Los Angeles: Getty Research Institute for the History of Art and the Humanities, 1999.

Warnke, Martin. "Ikonologie." In *Die Menschenrechte des Auges: Über Aby Warburg*, ed. Werner Hoffmann, 55–61. Frankfurt am Main: Europäische Verlagsanstalt, 1980.



Case Studies

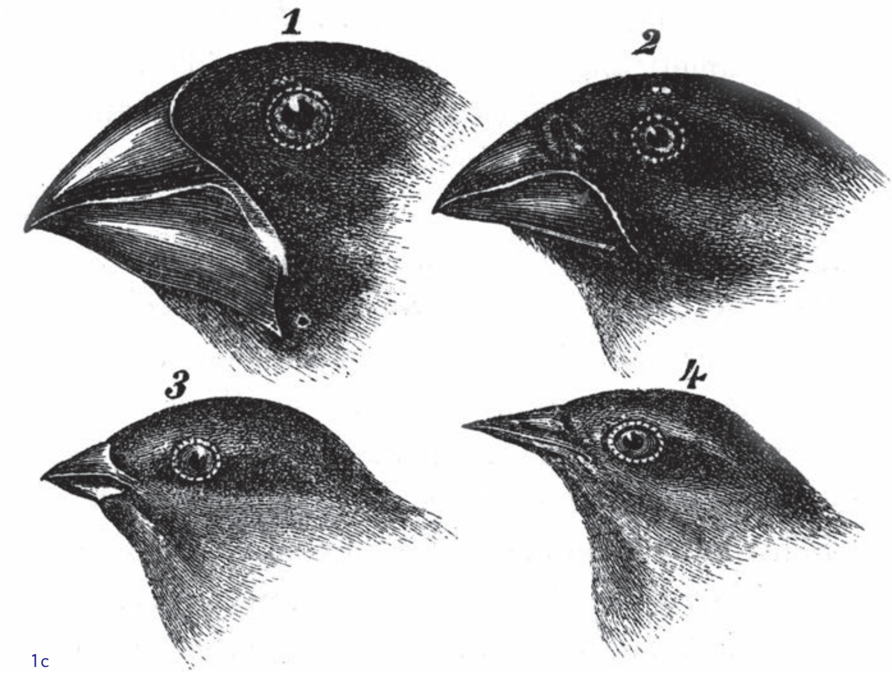
1a

1b

CHAINS OF REPRESENTATIONS

According to a traditional understanding, scientific images attain a purpose outside themselves by referring to phenomena and data. Since the 1980s, however, scholars in the field of science studies have increasingly pointed out that the traditional notion of a correspondence between a scientific image and a discrete object is untenable because it is impossible to clearly correlate the representation with what is represented. Consequently, the question of the referent in science cannot be posed in the sense of a simple illustration of, and references to, reality. The philosopher of science Ian Hacking contributed a vital impetus to the discussion of these issues in the early 1980s with his book *Representing and Intervening*. He emphasized that representation is only possible through the experimenter's intervention, so the represented can only emerge out of the intervening construction of a representation (Hacking 1983) . According to this view, representation cannot be understood in terms of references to reality or a correspondence with a discrete object; it must be conceived in terms of constructive processes (Lynch 1990 and1994; Hagner 1997). For this reason, the philosopher of science Hans-Jörg Rheinberger has proposed dispensing with the word *representation* in the context of the experimental-instrumental acquisition of findings and speaking instead of "visualizations" (Rheinberger 2001).

Furthermore, in studying experimental practices, the history of science has highlighted the reference of representations to other representations. These references are shaped by complex referential practices. Many authors writing on the history and philosophy of science therefore use the term *chains of representations* (Pickering 1995, Latour 1999) to metaphorically describe the process of one representation transforming into



1c

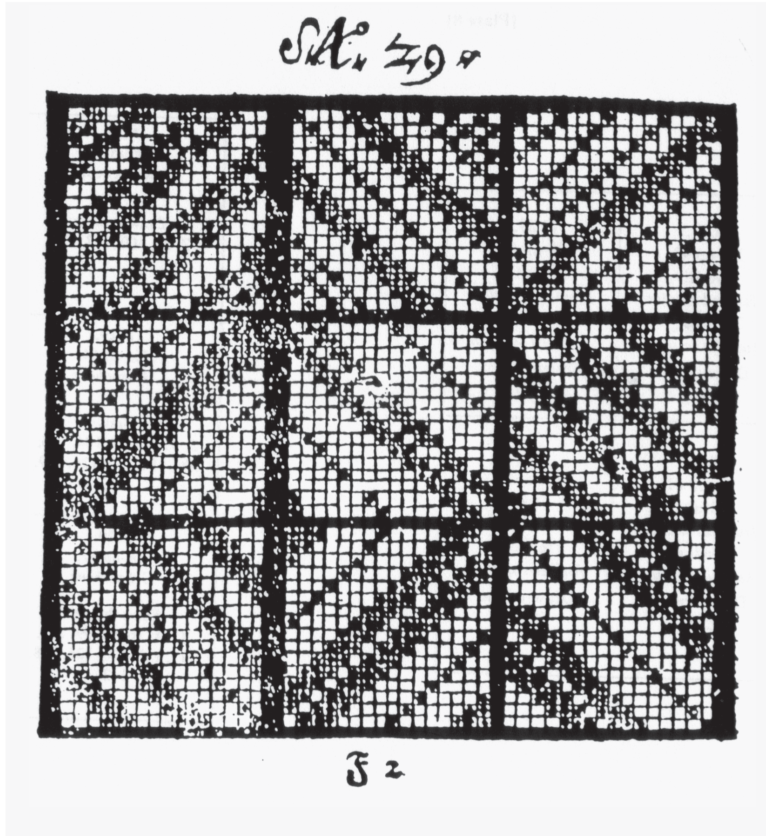
FIGS. 1a–1c: In her book *Darwins Bilder: Ansichten der Evolutionstheorie 1837–1874* (2007, 80–81), Julia Voss reconstructs a chain of representations in Latour's sense in the example of Charles Darwin's Galápagos finches. Shot by Darwin and his companions on the Galápagos Islands in the Pacific in 1835, the birds were preserved as skins (fig. 1a: Galápagos Island finch with a museum label in Darwin's own hand at the Natural History Museum, London). After they were sent to London in 1837, John Gould, curator of the Zoological Society, identified them as a genus of finch and sketched them for the first time. Based on these initial sketches, Gould's wife Elizabeth then made drawings, which she transferred to a stone that was subsequently used as the template in the lithographic printing process. The resulting lithographs (fig. 1b: *Geospiza strenua*; Elizabeth Gould's lithographic plates from *The Zoology of the Voyage of H.M.S. Beagle*, 1841) presented the finches as species of a new genus in color and with a section of landscape. Darwin examined, trimmed, and arranged the plates anew, creating a comparative sequence of images of four of the finch species collected on the Galápagos Islands (fig. 1c: The Galápagos finches in the German edition of Darwin's *A Naturalist's Voyage round the World*, 1899). Only in this overall view did the gradual changes in the finches become apparent, helping Darwin to pave the way for his theory of evolutionary speciation. Fig. 1a: Julia Voss, *Darwins Bilder. Ansichten der Evolutionstheorie 1837–1874* (Frankfurt a.M.: Fischer Taschenbuch Verlag, 2007), fig. 13. Fig. 1b: Charles Darwin, ed., *The Zoology of the Voyage of H.M.S. Beagle, Part III: Birds* (London: Smith, Elder & Co., 1841), plate 37. Fig 1c: Charles Darwin, *Gesammelte Werke: Reise eines Naturforschers um die Welt*, 2nd ed. (Stuttgart: E. Schweizerbart'sche Verlagshandlung, 1899), 413. © Natural History Museum, London.

another. This approach has always been practiced in the field of art history, where works are related back to their preliminary studies. Sketches, designs, and models also raise the question of how steps in the transformation from preliminary stages to the final work are to be interpreted (Morgan et al. 1984).

The ethnologist and sociologist of science Bruno Latour has made a central contribution to the concept of a chain of representations with his field study of a survey of the Amazon rainforest, which describes in detail how the scientists initially gathered and sorted plant and soil samples so as to reduce them over several stages to sketches and graphics. Latour emphasizes that, with each of these transformations, there is discontinuity, while there must also be constancy and resemblance. Latour sees the reference here not in a mimetic correspondence between the chain's first and final links—in his example, between the jungle on the one hand and the diagrams of the jungle that were eventually published on the other—but in the properties of the chain. Each link in the chain must necessarily refer to a previous one, and the chain must be able to be traced back to its beginnings (Latour 1999). The universality of this approach lies in the description of the transition and transformation between different media, such as objects in collections, graphs, drawings, and diagrammatic images (Figs. 1a–1c and 2a–2g). In this connection, Latour emphasizes the existence of specific conventions for different forms of representation. This suggests the importance of the media characteristics of different forms of representation: knowledge, too, is shaped by the media it is presented in. What should be investigated, then, is how the knowledge represented changes with such transformations of the media (Mersch 2006).

This approach may be productive in a historical *Bild-*

Fig. 3: Nine notations of possible tie-ups from Ziegler's *Weber Kunst und Bild Buch* (Ulm, 1677).



weave (the "ground" of the figure-ground distinction, as it were) in patterned fabrics. Yet *Bild* was in pattern-weaving also the general term for the schematic draft for a fabric made on paper; it is the historical term, that is to say, for pattern notation in weaving.[5]

The forms of patterns treated in Ziegler's publication represent a complicated special weaving technique practiced primarily in southern Germany.[6] These were geometrically patterned fabrics in which the weavers combined shapes such as squares, lines, and triangles to create abstract designs; the textiles were produced on so-called shaft looms. Aside from Ziegler's notation, there existed other conventions on how to notate fabric patterns, but these did not circulate publicly until the age of the encyclopedia in the eighteenth century.[7] Ziegler was thus one of the first to publish on the art and techniques of weaving, ending the guilds' exclusive control over what had heretofore been a strictly kept secret.[8] All of these forms of fabric pattern notation differed considerably from the well-known pattern drawdowns used in planning pictorial patterns (fig. 4), despite the sometimes close visual resemblance.[9] The latter patterns, which could be implemented in a variety of techniques, were widely disseminated in collections as far back as the early sixteenth century, but unlike the notations discussed here, they offered no directions regarding the technical realization on the loom. The following paragraphs will therefore address the technology of weaving and the question of what technical knowledge the notations connote.

5 For the historical use of the term *Bild* in weaving, see also Walther von Hahn, *Die Fachsprache der Textilindustrie im 17. und 18. Jahrhundert* (Düsseldorf: VDI, 1971).

6 This weaving technique produced patterns called "Spitzköper" (reverse twill) and "Schachwitz." The fabrics were also called "Bauerndamast" (country damask); today's standard term is *block damask*.

7 Schematic representations may be found in the French encyclopedic treatments of eighteenth-century weaving, where they appear under the label "translation"; see, e.g., Jean Paulet, *L'Art du fabricant d'étoffes de soie*, 7 vols. (Paris, 1773–1789). A third convention may be found in an Italian manuscript from Lucca that is dated to the 1680s, or only a few years before Ziegler's handbook of weaving. This notational format uses numerals. See Gino Arrighi, *Un manuale secentesco dei testori lucchesi* (Lucca: M. Pacini Fazzi, 1986).

8 Ziegler had various reasons to publish these materials, some of which related to his Protestant ideals about training and education. See Patricia Hilts, "Translator's Introduction," in Ziegler, "Weber Kunst und Bild Buch," 14.

9 On this practice, see Lesley Ellis Miller, "Representing Silk Design: Nicolas Joubert de l'Hiberderie and *Le Dessinateur pour les étoffes d'or, d'argent et de soie* (Paris, 1765)," *Journal of Design History* 17, no. 1 (2004): 29–53.

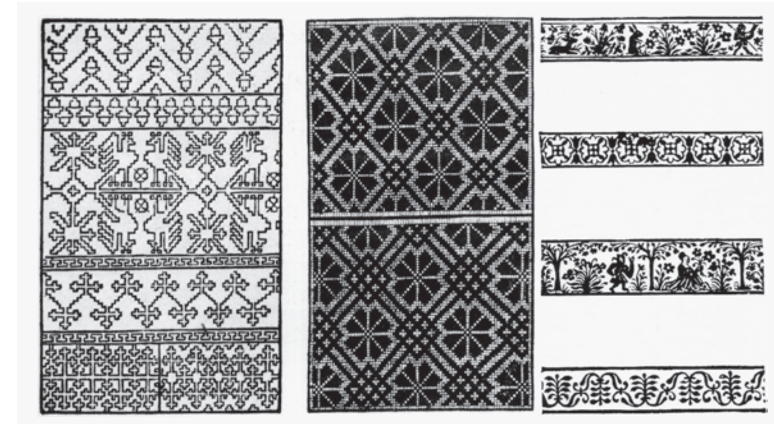


FIG. 4: Three plates from early pattern books: *Ein new Modelbuch* (probably Zwickau, 1526); *Ein new getruckt model Büchli* (Augsburg, 1529); *Furm oder modelbüchlein* (Augsburg, ca. 1523). Margarete Abegg, *Apropos Patterns for Embroidery, Lace and Woven Textiles* [1978] (Riggisberg: Abegg-Stiftung, 1998), 25, figs. 14, 15, and 4.

The Technical Procedure of Shaft-Weaving

Ziegler's notations cannot be appreciated without a basic familiarity with the loom for which they were set down, the shaft loom, which had come into general use in Europe in the thirteenth and fourteenth centuries; see figure 5 for a schematic illustration of a shaft loom. As the name indicates, the distinguishing feature of this weaving technology consisted of a system of shafts the weaver raised and lowered using pedals or treadles. To create a specific pattern using this process, the warp—the system of parallel threads held taut by the loom—is divided into groups and individually threaded through the eyelets (heddle eyes) of a system of threads running vertically between the shafts. Moving like the arms of a marionette, the shafts can raise the groups of warp threads, opening a "shed" through which the weaver passes the shuttle with the weft.[10] The operation of the shafts resembles that of an organ: by stepping on one of the pedals, the corresponding shafts raise a set of warp threads before the weaver picks the shuttle—that is, inserts a single weft thread—and drop back once the pick is complete. Operating another treadle reopens the shed for the

10 See Annemarie Seiler-Baldinger, *Systematik der textilen Techniken* [1973] (Basel: Wepf, 1991), 86; Eric Broudy, *The Book of Looms: A History of the Handloom from Ancient Times to the Present* (New York: Van Nostrand Reinhold, 1979), 102–23.

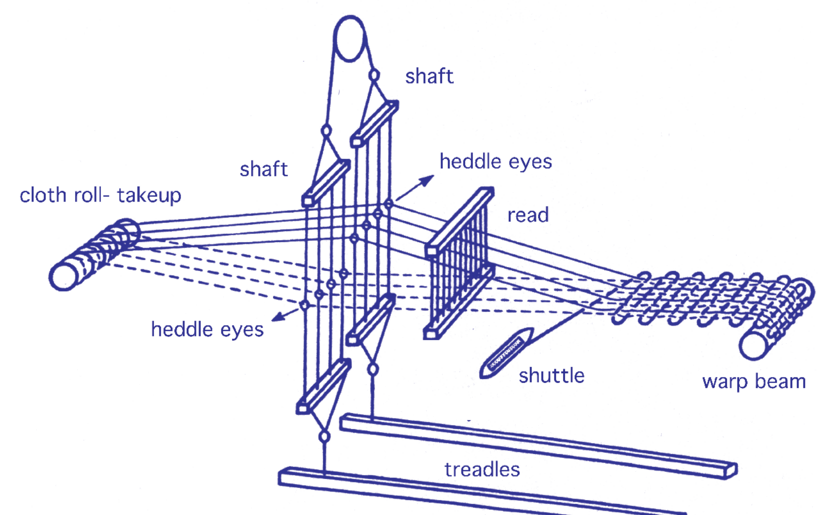


FIG. 5: Shaft loom with two shafts and two treadles (schematic illustration). Anna Döpfner, *Bindungen: Flechten und Weben* (Berlin: Museumspädagogischer Dienst, 1993), 11. Stiftung Deutsches Technikmuseum Berlin, Historisches Archiv.

subsequent row of the fabric, raising the next group of warp threads. The weaver throws the shuttle again, returning it to its initial position. The reed battens each row of the fabric to the completed fabric.

Depending on the weave to be created, different sets of warp threads are grouped together on several shafts. Two shafts (as shown in fig. 5) are sufficient for the plain or linen weave; all other weaves require more than two shafts. Threads may then be divided into a correspondingly larger number of groups and raised by operating the appropriate treadle. For instance, in order to produce a four-weave twill (the weave in denim, among other fabrics) with a "step" or offset between rows, the weaver counts off the warp ends from one to four and threads them into the first, second, third, and fourth shafts accordingly. Operating the treadles one after the other before beginning afresh creates the characteristic diagonal

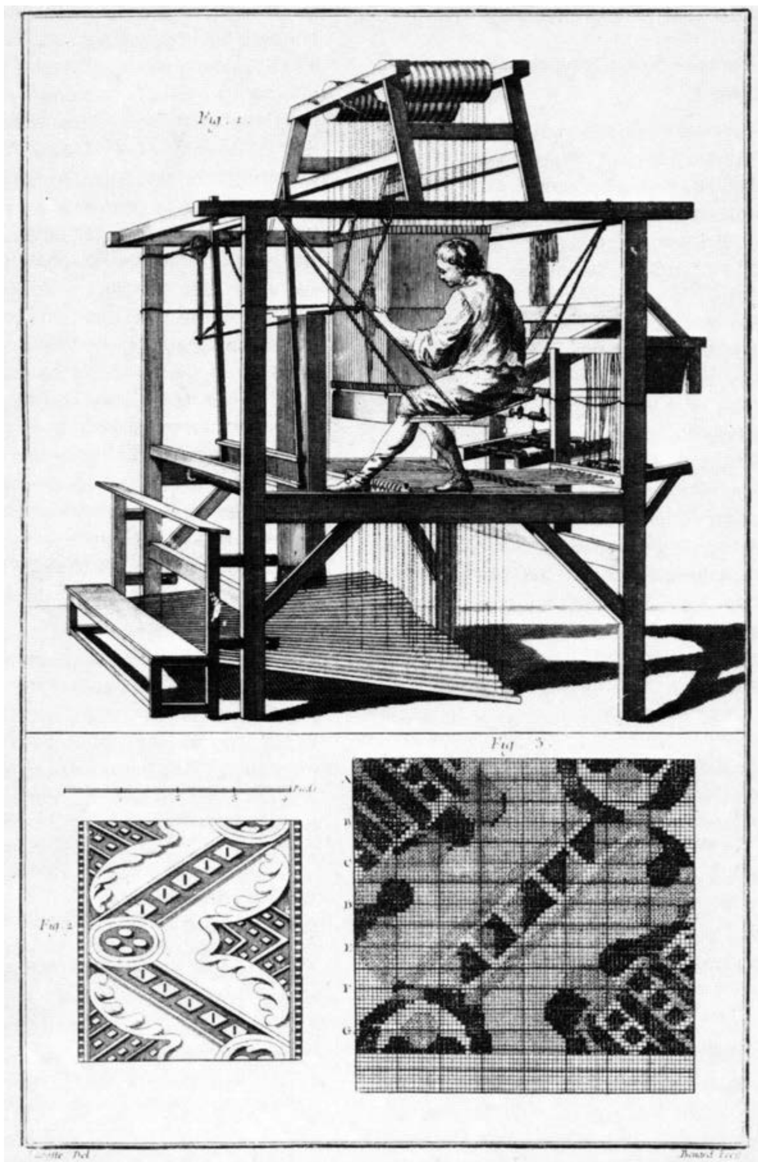


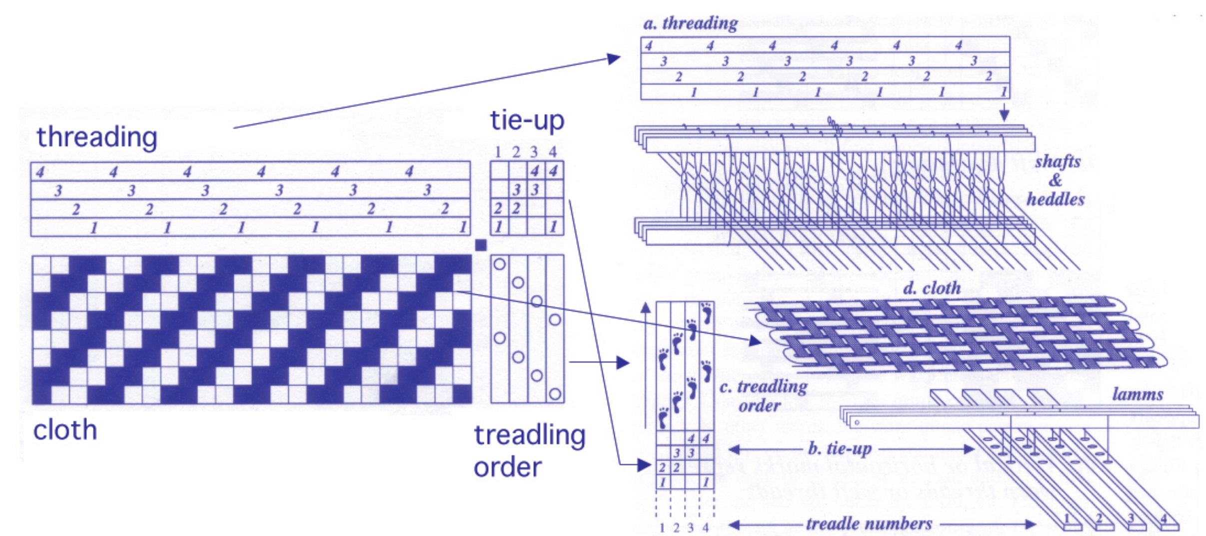
FIG. 6: Treadle loom for ribbon weaving from Diderot's *Encyclopédie* (Paris, 1751–1780). Denis Diderot and Jean-Baptiste le Rond d'Alembert, *Recueil de planches, sur les sciences, les arts libéraux, et les arts méchaniques, avec leur explication, L'art de la soie* (Paris, 1751–1780), *Passementerie*, plate vii.

ribbing. The possible combinations of a mere four shafts already allow for much longer patterns than groups of four picks; threading the warp into a larger number of shafts makes even more complex patterns possible. The pattern-weavers of Ulm used looms ranging from eight to more than thirty shafts similar to the shaft loom for *passementerie* weaving shown in an illustration in Diderot and d'Alembert's *Encylopédie* (fig. 6), taking the principle of shaft-weaving to the limits imposed by the need to arrange the shafts and treadles in the loom's legroom.

Marx Ziegler's System of Notation Compared to Contemporary Practice

The treadles, shafts, and warp threads of the loom return in abstract form in the notation on paper. The parallel arrangement of systems of threads and shafts in the device appears as orthogonal systems of lines forming rows and columns. By adapting the number of lines in the notations to the desired number of threads and shafts, the craftsman-artist can draft different patterns, not unlike the composer working on music paper, and plan their technical realization. To this end, the varying patterns are inscribed upon the scaffold of lines as series of strokes or dots, indicating to the weaver where he needs to tie knots and in what order he will have to operate the treadles.

FIG. 7: Schematic illustration of the modern form of pattern notation in relation to the parts of the shaft loom. Madelyn van der Hoogt, *The Complete Book of Drafting for Handweavers* [1993] (Petaluma, CA: Unicorn, 2000), collage of ills., 4, 5.



The specific quality of the historical forms of notation is best understood by comparing them to today's prevailing convention, the draft.[11] Figure 7 illustrates the basic weave pattern for twill as it appears in a modern textbook for manual weaving on a shaft loom. The arrows connect the schemata to the components of the loom they control. The structure of staggered squares shows the resulting weave as a pattern of black and white boxes. The modern *drawdown* here represents the order in which the threads interlace in the fabric: a black square tells the weaver that the warp thread passes over the weft thread; a white square, that the warp passes beneath the weft.[12] Three additional schematic representations accompany the drawdown. Along its upper edge runs the *threading*, which specifies the order in which the warp ends are threaded through

11 See Madelyn van der Hoogt, *The Complete Book of Drafting for Handweavers* [1993] (Petaluma, CA: Unicorn, 2000).

12 For some fabrics, a black square indicates that the warp thread passes *beneath* the weft thread.

Drawing and the Contemplation of Nature—Natural History around 1600: The Case of Aldrovandi's Images

Angela Fischel

Images have helped scholars gain knowledge of nature since the sixteenth century. The cabinets of the natural philosophers saw the compilation of large collections of drawings, documentary depictions of the natural world that recorded the forms of the animal and vegetal kingdoms.[1] *The collection built by the Bologna-based natural philosopher Ulisse Aldrovandi (1522–1605)*[2] *is among the most formidable of its kind. It has survived almost in its entirety, allowing us to illuminate how natural philosophy around 1600 worked with images. Aldrovandi saw himself as a pioneer of the modern natural sciences and championed the visual study of nature as the most important source of knowledge about it.*[3] *Closer inspection of his image collection, however, reveals that his drawings by no means derive directly from nature; many of the depictions of animals may be traced back to earlier printed sources. Other images stage their objects in suggestive compositions that exceed the purpose of objective documentation. This leads us to ask, then, what Aldrovandi meant by empirical study and, further, what specific functions images may have served in the context of early modern natural science.*[4]

One of the most spectacular drawings from Aldrovandi's collection shows two vipers (fig. 1).[5] The animals raise their heads in an aggressive posture; their bodies are intertwined to form a slightly asymmetrical ornament. The trompe-l'oeil drawing presents the vipers in a pictorial space that is visually continuous with the beholder's own environment, an effect underlined by the shadows and the use of perspective. The writhing snakes seem to come dangerously close to the beholder. The animals originally belonged to Francesco de' Medici, who sent the living specimens to Bologna to have them studied. At the same time, Aldrovandi had also asked for a drawing of the vipers—a prescient request, as it soon turned out: one of the two animals died during transport to Bologna, the other shortly after its arrival.[6] The death of the rare specimens left the collector with nothing but their likenesses. One of the functions of drawings in Aldrovandi's research practice was evidently to provide a vivid documentation of the forms of nature that would survive their physical demise. It remains remarkable, however, that a picture as dramatic and suggestive as the draftsman Jacopo Ligozzi's portrayal of the snakes would be used in this context. Ligozzi gave a very precise depiction of the animals, but what he shows is more than the phenotype of a rare species of viper: the use of trompe l'oeil also conveys a vigorous impression of the danger they pose, vividly illustrating an aspect of their nature as well.

1 The following discussion will be limited to drawings of animals in Aldrovandi's collection. For Aldrovandi's botanical drawings, see Enzo Crea, ed., *Hortus pictus: Dalla raccolta di Ulisse Aldrovandi* (Rome: Edizioni dell'Elefante, 1993). For Aldrovandi's image collection in general, see Giuseppe Olmi, *L'inventario del mondo: Catalogazione della natura e luoghi del sapere nella prima età moderna* (Bologna: Il Mulino, 1992); Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1996); and Brian Ogilvie, The Science of Describing (Chicago: University of Chicago Press, 2006). For recent literature on images in early modern zoology, see Sachiko Kusukawa, "Patron's Review: The Role of Images in the Development of Renaissance Natural History," *Archives of Natural History* 38, no. 2 (2011): 189–213. The zoological drawings from Conrad Gessner's collection are currently receiving a great deal of scholarly interest: Sachiko Kusukawa, "The Sources of Gessner's Pictures for the *Historia Animalium*," *Annals of Science* 67, no. 3 (2010): 303–28; Angela Fischel, "The 'Verae Icones' of Natural Philosophy: New Concepts of Cognition and the Construction of Visual Reality in Conrad Gessner's *Historia animalium*," *Yearbook for European Culture of Science* 6 (2011): 129–40; Florike Egmond, "A Collection within a Collection: Rediscovered Animal Drawings from the Collections of Conrad Gessner and Felix Platter," *Journal of the History of Collections* 25, no. 2 (2013): 149–70.

2 Ulisse Aldrovandi, who did most of his work at the University of Bologna, has always been considered a leading Italian natural philosopher of the sixteenth century. His most extensive project, a definitive natural history, remained incomplete. See Sandra Tugnoli Pàttaro, *Metodo e sistema delle scienze nel pensiero di Ulisse Aldrovandi* (Bologna: Clueb, 1981); Olmi, *L'inventario del mondo*, 22–157.

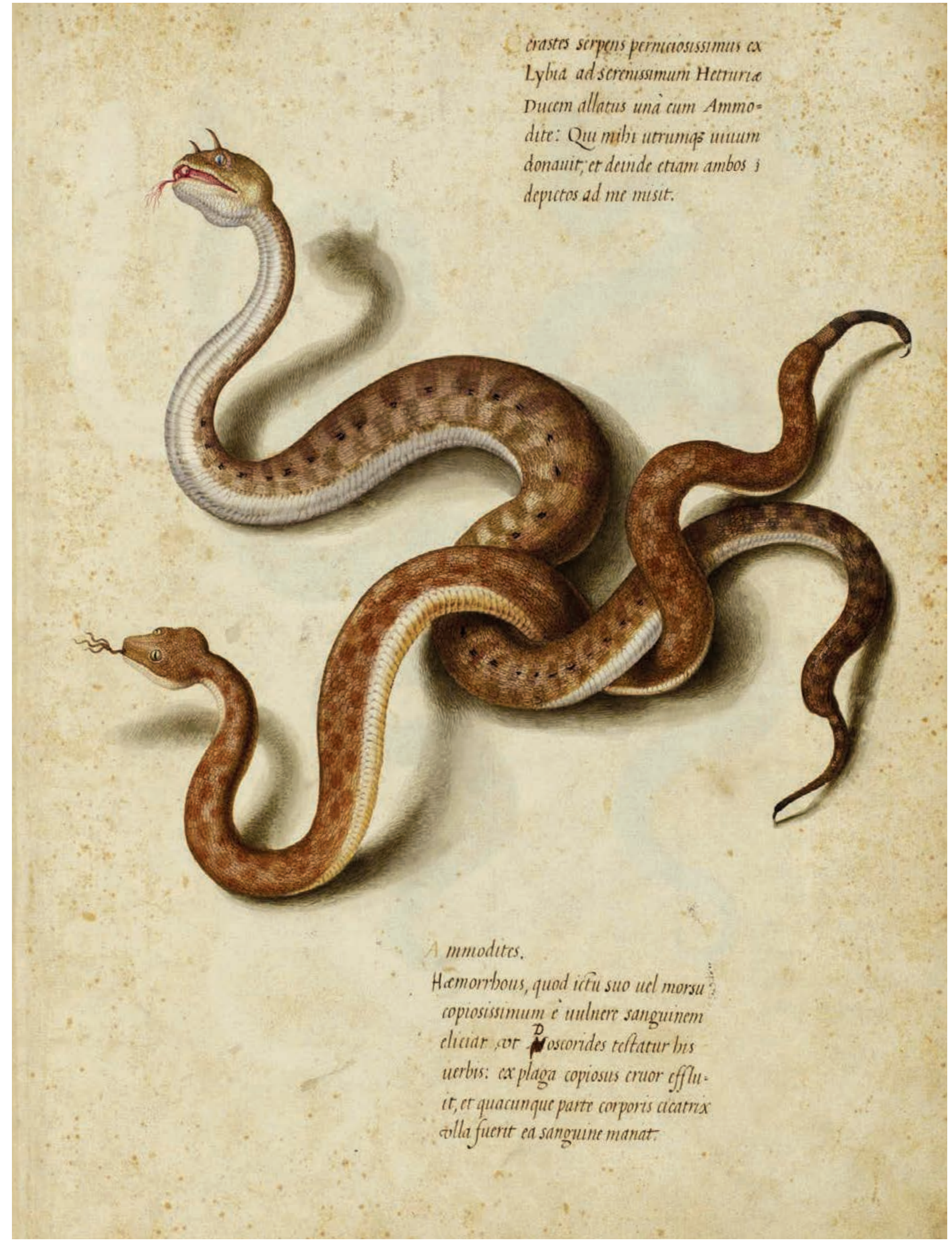


FIG. 1: Jacopo Ligozzi, Vipers, from Aldrovandi's collection of drawings, ca. 47.5 × 36 cm, 1577. Aldrovandi's collection of drawings, archive of the University Library of Bologna, Italy. *Tavoli di Animali* IV, c. 132, with permission of the University Library of Bologna.

Drawings constituted one part of Aldrovandi's natural history collection, which also included natural objects and preserved specimens;[7] herbariums containing dried vegetal specimens and collections of drawings of plants, numerous wood engravings made after the drawings, and a library.[8] The collection of animal drawings, which is now in the library of the University of Bologna, consists of six large leather-bound tomes.[9] The order in which the folios appear today obeys no recognizable system, instead laying out a vast and confusing mosaic of all sorts of conceivable—probable as well as less probable—forms. There are depictions of reptiles (fig. 1), birds (fig. 2), mammals, fishes (fig. 3), insects (fig. 4), prodigious births and monsters, seashells and snail shells, and fossils (fig. 5) but also empty sheets and others containing unfinished drafts (fig. 6), indicating the collection's incompleteness and openness to further expansion.

As shown in the following pages, Aldrovandi always devoted particular attention to his drawing collection. The importance he ascribed to it is also suggested by his writings, where he frequently refers to his drawing collection with particular pride. In addition, he expounded on the significance of images for the study of nature in numerous image-theoretical treatises.

3 It is illuminating to note that method, to Aldrovandi, meant more than merely a research procedure. As Tugnoli Pàttaro suggests, Aldrovandi's use of the term also comprised techniques of teaching and learning. Visual inspection and excursions were accordingly part of his tuition. See Tugnoli Pàttaro, *Metodo e sistema delle scienze*, 65–73.

4 Claudia Swan has also made important contributions to the study of drawing and concepts of truth in this context. See Claudia Swan, "*Ad vivum, naer het leven*, from the Life: Considerations on a Mode of Representation," *Word and Image* 11 (1995): 353–72; Claudia Swan, *Art, Science, and Witchcraft in Early Modern Holland: Jacques de Gheyn II (1565–1629)* (Cambridge: Cambridge University Press, 2005).

5 Aldrovandi had received this drawing from Francesco I de' Medici in Florence. A detailed account of its history can be found in Findlen, *Possessing Nature*, 241–48.

6 Aldrovandi experimented on the cadavers of the vipers, trying to find a recipe for theriac. The latter, a concoction already known to Galen that was regarded as the "antidote of antidotes," had featured importantly in the pharmacopoeia since the Middle Ages. Almost all early modern natural scientists sought to find a way to prepare this legendary compound. For extensive references, see Findlen, *Possessing Nature*, 241–43.

7 Raffaella Simili, ed., *Il Teatro della natura di Ulisse Aldrovandi* (Bologna: Compositori, 2001); Walter Tega, ed., *Guide to Palazzo Poggi Museum: Science and Art* (Bologna: Compositori, 2002).

8 Irene Ventura Folli, "La natura scritta: la libraria di Ulisse Aldrovandi (1522–1605)," *L'Archiginnasio* (Florence) 49 (1993): 495–506. For Aldrovandi's work in written formats, see Christa Riedl-Dorn, *Wissenschaft und Fabelwesen: Ein kritischer Versuch über Konrad Gessner und Ulisse Aldrovandi* (Vienna: Böhlau, 1989); Fabrian Krämer, "Aldrovandi's Pandechion," in "Paper Technology: Wissenstechniken in der frühneuzeitlichen Wissenschaft," ed. Volker Hess and Andrew Mendelsohn, special issue,

FIG. 2: Birds, from Aldrovandi's collection of drawings, ca. 47 × 35 cm, second half of the sixteenth century. Aldrovandi's collection of drawings, archive of the University Library of Bologna, Italy. *Tavoli di Animali* I, c. 67, with permission of the University Library of Bologna.

FIG. 3: Fish, from Aldrovandi's collection of drawings, ca. 47 × 35 cm, second half of the sixteenth century. Aldrovandi's collection of drawings, archive of the University Library of Bologna, Italy. *Tavoli di Animali* VI, c. 11, with permission of the University Library of Bologna.

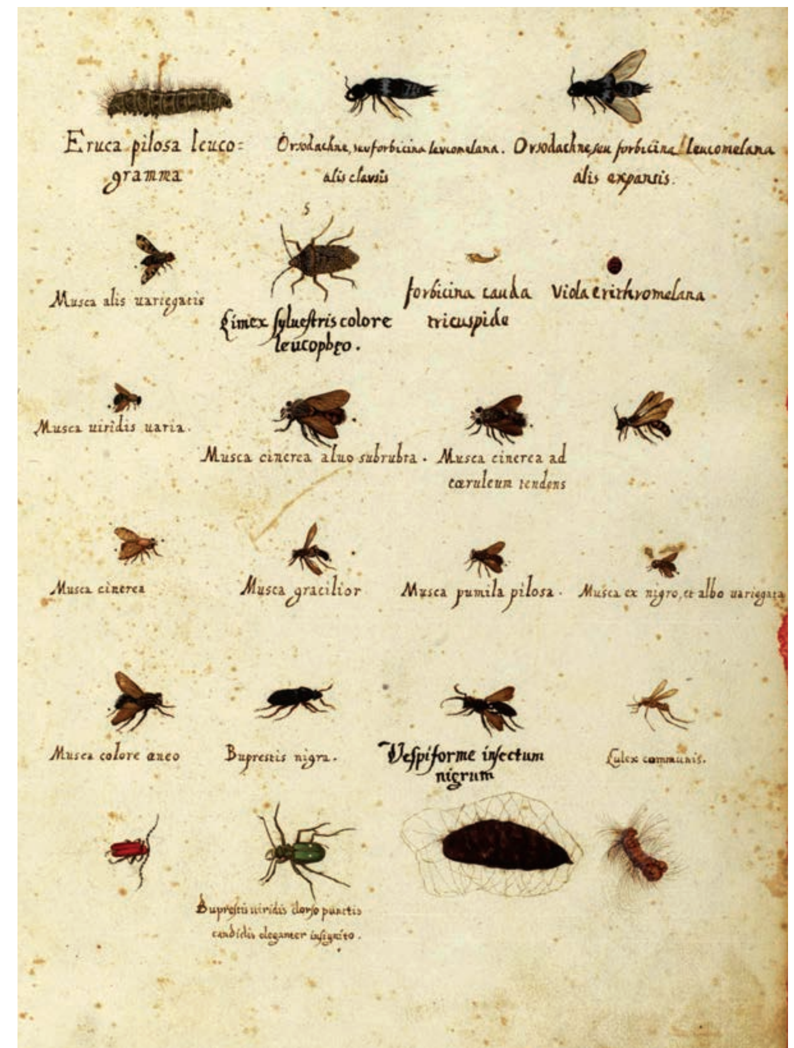


FIG. 4: Insects, from Aldrovandi's collection of drawings, ca. 47 × 35 cm, second half of the sixteenth century. Aldrovandi's collection of drawings, archive of the University Library of Bologna, Italy. *Tavoli di Animali* VII, c. 15, with permission of the University Library of Bologna.

FIG. 5: Fossils and a nautilus shell, from Aldrovandi's collection of drawings, ca. 47 × 35 cm, second half of the sixteenth century. Aldrovandi's collection of drawings, archive of the University Library of Bologna, Italy. *Tavoli di Animali* VI, c. 69, with permission of the University Library of Bologna.

NMT: Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin 21 (2013): 11–36.

9 For an overview of the collection, see Antonino Biancastello, ed., *Animali e creature mostruose di Ulisse Aldrovandi*, exhibition catalogue (Milan: Federico Motta, 2004). A complete digital copy of the collection of drawings may be found at www.filosofia.unibo.it/aldrovandi/ (accessed May 3, 2012).

10 See Sachiko Kusukawa and Ian Maclean, eds., *Transmitting Knowledge: Words, Images, and Instruments in Early Modern Europe* (Oxford: Oxford University Press, 2006); Angela Fischel, *Natur im Bild: Zeichnung und Naturerkenntnis bei Conrad Gessner und Ulisse Aldrovandi* (Berlin: Mann, 2009).

11 This reference is all the more remarkable since the term *substance* usually describes ideal characteristics but not individual physical properties. Aldrovandi, however, tries to connect his new, empirical ideal of natural history to this classical Aristotelian term. This new view of Aristotle differs strongly from earlier (for example, late medieval) references to Aristotle's philosophy. Prior to Aldrovandi and his precursor, Conrad Gessner, knowledge of nature was by no means based on perception of the outer appearance of an animal or plant. For an early modern interpretation of Aristotle in biology, see James G. Lennox, *Aristotle's Philosophy of Biology: Studies in the Origins of Life Science* (Cambridge: Cambridge University Press, 2001). For Aldrovandi's reference to Aristotle, see also Tugnoli Pàttaro, *Metodo e sistema delle scienze*, 69–73; Holger Steinemann, *Eine Bildtheorie zwischen Repräsentation und Wirkung: Kardinal Gabriele Paleotti's "Discorso intorno alle imagini sacre e profane"* (1582) (Hildesheim: Olms 2006). Cf. below, p. 179 and n. 27.

Empirical Science and the Politics of the Image

Aldrovandi was one of the few early modern zoologists to examine the matter of the image as such at length; with Conrad Gessner, he was among the first to address the particular significance imagery had for the philosophy of nature.[10] Aldrovandi's writings advocate the employment of images and give a prominent role to visual perception and sensory experience in connection with his call for a transformation of natural history into a science founded on empirical data. Tactile and visual perception and experience, he argues, must form the basis for any profound study of nature; only the outward senses provide the access to the world that enables the human understanding to know it. In this context, Aldrovandi developed an interesting reading of Aristotle, who, he writes, characterized the experience of individual objects of physical nature as the first step toward knowledge of the substance of the world.[11]

FIG. 6: Sea monster, unfinished drawing, from Aldrovandi's collection of drawings, ca. 47 × 35 cm, second half of the sixteenth century. Aldrovandi's collection of drawings, archive of the University Library of Bologna, Italy. *Tavoli di Animali* VI, c. 72, with permission of the University Library of Bologna.

His description of his own work clearly expresses the same ideal: in "my natural history [. . .] I have described not a single object I did not see with my own eyes, touch with my own hands, and dissect into its external and internal parts. [. . .] Over time, I have collected these objects in my small natural world, where anyone can come—and they do come all day long—to see and contemplate them, preserved in likenesses drawn from life, in our museum."[12]

The empirical study of nature, this account indicates, did not simply mean perception of natural objects or their immediate study *in situ*. On the contrary, turning perceptions of nature into data that would be generalizable and communicable in scientific terms required technical mediation. In the museum, the following discussion aims to show, the drawing archive is a prerequisite for the scholar's study of nature's forms and appearances.[13]

12 Ulisse Aldrovandi, "Discorso naturale," in Tugnoli Pàttaro, *Metodo e sistema delle scienze*, 180.

13 In the "Discorso" and even more extensively in his last will, Aldrovandi also offers concrete information about the scope and status of his picture collection. Ulisse Aldrovandi, "Discorso naturale," 183; Giovanni Fantuzzi, *Memorie della vita di Ulisse Aldrovandi, Medico e Filosofo Bolognese* (Bologna: Lelio dalla Volpe, 1774), 67–85.