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Neo-Classical Aesthetics of Art and Science: Hermann Helmholtz and the Frog-Drawing Machine

THE HANS RAUSING LECTURE 2007
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M. Norton Wise[1]

Ladies and Gentlemen!

It is an honor and a great pleasure for me to deliver the Hans Rausing Lecture in this auspicious year when the new Rausing Professor H. Otto Sibum has first taken up his chair and in the presence of his esteemed predecessor Tore Frängsmyr. The stars are in conjunction for a bright future for the history of science at Uppsala University.

Professor Sibum has been my valued personal and intellectual friend for many years. His wholly original work on material and bodily practices in experimental physics and precision measurement has been a continuing source of inspiration for my own attempts to understand how the techniques and instruments through which we act in the world shape our understanding of it, how they provide tools to think with. Tonight I want to carry that project a bit further to explore something of the aesthetics of experiment. For our ideas of the beautiful are always in play as we craft our materials to produce the results we seek.

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[1] This paper is adapted from the manuscript for Bourgeois Berlin and Laboratory Science (in preparation). Portions have appeared in M. Norton Wise, "What can Local Circulation Explain?" *HoST (Journal of the History of Science and Technology)*, 1 (2007), 15–73.

The Question

How can aesthetic values in the fine arts translate into technical methods and meanings for precision measurements? That is the question posed visually by the *cover illustration* for this lecture. In the context of Berlin in the 1830s and 40s, how might we conceive the relation between the neo-classical aesthetics of W.E. Daege's painting and Hermann Helmholtz's sophisticated apparatus for drawing curves of contracting frog muscles? It is a question in what is sometimes called the cultural history of science. I will give an answer that looks for the

Figure 2.. *K.F. Schinkel "Blick in Griechenlands Blüthe" (1825), detail from the extant copy by Wilhelm Ahlhorn (1836). Berlin, Staatliche Museen Preussischer Kulturbesitz, Nationalgalerie, Inv-Nr. NG 2/54.*

ways in which scientists, as participants in the culture they inhabit, draw resources from it for understanding and solving problems in their own work. In pursuing analyses of this kind it is helpful to focus on technological mediators between culture writ large and scientific explanation, for it is sometimes relatively easy to see how particular technologies function as both cultural embodiments and generators of new knowledge. Their materiality and their practical function give them a reality and a grip on action that is hard to obtain otherwise. Each section below aims to contribute to a narrative movement from art to technology to science. They aim also to provide a visual understanding of the relations involved. [2]

Architecture of Karl Friedrich Schinkel

A good sense of the role of neo-classical aesthetics for the educated elite *(Bildungsbürgertum)* of Berlin while Helmholtz was growing up nearby in Potsdam can be obtained from the buildings designed by the prolific and brilliant Karl Friedrich Schinkel, one of the leading lights among those who sought to refashion the city as a new Athens on the Spree *(Spreeathen).* His architectural vision of the imagined republic is apparent in his 1825 painting "View into the Flowering of Greece" *(Blick in Griechenlands Blüthe)* **(figure 1).** Here the usual neo-classical ideals of balance, harmony, symmetry, and reason combine with an image of civic humanism and cooperative work. As the chief architect of the king, Schinkel produced a series of state buildings that still evoke their intended function as he

[2] This discussion supplements earlier accounts from which I have benefited greatly: Kathryn M. Olesko and Frederic L. Holmes, "Experiment, Quantification, and Discovery: Helmholtz's early Physiological Researches, 1843–50," in David Cahan (ed.), *Hermann von Helmholtz and the Foundations of Nineteenth-Century Science* (Berkeley: University of California Press, 1993), 50–108; Frederic L. Holmes and Kathryn M. Olesko, "The Images of Precision: Helmholtz and the Graphical Method in Physiology," in M. Norton Wise, *The Values of Precision* (Princeton: Princeton University Press, 1995), 198–221.

Figure 2. *Karl Daniel Freydanck, "Das neue [soon alte] Museum in Berlin" (1838). KPM-Archiv, Schloss Charlottenburg, Inv. Nr. 38.*

conceived it. They were to provide public spaces that would shape the experience and consciousness of a newly cosmopolitan citizenry.[3] His art museum **(figure 2)**, built between 1823 and 1830, captures this sense of uplifting public space. Even while strolling around the grassy square, visitors were to perceive themselves as citizens of a modern state, as opposed to subjects of an absolute monarchy, even though the expectation of a Prussian constitution following the War of Independence/Freedom *(Befreiungskrieg/Freiheitskrieg, 1813–15)* had shattered on the reactionary politics associated with the Karlsbad Decrees of 1819. The new museum was designed not only to house the large royal collections of classical sculptures and more modern paintings that had been assembled over the years but to transform

[3] Of the many books on Schinkel's architecture, I find particularly illuminating Barry Bergdoll, with photographs by Erich Lessing, *Karl Friedrich Schinkel: An Architecture for Prussia* (New York: Rizzoli, 1994).

them into a means of public education and aesthetic inspiration. We see this vision in the second floor entry hall **(figure 3)** where a father on the left interprets for his son the mythic lessons for humanity contained in the frescoes with which Schinkel surrounded the entry. Similarly, two young gentlemen on the right apparently engage in elevated conversation, as though a natural expression of enlightened virtue within a rationalized perspective space dominated by the clean and simple lines of great ionic columns (as also in figure 1).

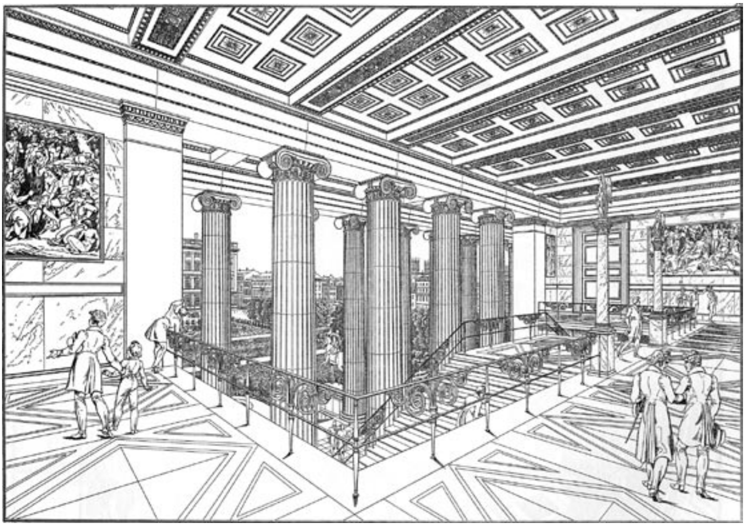

Figure 3. *K.F. Schinkel, "Perspectivische Ansicht von der Haupt-Treppe des Museums durch den Porticus auf den Lustgarten und seine Umgebungen," Sammlung architektonischer Entwürfe (Berlin, 1819-40; reprint, Collections of Architectural Designs, Chicago, Exedra Books; New York, Princeton Architectural Press, 1981), 43.*

Schinkel's architecture, however, was not reserved for high art. Already in 1821 he had remodeled and extended the large building on the right in **figure 4**, known as the House of Industry *(Gewerbehaus)*. This was the domain of his intimate friend Peter Beuth, who led the campaign of the trade ministry to jumpstart industrialization in

Figure 4. *Eduard Gaertner, "Die Klosterstrasse" (1830). Berlin, Staatliche Museen Preussischer Kulturbesitz, Nationalgalerie, Inv. Nr. A II 736.*

Prussia. Schinkel's severely classical building housed the ministry's Technical Deputation for Industry, which made use of four scientific and industrial laboratories as well as large collections of models and drawings. It also housed two associated institutions aimed at promoting a new future for Prussia. To train modern entrepreneurs, Beuth established the Industrial Institute *(Gewerbeinstitut)*, where ambitious young men could join a basic education in the sciences, mathematics, and technical drawing with the latest material processes and machines, helping them to found the industries of a modernized economy. Finally, to promote professional interaction and dissemination of knowledge among people in arts, crafts, manufacturing, and science a new Union for the Advancement of Industry *(Verein zur Beförderung des Gewerbefleisses)* met in the *Gewerbehaus* and made use of its resources to publicize its activities.[4]

The painter Eduard Gaertner, known for his architectural realism, has captured this clustering of industrious modernizers in his rather formal street scene. In front of the House of Industry, Schinkel and Beuth (in tophat and cap, respectively) survey the activity while in the street Gaertner greets his mounted fellow artist, Franz Krueger, known for his portraiture of horses, buildings, and people. On the left, the prominent sculptor Christian Daniel Rauch (in white trousers) stands before his atelier conversing with friends. Here in the *Klosterstrasse* and surrounding area, craftsmen of many sorts created the material objects that embodied the juxtaposition of neo-classical aesthetics and industrial development represented in the close personal and professional relationship of Schinkel and Beuth. [5]

Pegasus and the Muses

Such a movement toward the future needed a symbol of inspiration. Schinkel and others found it in Pegasus[6], the flying horse, whose elegant form appears on the rear ridge of the Royal Theatre *(Schauspielhaus)* **(figure 5)**. The Theatre, built between 1818 and 1820, is another of Schinkel's great civic buildings. It sits on the central market square, the *Gendarmenmarkt*, between the twin eighteenth century churches that marked the complementary relationship of two of the most important groups in the city, German Lutherans and French Hugenots. Thus the square was already one of the most important public spaces in Berlin when Schinkel designed the theatre

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[4] Conrad Matschoss, "Geschichte der KöniglichTechnischen Deputation für Gewerbe. Zur Erinnerung an das 100 jährige Bestehen. 1811–1911," *Beiträge zur Geschichte der Technik und Industrie. Jahrbuch des Vereins deutscher Ingenieure*, 3 (1911), 239–275. Matschoss, *Preußens Gewerbeförderung und ihre grossen Männer* (Berlin: Verein der Deutschen Ingenieure, 1921).

[5] Dominik Bartmann (ed.), *Eduard Gaertner, 1801–1877* (Berlin: Stiftung Stadtmuseum Berlin, 2001), 275–277. In the same volume see Sybille Gramlich, "Eduard Gaertner und die Berliner Archtecturmalerei," 31–54.

[6] For the significance of Pegasus in Schinkel's work, I draw especially on Andrea Linnebach, "Pegasus in der Kunst des 19. Jahrhunderts von Karl Friedrich Schinkel bis Odilon Redon," in Claudia Brink and Wilhelm Hornbostel (eds), *Pegasus und die Künste* (Munich: Deutsche Kunstverlag, 1993) 111–123.

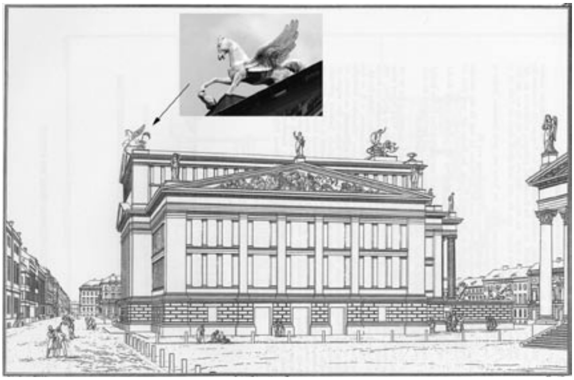

Figure 5. *K.F. Schinkel, "Perspectivische Ansicht der seitenfaçade des neuen Schauspielhauses," Sammlung architektonischer Entwürfe (Berlin, 1819–40; reprint, Collections of Architectural Designs, Chicago, Exedra Books; New York, Princeton Architectural Press, 1981), 11.*

Figure 6. *K.F. Schinkel, detail of Pegasus and the Muses, from Schinikel's preparatory painting for a fresco on the life of mankind, "Entwicklung des Lebens auf der Erde vom Morgen zum Abend (Menschenleben)." Christoph Martin Vogtherr, Das königliche Museum zu Berlin:, supplement to Jahrbuch der Berliner Museen, 39 (1997), published separately (Berlin: Gebruder Mann, 1997), 131 (foldout).*

to capture in classical imagery the functions of theatrical performance for an enlightened citizenry. On the corners of the roof stand the nine muses. They act here under the gaze of Apollo Musagetes (leader of the muses), whose chariot above the front ridge is about to soar into the sky pulled by griffins, but their creative spirit for the arts and sciences is associated with Pegasus. Here his hoof strikes a rock on Mount Helicon, the sacred home of the muses, causing the spring of Hippocrene to flow, which became the medium for their cultural inspiration of humanity.

Not surprisingly, Schinkel employed the same theme for another home for the muses, the art museum. A long fresco on the back of the entry hall in figure 4 (not visible) depicted the life of mankind from morning/springtime to night/winter. In the central position of noon/summer **(figure 6)**, Pegasus appears on Mount Helicon surrounded by muses with the waters of Hippochrene falling into a pool below, "from which happy mankind receives the drink of spiritual awakening."[7] Crucially for the message that Schinkel and his collaborators sought to convey in the museum as a whole, this scene pointed toward the future of humanity. They did not present the great sculptures and paintings on view as monuments to the past glories of art but as sources of inspiration for a new social and cultural order.

This message of Pegasus and the muses extended to the material and technological order as well. Note the smokestack to the right of the museum in figure 8. It marks the presence of a steam engine, built by one of the earliest engine builders in Berlin, which pumped water from the Spree River to a reservoir on top of the museum to supply a fountain rising 60 feet in the center of the square. To power this symbol of progress and a variety of smaller fountains, along with

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[7] Described by Franz Kugler, after Schinkel's own account, in "Vorhalle des Museum's in Berlin. Drittes Bild," *Museum: Blätter für bildende Kunst*, 1 (1833), 9–12.

irrigation for a colorful public *Volksgarten* (garden of the people), Schinkel and the garden architect Peter Joseph Lenné had originally planned a grand five-story tower in neo-classical style housing two engines in a lower gallery with three reservoirs above.[8] For budgetary reasons, they had to settle for the modest house and square shown in the painting. Nevertheless, the technological modernism that they sought to promote is evident in a later view from behind the engine house **(Figure 7)**. It celebrates *Das Neue Museum* (New Museum, built 1841–55), but the smoking chimney shares visual prominence with the museum. Their relation should remind us that steam engines and clouds of smoke did not yet connote urban blight but rather the civilizing power of material progress.

The orientation toward the future is apparent more widely in the use of the term "museum," as in a weekly magazine of art, edited by Schinkel's friend and biographer Franz Kugler, titled simply *Museum: Newspaper for Figurative Arts* (**figure 8**). With the art museum and fountain as its emblem, it carried primarily news of rejuvenating developments in German fine arts but included also their manifestation

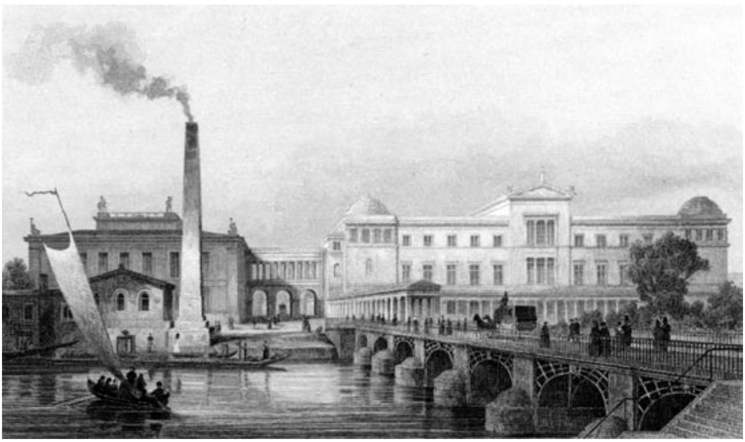

Figure 7. *[W.] Loeillot, "Das neue Museum" (ca. 1850). Author's copy.*

Figure 8. *Masthead, Museum: Blätter für Bildende Kunst, 5 (1837), with the exhuberant fountain escaping its basin before the art museum.*

in products for the consumer market. A regular column on "Kunst- und Kunst-Technik in ihren neusten Erscheinungen" ("Arts and Crafts in their latest Forms," but see *Technik* below) included each year a report on the annual fest and exhibition of Beuth's *Gewerbe-Verein*. In 1836 it noted that "Since the crafts penetrate into social life with more vitality and versatility than the fine arts, exhibitions of this kind obtain a festive national character, which has the most meaningful influence on the consciousness and opinions of the people."[9]

Aesthetics and utility working together would create the conditions for social renewal. For the fest, the rising star of Berlin painting, Adolph Menzel, designed a placecard (**figure 9**) as a

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[8] Paul Ortwin Rave, *Berlin: Stadtbaupläne, Brücken, Straßen, Tore, Plätze*, vol. 2.1 of *Karl Friedrich Schinkel. Lebenswerk* (Berlin: Deutscher Kunstverlag, 1948), 116–118. Engine tower in Rave, *Berlin: Bauten für die Kunst, Kirchen/Denkmalpflege*, vol. 1 of *Schinkel. Lebenswerk* (1841), 226.

[9] "Das Stiftungsfest des Gewerb-Vereins zu Berlin," *Museum: Blätter für bildende Kunst*, ed. F. Kugler, 4 (1836), 47–49, on 47.

Figure 9. *Adolph Menzel, placecard (1836), for the annual celebration of the Society for the Advancement of Industry, held on 24 January, the birthday of Frederick the Great, honored for his policies of economic modernization. Museum: Blätter für bildende Kunst, 4 (1836), 47.*

composition of emblematic images of the traditional crafts. But these familiar workers are reaching out to hold the winged smokestack of a steam locomotive. Here was Pegasus as the guiding spirit of industrial modernization, surrounded by clouds of healthy smoke.

Schinkel himself expressed this expectant sense of progressive dynamics in his hope for art becoming more like science. "It would perhaps be the greatest blossoming of a new way of dealing with the world if the fine arts moved forward somewhat in the way experiment precedes discovery in science, which can be seen as a characteristic element of the modern period [*die neue Zeit*]." [10] In this conception of modernity, works of art collected in museums would be like successful experiments in the making of history, displayed for their capacity to stimulate experimental exploration. Art, like science, would aim at discovery.

"The Origin of Drawing"

The question now arises more directly of what specific aesthetic ideals may have crossed the domains of art, technology, and science. One route into the subject can be found in a particular genre of drawings and paintings with titles like "discovery of painting" or "origin of drawing" produced by Berlin artists, including at least: Christian Bernhard Rode (1790), Gottfried Schadow (1804), Franz Ludwig Catel (1806), Schinkel (1830), Johann Erdmann Hummel (1830s), and Wilhelm Eduard Daege (1834).[11] In their most typical form they give various depictions of the ancient myth of Dibutades, the Corinthian maid whose young lover was about to go off to war and who had the idea of tracing his shadow on the wall in order to keep his image before her. Her father Butades, a potter, then filled the silhouette with clay and fired it in his kiln.

The myth had particular relevance for neo-classical aesthetics because it gave such prominence to the firmly drawn line bounding smooth surfaces, rather than color, as the foundation of art. This aspect

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[10] Goerd Peschken, *Das Architektonische Lehrbuch. Karl Friedrich Schinkel. Lebenswerk*, ed. Margarete Kühn (Munich: Deutsche Kunstverlag, 1979), 71, 115.

[11] Hans Wille, "Die Erfindung der Zeichenkunst", in Ernst Guldan (ed.), *Beiträge zur Kunstgeschichte: Eine Festgabe für H. R. Rosemann* (Munich; Deutscher Kunstverlag, 1960), pp. 279-300, who shows a different version of Hummel's drawing from the one below. K. F. Schinkel: *Architektur, Malerei, Kunstgewerbe* (Berlin, 1981), catalogue no. 207a, p. 267. Wilhelm Eduard Daege in Nationalgalerie Berlin, Inv.-Nr. A I 216.

Figure 10. *K.F. Schinkel, "Erfindung der Malerei" (1830), repeating a scene from the preparatory fresco painting "Entwicklung des Lebens auf der Erde vom Morgen zum Abend (Menschenleben), just preceding Pegasus and the Muses, figure 6 above. Wuppertal, Von-der-Heydt-Museum G 184.*

is particularly apparent in Schinkel's version, "Die Erfindung der Malerei" ("The Discovery of Painting") (**figure 10**), which transforms the characters so that a youthful male does the drawing in a group of classically figured nudes placed in a pastoral scene with sheep and shepherds, as though representing nature herself. Unmistakable is the weight Schinkel places on the drawn line, making it literally charcoal black, standing out sharply from its white background.

A closely related aspect of neo-classical aesthetics is the ideal of beauty apparent in the bodies of the allegorical figures. They are almost androgenous in their smoothly muscled athletic physiques, like those of adolescents.[12] The same is true in the "Discovery of Painting" done by Daege two years later (**figure 11**), which returns to the original myth. Dibutades and her lover, in their purity and perfection, show no signs of hardship or battle, despite the props of sword and helm. In both paintings, the "Discovery" is of an ideal human *Form* rather than

Figure 11. *Wilhelm Eduard Daege, "Die Erfindung der Malerei" (1832). Berlin, Staatliche Museen Preussischer Kulturbesitz, Nationalgalerie, Inv.-Nr. A I 216.*

[12] Mechthild Fend illuminates the neo-classical line and its gender-coding in *Grenzen der Männlichkeit* (Berlin, Reimer, 2003); esp. ch. 3, "Körpergrenzen in Fluß: Das Ideal und seine Ambivalenzen in der Kunsttheorie des Neoklassizismus". For a succinct survey see George Mosse, *The Image of Man: The Creation of Modern Masculinity* (New York: Oxford University Press, 1996), 24–36, on Johann Joachim Winckelmann's canonical articulation of the neo-classical ideal of masculine beauty, and 40–45, on the perceived role of gymnastics in sculpting this ideal.

of a particular *Gestalt* (shape). The silhouette does not capture reality in its irregularities and imperfections but only in its smoothed outlines. Furthermore, the artist cannot simply copy nature but can attain the beautiful only through an *Anschauung* (an intuitive perception as opposed to an analytic concept) of its proper *Form*. These basic terms, which I will leave in italics to indicate their special meaning, are characteristic of the idealist tradition in which both artists worked, deriving ultimately from Plato but represented more proximately in the philosophies and aesthetics of Kant, Goethe, Schiller, and others, especially Fichte and Hegel in Berlin. Among Schinkel's and Daege's immediate contemporaries in the Berlin Academy of Art a great deal of diversity existed. Nevertheless, they generally shared the terms of an idealist neo-classicism and in this we will find that they shared a great deal with Helmholtz.

But first consider the "Origin of Drawing" by Hummel (**figure 12**). The space of linear projection and perspective signals his subject as professor at the Academy of Art, where he taught architecture, projection, and optics. While maintaining the ideals of neo-classicism, Hummel transforms their significance by including the potter Butades, who normally did not appear at all. Here he shares prominence with the lovers while engaged in his everyday work of manufacturing vases, all with the same classical form, which we see his assistant placing on drying racks in the background. The origin of drawing is now manifested in Butades' concentrated attention on his daughter's drawing hand in relation to his own shaping hands, the relation of artist to craftsman. She is the muse who inspires Butades with the beauty of *Form*, the *Anschauung*, that he impresses on his vase. It was in fact the capacity for *Anschauung* that Hummel sought to teach his students in their practice of projective drawing. "Through industrious exercise," he said, "the mind as well as the eye becomes practiced in correctly conceiving the appearances in nature and in making the laws on which they rest more intuitively apparent [*anschaulicher*]." [13]

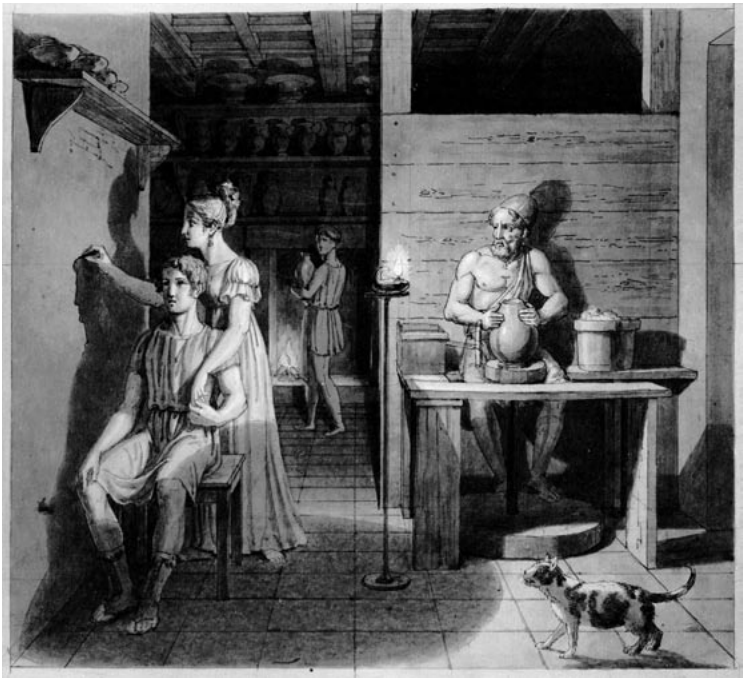

Figure 12 *Johann Erdmann Hummel, "Die Entstehung der Zeichenkunst" (ca. 1834). Berlin, Staatliche Museen Preussischer Kulterbesitz, Kupferstichkabinett, SZ 39.*

Just as Dibutades' line captures the visual essence of her lover, so a similar line defines Butades' vase, whose silhouette he shapes in clay as it rotates on his wheel.

The value that Hummel's drawing places on the movement between artistic inspiration and craft production characterized much more generally the goal of cultural reformers who sought to elevate civic consciousness by elevating public taste, much as Schinkel's architecture would shape public life. We have seen that vision above

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[13] Johann Erdmann Hummel, *Die freie Perspektive erläutert durch praktische Ausgaben and Beispiele, hauptsächlich für Maler und Architekten*, 2 vols. (1823; 1825), 2nd ed. (Berlin; Herbig, 1833), 1, vii-viii.

with respect to *Kunst-Technik* at the annual exhibition of the *Gewerbe-Verein* and its vital effect on "the consciousness and opinions of the people." To see it in practice we need only glance through the pages of the volume of *Prototypes for Manufacturers and Craftsmen*[14] that Beuth and Schinkel edited for the Technical Deputation for Industry, which served as a kind of canon of Forms, all classical, for the consumer goods of bourgeois life: tableware, wallpaper, fences, furniture, and architectural ornamentation. The vases in (**figure 13**) are exemplary, displaying the same relation of ideal line to material object that Hummel had depicted in his "Origin of Drawing."

Figure 13. *Technische Deputation für Gewerbe [P. C. W. Beuth and K. F. Schinkel] (eds.), Vorbilder für Fabrikanten und Handwerker, (Berlin, 1821), Abtheilung II, Blatt 1.*

Helmholtz: Teaching Anatomy as Art

In the fall of 1848, Hermann Helmholtz began teaching the anatomy class at the Academy of Art in Berlin while serving also as assistant to Johannes Müller at the Anatomical Institute. Having completed his medical training at the Friedrich-Wilhelms Institute for military doctors in 1843, he had been serving as a medical officer in the army in his home town of Potsdam while doing the research and writing that earned him his early reputation as a physiologist with the experimental and mathematical skills of a physicist. Not usually observed, however, is that Helmholtz had considerable training in drawing. Like other students while he was at the Gymnasium in Potsdam, he would have taken drawing classes two hours per week for five years, beginning with simple line drawings of geometrical figures and concluding with three years on shaded drawings of natural objects and plaster casts.[15]

Worth noting also is the fact that Helmholtz's father Ferdinand, philologist and subrector of the Gymnasium, contributed a long article in 1837 to the examination program on "The Importance of General Education for the Beautiful," which drew heavily on the ideas of Fichte and of his son Immanuel, also a philosopher and a close friend of Ferdinand's. Ferdinand Helmholtz's discussion structured the curriculum around the role of art and the gradual acquisition of a deep feeling for "the beautiful," which he identified with the "*Form* of the godly life." Although drawing in particular played only a minor role in this sweeping account, it did serve to epitomize the goal of bringing the Idea or *Form* of any object of interest to anschaulich expression: "It is especially through drawing that this sense for the careful execution of the *Form* as beautiful down into the minutest details, this decisive power of the Idea, must be awakened and exercised."[16]

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[14] Technische Deputation für Gewerbe [P. C. W. Beuth and K. F. Schinkel] (eds.), *Vorbilder für Fabrikanten und Handwerker*, (Berlin, 1821).

[15] The usual course of study is presented in "Der Jahresbericht," by Director Dr. Rigler, in *Zu der öffentlichen Prüfung der Zöglinge des hiesigen Königlichen Gymnasiums den 21sten und 22sten März laden ganz ergebenst ein Director und Lehrercollegium* (Potsdam: Decker'schen Geheimen Oberhofbuchdruckerei-Etablissement, 1837), 45-58; drawing classes on 53

[16] Ferdinand Helmholtz, "Die Wichtigkeit der allgemeinen Erziehung für das Schöne," in Ibid., pp. 1-44, on 23 and 34.

Although young Helmholtz disagreed with his father about many things, they shared this Idealist vocabulary of art, with its emphasis on the crucial role of Anschauung in the immediate perception of ideal *Forms*, without conscious reflection. In his trial lecture (*Probevortrag*) for the Academy of Art, this is particularly evident in the distinction that operates between *Form* and *Gestalt*, as introduced above with respect to the "Discovery" paintings.

"The creative artist sketches his *Gestalt* without calculation of all the details, guided only by the sense for the ideal beautiful [*das ideale Schöne*] which lives in his breast and in his eye. . . . the genius of the artist is just the mysterious power to find and to represent, in original *Anschauung* . . . that which the pondering reflection must then also recognize and justify as true and perfect [the *Form*]." [17]

But how does one acquire the capacity for *Anschauung*? Is it innate or acquired? That question had been the subject of extended argument among philosophers and physiologists at least since Kant. Over the next twenty years Helmholtz would become well known for articulating a position that probably derived from Fichte. Without entering on its many complexities, it is an empiricist position arguing that we can only have knowledge of an external world through our action in it and through the inferences that our mind derives from the effect of that action on us.[18] For example, we acquire our capacity for spatial perception through a mutual adaptation of the physical movement of our eyes to the ordering capacity of our minds in a psychological process that he ultimately would call "unconscious inference." Helmholtz's empiricism, however, maintained the Idealist emphasis on the freedom and independence of the mind in producing *Anschauungen*.

Nothing quite like his mature view appears in the 1848 trial lecture. Nevertheless Helmholtz was already assuming that the artist's sense of beauty rests on *Anschauungen* that are developed through training, much as Hummel taught. If the ancients possessed a marvelous sense of truth and beauty, it derived from their "much richer opportunity to educate their *Anschauung* of the human bodily form." Modern artists could compensate in the anatomy class where they would learn intuitively to see the "anatomical mechanisms" that underlay the external shapes of muscles, no doubt by actively drawing for themselves the muscles, tendons, and bones whose functions Helmholtz would demonstrate on prepared specimens and on living models. [19]

To recognize that *Anschauung* requires education through action brings the question of means—tools, practices, and technical knowledge—directly in contact with aesthetics. Helmholtz would later refer to this combination as Technik. But even in 1848 he believed that technical training in anatomy was ctitically important to recognizing Forms and their causes and to differentiating essential from non-essential features, although it could never replace the artistic spirit (*künstlerische Geist*).

> "[Anatomy] can never replace the *Anschauun*g of these *Forms* and the artistic sense of beauty. It [anatomy] is a means which facilitates for the artist his spiritual victory over the ever-changing manifoldness of his earthly object, the human *Form*, a means which

[17] Helmholtz, "Probevortrag," in Leo Koenigsberger, *Hermann von Helmholtz*, 3 vols (Braunschweig: Vieweg, 1902–3), I, 95–105, on 99.

[18] See Gary Hatfield, *The Natural and the Normative: Theories of Spatial Perception from Kant to Helmholtz* (Cambridge, MA: MIT Press, 1990), ch. 5, and several articles in David Cahan (ed.), *Hermann von Helmholtz and the Foundations of Nineteenth Century Science* (Berkeley: University of California Press, 1993): Timothy Lenoir, "The Eye as Mathematician: Clinical Practice, Instrumentation, and Helmholtz's Construction of an Empiricist Theory of Vision," 109–153; R. Steven Turner, "Consensus and Controversy: Helmholtz on the Visual Perception of Space," 154–204; Michael Heidelberger, "Force, Law, and Experiment: The Evolution of Helmholtz's Philosophy of Science," 461–497; and Robert DiSalle, "Helmholtz's Empiricist Philosophy of Mathematics: Between Laws of Perception and Laws of Nature," 498–521.

[19] Helmholtz, "Probevortrag," 100-101. In considering the education of Anschauung, I have found particularly helpful Henning Schmidgen, "Pictures, Preparations, and Living Processes: The Production of Immediate Visual Perception (Anschauung) in late-19th-Century Physiology," *Journal of the History of Biology*, 37 (2004), 477–513, and Richard Kremer, "Building Institutes for Physiology in Prussia, 1836–1846," in Andrew Cunningham and Perry Williams (eds.), *The Laboratory Revolution in Medicine* (Cambridge, Eng.: Cambridge University Press, 1992), 72–109. To their accounts I would add the aesthetic dimension of Anschauung.

should sharpen his view of the essential in the *Gestalt*, and which should equally make transparent to him the entire *Gestalt*. . . . But art, I would like to say, begins only beyond anatomy. The artistic spirit reveals itself first in the wise application of the *Forms* whose interconnection and elementary features anatomy has taught; it reveals itself in the decisive characteristic of the *Gestalt*." [20]

Thus it is through the realization of the essential *Form* that an artist produces the beauty of a particular *Gestalt*. And just because it is the *Form* and not the *Gestalt* that is of primary interest, the artist's task is not to copy nature but to capture the "Ideal," to awaken in the viewer "the feeling of harmonious and lively beauty."

"The artist should never attempt to imitate in the truest possible way, because his model is always only a person grown up in earthly imperfection, never corresponding to the *Ideal*; rather he should modify the individual *Gestalt* until it is the perfected impression of its spiritual content." [21]

In this statement we should see immediately the significance of smoothed lines and surfaces in neo-classical aesthetics and the role of anatomy in the process of modification. The same goals, I will argue, informed Helmholtz's physiological experiments and the sophisticated instruments he developed to extract perfected curves from the earthly imperfection of particular measurements. In both cases the artist/scientist required a kind of "*Kunst-Technik*" to carry out his work.

The Curve among "Younger Scientists"

Helmholtz was by no means alone in his recognition of the curve as a means of capturing nature's essential truths. In 1845 he had joined with a group of reforming and ambitious young men in Berlin who formed the Berlin Physical Society (*Physikalische Gesellschaft zu Berlin*) and who made the curve their emblem of progress in scientific knowledge. Two leading figures were Emil du Bois-Reymond and Ernst Brücke, both students of Müller, like Helmholtz, and both of whom had made the difficult choice to become physiologists rather than to follow their heritage in families of artists. Brücke preceded Helmholtz in lecturing at the Academy of Art and du Bois followed him. Interestingly, the Physical Society had emerged from a small group that du Bois had organized in 1841 as the Union of Younger Scientists (*Verein der Jüngeren Wissenschaftler*), paralleling the Union of Younger Artists (*Verein der Jüngeren Kunstler*), which Adolph Menzel joined in 1834.[22] Menzel's placecard for the fest of the Gewerbe-Verein (figure 9) is representative of a humorous series of invitation cards that he drew for the Younger Artists, featuring their patron saint Albrecht Dürer, whose mastery of the line in woodcuts and engravings Menzel celebrated. One hallmark of the Dürer reference, deriving from his marginal drawings for the *Prayerbook of Maximillian I*, is the arabesque of intertwined harmonic curves at the bottom of the drawing and the way in which it morphs into the figures forming the locomotive. This style had become exceedingly widespread in association with multiple republications of the Prayerbook from 1808 and with the 300th anniversary of Dürer's death in 1828.[23]

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[20] Helmholtz, "Probevortrag,"102–103.

[21] Helmholtz, "Probevortrag," 101

[22] Estelle du Bois Reymond, *Jugendbriefe von Emil du Bois-Reymond an Eduard Hallmann* (Berlin; Reimer, 1918), 29 March 1841, p. 86. Finckelstein, *Emil du Bois-Reymond*, p. 213. Ingo Schwarz und Klaus Wenig (eds), *Briefwechsel zwischen Alexander von Humboldt und Emil du Bois-Reymond* (Berlin; Akademie Verlag, 1997), p. 36. Gisold Lammel, *Adolph Menzel und seine Kreise* (Dresden, Basel: Verlag der Kunst, 1993), 50–55.

[23] Werner Busch, *Die notwendige Arabeske: Wirklichkeitsaneignung und Stilisierung in der deutschen Kunst des 19. Jahrhunderts* (Berlin; Mann, 1985), gives a thorough discussion of the arabesque genre, taken in its broadest sense to characterize an era of complexly interwoven modes of literary as well as graphic representation. On the Prayerbook see Friedrich Teja-Bach, *Struktur und Erscheinung: Untersuchungen zu Dürers graphischer Kunst* (Berlin; Gebrüder Mann, 1996), pp. 165–193

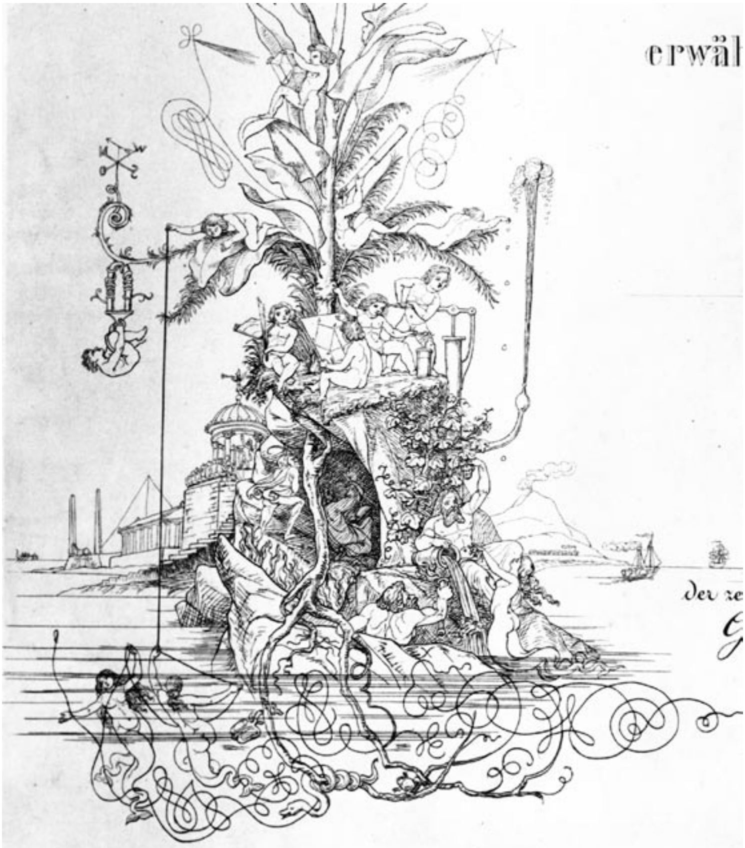

Figure 14. *Detail from Emil du Bois-Reymond, Membership Certificate, Physikalische Gesellschaft zu Berlin (1845). Staatsbibliothek zu Berlin, Preussischer Kulturbesitz, Handschriftenabteilung, Sammlung Darmstädter, Emil du Bois-Reymond, 3 k 1841 (3), Blatt 59.*

Clearly following this style, du Bois-Reymond made an allegorical drawing (**figure 14**) for the certificate of membership of the new Physical Society in 1845. It is a tree of knowledge on which the boy heroes of modern science, with smoothly muscled classical bodies, perform their various feats using physical instruments.

Their promontory on the bay of Naples emerges from a narrative of classicism on the left—galley, obelisks, sphinx, pyramid, Parthenon, and enlightenment temple of learning, with a professor lecturing to passively attentive students—and of industrialization on the right—sailing ship, steamship, and railroad, against a gently smoking Mount Vesuvius. It is the union of neo-classical education with industrial drive that gives rise to their now fully active experimenting role.

They are working above ground in the light of day. Underground, where the roots of their tree lie buried, are the mythological figures of a more primitive culture. Mephistopheles steps from the flames of Hades to observe the searching figure in the cave from Plato's *Republic*, who with book in hand is attempting to decipher shadows on the wall. He lacks the instruments of modern science for ascending to knowledge of nature. Outside, Neptune and Pluto cavort with nymphs, two of whom are tangling the truth of a perfectly straight plumb line among the confused roots of the past where the aesclepius, symbol of ancient medicine, dwells and from where Du Bois-Reymond and Helmholtz have extracted the lowly frog for experiments on muscles and nerves.

Returning to the tree, a young Newton in the higher branches decomposes sunlight with a prism and ties it to the trunk of knowledge through an arabesque of harmonic curves. Similarly, training his telescope on a distant comet, a symbolic Halley analyzes the motion of a comet into lines of epicyclic motion, likewise tied to the tree. On the right, a Galilean youth demonstrates the law of free fall, while on the far left, Du Bois-Reymond himself performs gymnastic exercises on an electromagnet, representing both his many years as a gymnast and his signature work in animal electricity.[24] Others at the base of

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[20] Sven Dierig, "'Die Kunst des Versuchens': Emil Du Bois-Reymonds *Untersuchungen über thierishce Elektricität,*" in Henning Schmidgen, Peter Geimer, and Sven Dierig, *Kultur im Experiment* (Berlin: Kadmos, 2004), 123–146, on 127–131.

the tree produce the famous Chladni figures by bowing on a metal sheet covered with dust, analyze a geometrical figure on a tablet, study electrostatics through the discharge a Leyden jar, and explore hydrodynamics with a strangely phallic pump.

The prominence in this scene of physical instruments and of curves is everywhere apparent, as is the idea, that the instruments are the means of reading nature's messages and inscribing them in curves. This conception of knowledge-making played an extraordinarily important role among members of the Physical Society. As an ideal it carried across science, technology, and art. Even late in the century, writing on *Beauty and Defect in the Human Figure*, Brücke focused on the line as the critical feature of ideal art. "To be beautiful," a figure "must display good lines in all postures whatsoever that arise in ideal art and in all views, for the guidance of the lines is first and most important in every work of art that makes higher claims." [25] We have seen a similar sentiment expressed by Hummel with respect to the lines of projective drawing making the laws of nature *anschaulich*. And indeed, it was in the expression of laws of nature that the members of the Physical Society found lines and curves especially effective. As Du Bois-Reymond put it for the problem of relating effects to causes in physiology: "The dependence of the effect on each circumstance presents itself in the form of a curve . . . whose exact [mathematical] law remains . . . unknown, but whose general character one will in most cases be able to trace [as a curve]." [26]

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[25] Ernst Brücke, *Schönheit und Fehler der menschlichen Gestalt* (Wien & Leipzig: Braumüller, 1892), 3.

[26] Emil Du Bois-Reymond, *Untersuchungen über thierische Elektricität*, vol. I (Berlin: Reimer, 1848), 26–27.

Helmholtz's Early Frog-Drawing Machine

To measure the force of contracting frog muscles had been a goal of physiological experimenters for several decades before Helmholtz began his work on the problem in 1848, at the same time as he began teaching at the Academy of Art. His immediate reference was the publication in 1847 of Eduard Weber's comprehensive experimental analysis using the "myodynamometer" of **figure 15**. When stimulated by an electric impulse through the wires c and d, the tongue muscle contracted by an amount that could be measured rather accurately by reading the deflection of the silk fiber *hi* with a telescope placed 10 feet away. The stimulating current was produced by an alternating current generator, which kept the muscle in a state of constant contraction. Weber's basic procedure involved measuring the length of an unexcited muscle under a given load in the pan and then its contracted length when stimulated. From such measurements, carried out over widely varying conditions, he established that for a given muscle in a given state of tiredness the amount of contraction depended only on the length of the muscle and that the weight it could lift depended only on its cross-section. Knowing the load and the height of

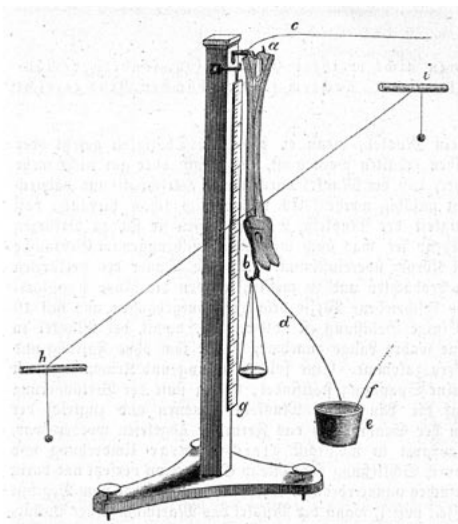

Figure 15. *Myodynamometer from Eduard Weber, "Muskelbewegung," in Wagner (ed.), Handwörterbuch der Physiologie, III, part 2, 69 and 86.*

contraction, he could also calculate the work done by the muscle (work = weight x height), although this was a secondary consideration. [27]

Two aspects of Weber's extensive study attracted Helmholtz's attention. First, his measurements with the myodynamometer were essentially static, looking only at the difference between the contracted and uncontracted state and not the process of contraction. Second, he had concluded that the action of the muscle could best be understood by analogy to an elastic band or spring, but one whose modulus of elasticity varied with length, state of tiredness, and other factors. This description provided a new analytic model for the muscle's external behavior, abstracted from internal chemical and physical changes.

From the beginning of his own experiments, Helmholtz set out to investigate the temporal process of contraction and relaxation of a muscle. This interest certainly derived in large part from his previous studies in physiology and physics, particularly his now classic paper of 1847 on conservation of energy, as also from Du Bois-Reymond's electrophysiological experiments, suggesting that a continuously excited muscle must actually be undergoing repeated cycles of contraction and relaxation. But importantly for consideration of Helmholtz's aesthetics, these physical and physiological concerns with the temporal process of muscle action merged directly with one of the purposes of teaching anatomy to art students, which he highlighted in his trial lecture at the Academy of Art. Human models maintaining fixed poses, he observed, display nothing like "the *Forms* of the moved body" in its capacity to act. "The artist must know which muscles swell with the motion . . . if their figure should not seem to stand still like the model." [28] For muscles in action, ideal *Forms* were dynamic *Forms*.

His immediate task, Helmholtz said two years later, had been to discover "in what lengths of time and stages the energy of the muscle [its capacity to do work] rises and falls after momentary excitation?" [29] **Figure 16** suggests the basic structure of the original machine that he

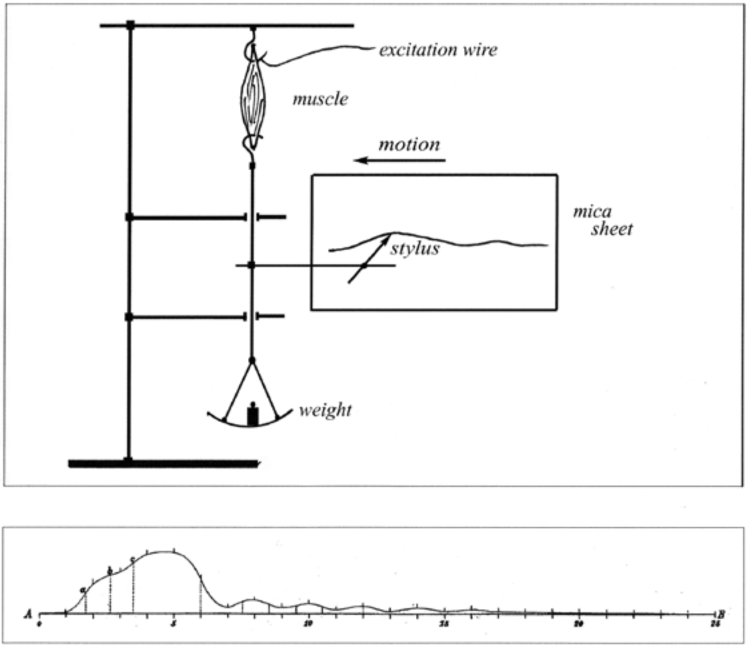

Figure 16. *Sketch of Helmholtz's initial frog-drawing machine (Froschzeichenmaschine) of 1848 (top) with an actual curve draw by a muscle (bottom) from "Messungen über den Zeitlichen Verlauf," Wiss. Abh., II, Tafel V, Fig. 3.*

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[27] Eduard Weber, "Muskelbewegung," in Rudolph Wagner (ed.), *Handwörterbuch der Physiologie mit Rucksicht auf physiologische Pathologie* (Braunschweig: Vieweg, 1846), vol. 3, part 2, 1–122.

[28] Helmholtz, "Probevortrag," 102.

[29] Helmholtz, "Messungen über den Zeitlichen Verlauf der Zuckung animalischer Muskeln und die Fortpflanzungsgeschwindigkeit der Reizung in den Nerven," *Müller's Archiv für Anatomie, Physiologie, und wissenschaftliche Medizin*, 17 (1850), 276–364; in *Wissenschaftliche Abhandlungen von Hermann von Helmholtz*, 3 vols (Leipzig: Barth, 1882–95), II, 764–843, on 786. With some loss of nuance, I substitute the modern "energy" for Helmholtz's *Energie*, which he had newly adopted here and which had wider connotations than "energy." For analysis see Wise, *Bourgeois Berlin*, ch. 8.

designed for this purpose along with an example of an actual curve drawn by a frog's calf muscle. As the muscle contracted it raised a stylus, which scratched its position into a sheet of mica moving under it. The instrument itself was directly adapted from an early version of the Watt "indicator" used on steam engines to plot a curve of the pressure inside the cylinder as the piston went through a full cycle. As Carl Ludwig described the result: "Helmholtz has had the curve . . . drawn directly by the frog muscle; this occurred according to the principles of the graphic method of Watt."[30] From this indicator diagram, mechanics and engineers calculated the work done by the engine during one cycle. This was precisely the sort of temporal curve and associated calculation that Helmholtz had in mind for the dynamics of muscle action.

The earliest surviving record of his instrument appears in a letter to his fiancée Olga von Velten in July 1848.

> "I have now finished building my frog-drawing machine (*Froschzeichenmachine*) and have already made a few trial drawings on small sheets of mica, with a leaf spring inserted in place of the frog muscles. Carried by the spring, the weight oscillated up and down and sketched its motion. The drawings (*Zeichnungen*) are much more beautiful than the earlier ones, very fine and regular."[31]

Without overemphasizing Helmholtz's concern with the "beautiful" in his curves, it is worth noting that their beauty appears to consist here in their approach to the harmonic oscillations of a perfectly elastic spring. Only an instrument capable of expressing this *Form* for the ideal spring would be able to render the equivalent *Form* for a muscle and thus serve as a proper frog-drawing machine.

Helmholtz had intended this initial apparatus only to allow him "to experience just so much of the simple contraction as I needed in order to be able to construct the definitive apparatus."[32] Nevertheless, it produced a striking result. The successive inflection points at *a, b, c* (equilibrium points) told him that the muscle did not immediately contract with its full capacity to raise the weight (its energy), as Weber had supposed.

> "We extract from this the previously unknown fact that . . . the energy of the muscle does not completely develop in the moment of an instantaneous excitation but, for the most part, only after the excitation has already ceased does it gradually increase, reach a maximum, and then disappear again." [33]

On the elastic band analogy, this increasing energy meant that the modulus of elasticity of the muscle had to be increasing, since the equilibrium points moved higher. The electrical stimulus acted only like a trigger, initiating a process in the muscle—chemical, electrical, thermal, or mechanical—that continued in time as its energy developed.

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[30] Carl Ludwig, *Lehrbuch der Physiologie des Menschen* (Heidelberg: Winter, 1852), 333. Helmholtz described the instrument in 1850 in "Messungen über den Zeitlichen Verlauf," 767–771.

[31] Helmholtz to Olga von Velten, 18 July 1848, in Richard L. Kremer (ed.), *Letters of Hermann von Helmholtz to his Wife*, 1847–1859 (Stutttgart: Steiner Verlag, 1990), 43.

[32] Helmholtz, "Messungen über den Zeitlichen Verlauf," 767.

[33] Helmholtz, "Messungen über den Zeitlichen Verlauf," 770.

A New Machine

Although Helmholtz's preliminary frog-drawing machine had produced a dramatic result, he was concerned that his graphical method was flawed by internal friction in the muscles and not sufficiently precise to be convincing by itself. He would not return to this direct drawing method until two years later, after he had received a professorship in Königsberg and after he had developed a quite different, and indirect, method. It effectively constructed the curve of increasing energy one point at a time.[34] This indirect method enabled him to conclude that a smoothed version of the original curve was its true *Form*, which he now called the "*Form* of the rise of energy " (*Form der Ansteigung der Energie*) and which he occasionally distinguished from the *Gestalt* of contingently variable curves like the original.[35]

Basing himself on the stability of this *Form* and on a sophisticated calculation using the method of least squares, he was also able to demonstrate another stunning result: stimulation of the muscle through a length of its nerve required time for propagation in the nerve itself. It was this discovery of the time for propagation of the nerve impulse that gained him immediate attention, and some disbelief (as well as enduring fame).

In order to make the *Form* of the curve completely *anschaulich* and thereby to make equally *anschaulich* his discovery of propagation

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[34] Holmes and Olesko, "Experiment, Quantification, and Discovery," give extensive discussion.

[35] Helmholtz, "Messungen über den Zeitlichen Verlauf," 791–794, 820. Similar usages of *Gestalt* and *Form* appear at 768 and 770.

[36] Described in Helmholtz, "Ueber die Methoden, kleinste Zeittheile zu messen, und ihre Anwendung für physiologische Zwecke," read to the Physikalisch-ökonomische Gesellschaft zu Königsberg, 13 December 1850; published in *Königsberger naturwissenschaftliche Unterhaltungen, 2* (1850), 1–24; in *Wiss. Abh.*, II, 862–879, and Helmholtz, "Messungen über Fortpflanzungsgeschwindigkeit der Reizung in den Nerven. Zweite Reihe," *Müller's Archiv für Anatomie, Physiologie, und wissenschaftliche Medizin, 19* (1852), 199–216; in *Wiss. Abh.*, II, 844–861.

time, which depended on that *Form*, Helmholtz developed in 1850 a much more sophisticated version of his frog-drawing machine, shown in his own drawing in the cover illustration and **figure 17.** [36] He based his new design on a more modern indicator (a), with a rotating drum replacing the plane sheet and with a stylus drawing on its smoked surface. For other technologies he turned again to engineers, especially to his friend in the Physical Society, Werner Siemens, co-founder of a small telegraph firm that would become the giant Siemens Corporation. As a lieutenant in the artillery corps, Siemens had in 1845 designed an "electrical chronoscope" for measuring the velocity of cannon balls

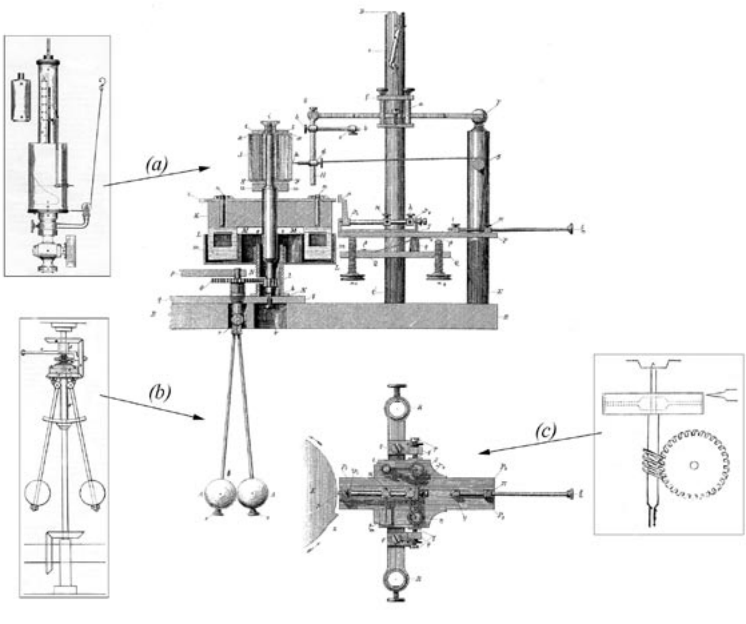

Figure 17. *Helmholtz's final frog-drawing machine, of 1850–52 ("Messungen über Fortpflanzungs-geschwindigkeit," Tafel II, Figs. 1, 3), showing the resources he incorporated (see n. 37): (a) typical steam engine indicator (Hopkinson, Indicator, facing 9); (b) conical pendulum regulator (Siemens, "Beschreibung des Differenz-Regulators," 9); (c) spark-registering cylinder for measuring the velocity of cannon balls (Siemens, "Ueber Geschwindigkeitsmessung," 66).*

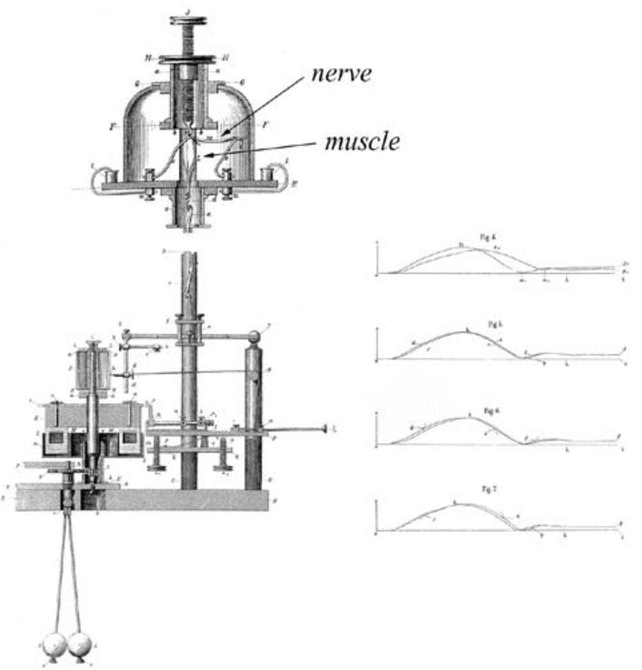

Figure 18. *Helmholtz's final frog-drawing machine with the muscle housing added from "Messungen über den Zeitlichen Verlauf," Tafel V, Fig. 2, and with frog drawings from "Messungen über Fortpflanzungsgeschwindigkeit," Tafel II, Figs. 4–7.*

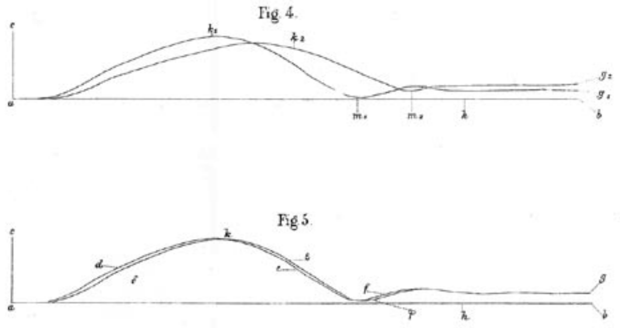

Figure 19. *Detail of frog drawings of figure 18, showing the irregular results from a tiring muscle (Fig. 4) for comparison with the fully congruent curves from a fresh muscle (Fig. 5).*

with extremely high precision. It depended on measuring the travel time of the cannon ball passing through two gates, which triggered electrical sparks registered on a cylinder rotating at high speed (c). Helmholtz combined this "happy idea . . . of letting the electricity itself do the drawing" with the indicator to obtain a precise timing mechanism. Another Siemens invention, his "differential governor" (b), may have supplied the idea of using a conical pendulum for a regulating device (although it was never fully functional).[37] A skilled Königsberg mechanic then realized the composition of these three elements according to Helmholtz's designs.

Figure 18 adds to this composition the frog muscle itself inside its bell-jar housing, showing its long nerve *w* with two electrical leads contacting it at a separation of about 4 cm. When stimulated, the muscle would lift the hook at its lower end and thereby the framework carrying the stylus, which would then draw a curve on the rotating drum. The adjoined series of pairs of curves, Fig. 4 – Fig.7, were produced by muscles under a variety of conditions. Fig. 4 (enlarged in **figure 19**) gives two curves drawn by a rapidly tiring muscle which was stimulated twice in succession at the same point on the nerve. They clearly do not maintain a constant shape. For k_2, the muscle lifted the stylus to a lower height in a longer time, relaxed much less rapidly, and extended less fully. Using Helmholtz's language from the Academy of Art, these curves show the "earthly imperfection" of a particular *Gestalt*. They could never be used in an

[37] For the indicator, see e.g., Joseph Hopkinson, *The Working of the Steam Engine Explained by the use of the Indicator,* 2nd ed. (London: Weale, 1857). Werner Siemens, "Anwendung des elektrischen Funkens zur Geschwindigkeitsmessung," *Poggendorff's Annalen der Physik und Chemie*, 66 (1845), 435–445; *Wissenschaftliche und technische Arbeiten von Werner Siemens*, 2 vols (Berlin: Springer, 1891), I, 8–14. Werner Siemens, "Ueber Geschwindigkeitsmessung," *Fortschritte der Physik im Jahre 1845*, 1 (1847), 46–72. Helmholtz, "Methoden, kleinste Zeittheile zu messen," 867. Werner Siemens, "Beschreibung des Differenz-Regulators der Gebrüder Werner und Wilhelm Siemens," *Dingler's polytechnisches Journal*, 98 (1845), 81, in Siemens, *Wiss. u. Tech. Arbeiten*, II, 2–11.

argument that depended on the shape being invariable, on being the "perfected impression" of an Ideal *Form*.

In contrast, Fig. 5 gives results for a fresh muscle stimulated first at one end of the nerve and then at the other. They are entirely congruent except for a slight lateral displacement, indicating no change in the action of the muscle. They both give a full visual picture of the course of the contraction: from the moment of stimulation at *a*, to the delayed onset of contraction, through the definite and highly reproducible shape of the working process of the muscle, to its return, almost to its original extension. Anyone observing the curves attentively would have an immediate *Anschauung* both of this "*Form* of the rise of energy" and of the relative displacement between them. Because the displacement depended only on the difference in the point of stimulation, it would also be apparent that it measured the time taken for the nerve impulse to propagate through the nerve. On the basis of this measurement, probably made by actually shifting one curve until it was superposed over the other, Helmholtz gave a velocity estimate of 27 m/sec, in close agreement with his previous results.

Helmholtz as Artist: Beauty and Technik

We saw in Helmholtz's trial lecture at the Academy of Art his expression of the common view that the role of the artist was not to copy natural objects but to discover in them the underlying Ideal that made them worthy of the term "beauty." The study of anatomy could never by itself supply this refined sense of beauty (*Schönheitssinn*), but it could smooth the way to acquiring it through an understanding of the causes of the various shapes expressed in the human body. Most importantly, anatomy could teach the artist to differentiate essential from inessential features of the human *Form*, so as to eliminate everything accidental in the interests of reaching the clarity and simplicity of its ideal content. The preceding discussion shows that this goal matches rather closely Helmholtz's program for revealing the *Form* of the curve of energy. If the beauty of the curve was only rarely his direct concern, its *Form* was his constant obsession. And as in the case of human muscles in motion for the artist, the *Form* of the contracting frog muscle was dynamic. Through his entire succession of mechanical contrivances, he aimed at revealing this *Form* as it developed in time.

Helmholtz continued to develop his aesthetic values as his physiological work carried him from hearing to music and from vision to visual art, with an ever-increasing emphasis not only on the laws but on the mechanisms underlying the beautiful. One of his much-discussed popular lectures, delivered several times and printed in 1876 as "Optisches über Malerei," will serve to make the issue more concrete. He reiterated his idealist perspective:

> "The human figures in the work of art cannot be the everyday people, as we see them in photographs, but rather expressively and characteristically developed *Gestalten,* where possible beautiful *Gestalten*, which perhaps correspond to no Individuum who is living or has lived but rather such a one as could live and as must exist in order to bring any particular side of the human essence into our lively *Anschauung* in full and undistorted development." [38]

Now in much more detail than for anatomy, Helmholtz developed the argument that in order to bring such "idealised types" into existence the artist had to understand, if only intuitively, the constraints imposed by the "physiological-optical" characteristics of vision on any attempt

[38] Hermann Helmholtz, "Optisches über Malerei," P*opuläre Wissenschaftliche Vorträge* (Braunschweig: Vieweg, 1865–76), drittes Heft (1876), 55–97, on 60.

to reproduce on a flat surface the naturalistic effects of light, color, shade, and three-dimensionality. Most obviously, binocular vision, motion, and turbidity of the air always threatened to betray the naïve use of perspective drawing and true-color pigments on a flat surface. Understanding their effects, however, could allow the artist to produce naturalistic imitations with shadows, shading, and subtle changes of color and focus. Much more difficult were the problems of natural brightness and color contrast versus the brightness and color of pigments, all as perceived through the eye's sensitivity to light and its three-color receptors. Helmholtz famously analyzed the physiology of vision in his *Handbuch der physiologischen Optik* of 1867, which attained great currency in the theory and practice of painting in the late 19th century. His aim in the essay, however, was to show that with respect to art the aestheticians had wrongly failed to take into account the technical means required by the artist to produce representations having the "easiest, finest, and most exact intelligibility (*Verständlichkeit*)." Studying what was required to attain such "sensual intelligibility" made it apparent that the task always involved "a kind of optical deception," that a literal copy of nature was simply a chimera, for even if it could be produced it would be unintelligible, a monster. [39]

Helmholtz put his conclusion in a pointed form: "The artist cannot copy nature; he must translate it. Nevertheless, this translation can give us an impression, anschaulich in the highest degree and penetrating, not merely of the represented objects but even of the strengths of light, modified in the highest degree, under which we see them." The goal of such translations of nature into the language of the senses was not ultimate reality; nor was it an unmediated and uninterpreted image; it was rather "truth-to-nature" (*Naturwahrheit*). Truth-to-nature is here the truth of an "ideal type." A work of art that attains this truth has the capacity to direct our slumbering conceptual connections, our associated feelings, and our scattered memories toward a common goal: "to combine in vital *Anschauung* an ideal type which lies scattered in isolated pieces and overgrown by the wild undergrowth of chance." This explains the power of art over reality. While reality (*Wirklichkeit*) always mixes the "disturbing, fragmenting, and injurious in its impressions, art can collect all the elements for the intended impression and allow them to act unconstrained." [40]

The translations required to produce such truth-to-nature, however, did not derive from talent alone, they demanded a variety of acquired skills, techniques, and sensitivities that Helmholtz collected under the *Technik* of the artist. It was this *Technik* that his scientific exploration of painting clarified. The term *Technik* here (as in previous uses above) extends beyond both technique and technology, though it includes both, carrying also the connotations of fundamental knowledge and aesthetic striving. "Thus the characteristics of the artistic *Technik*, to which the physiological-optical investigation leads us, are in fact intimately interrelated with the highest tasks of art." [41] Grimms' 19th century dictionary gives *Technik* as "the artistic or craft activity and the sum of experiences, rules, principles, and know-how according to which, through practice, an art or craft is pursued," with citations for the fine arts from Goethe, Schiller, and others. [42] In this connection of art to right action, *Technik* maintains its origins in the Greek *technê*.

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[39] Helmholtz, "Optisches über Malerei," 58, 96

[40] Helmholtz, "Optisches über Malerei," 95, 96. Helmholtz's idealized "truth-to-nature" corresponds closely with the meaning ascribed to that term for the 18th century, in contrast with "mechanical objectivity" for the 19th century, by Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007), ch. 3, "Mechanical Objectivity"; and "The Image of Objectivity," *Representations, 40* (1992) 81–128, on 84–98. Their focus, however, is on atlases, in the natural historical tradition, rather than on natural philosophy in the sense of experimental and theoretical physics, with their strong idealist character, for which I am skeptical of the distinction.

[41] Helmholtz, "Optisches über Malerei," 70, 97

[42] Helmholtz, "Optisches über Malerei," 97. *Deutsches Wörterbuch von Jacob und Wilhelm Grimm (Erstbearbeitung) auf CD-ROM*, H.-W. Bartz et. al. (eds), (Universität Trier & Berlin-Brandenburgischen Akademie der Wissenschaften, 2001). I thank Lorraine Daston for an illuminating discussion of *Technik*.

And it is surely these origins that Helmholtz's usage reflects directly, informed by his Gymnasium education and his philologist father. Of the various authors he might have considered, Plato seems most directly relevant here.

Greek usage generally made no sharp distinction between *technê* as art or craft and *epistêmê* as knowledge. According to a detailed survey of their relations by Richard Parry, *technê* includes all kinds of practical action, from medicine, farming, and political rule to geometry, music, and painting, but it is also knowledge, *epistêmê*, rather than mere practice, because it can give an account of its activities and accomplishments in terms of the nature of the object sought. For Plato, in the *Republic*, this knowledge of the "real" nature of things is the knowledge of forms, especially the forms of the beautiful, the good, and the just. It is the knowledge required of philosophical rulers. Such knowledge of unchanging forms, as *epistêmê*, is often understood as purely intellectual, inaccessible to the changeable world of the senses and therefore to *technê*. But in *Republic* VI Plato has Socrates giving a more interesting discussion, one that represents more closely the view of Helmholtz and his contemporaries in humanistic Berlin. Political rule is *technê*. The philosophical ruler employs knowledge of the forms as a guide in his craft, attempting to imitate them in practice, like a painter imitating the forms of nature. In Parry's distillation, "Like painters, philosophers look to (*apoblepontes*) the truest paradigm, always referring to it and contemplating it as accurately as possible; in this way they establish here the laws respecting the fine, the just, and the good."[43] Extending Plato's analogy, the painter, like the philosopher, is able to realize the forms and laws through his *technê*, or in Helmholtz's German his *Technik*.

Like Plato's Socrates, Helmholtz sought to introduce technical science into the aesthetic considerations of academic art, through *Technik*, as a necessity for the highest ideals of art. And in much the same way, he and his compatriots in the Berlin Physical Society sought to introduce technical experimental science into the university as a necessary component of its philosophical research ideal. In both cases the claims of the intellectual ideal (Plato's "real" forms) could only be attained through a deep engagement with the technological real, which provided the means for translating nature into terms compatible with the human sensory apparatus and thereby accessible to human understanding.

"Artistic *Technik*" had a well-defined purpose for Helmholtz. It generated the truth-to-nature of the immediate sensory impression. "It must act certainly, quickly, unambiguously, and with precise definition, if it is to make a lively and powerful impression. These are the points that I have sought to summarize under the name of intelligibility (*Verständlichkeit*)." As it happens, these are much the same criteria that Helmholtz sought to fulfill for the intelligibility of his curve of energy. In continuing to perfect the graphical method, for example, he expected it to lead "to a more satisfying and quicker representation of our results on the velocity of propagation in the nerves." [44] He could have elaborated "more certain, quick, unambiguous, and precise," for these are the qualities that the entire *Technik* of the frog-drawing-machine needed to fulfill if it were to enable the muscle to produce direct visual impressions of its dynamic action.

In summary, the nature of the muscle and nerve processes stood in relation to the curve of energy much as the nature of the human subject stood in relation to the lines and surfaces of a finely executed painting. Both required a highly developed *Technik* in order to translate nature into a refined representation. Far from producing a true

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[43] Parry, Richard, "Episteme and Techne", *The Stanford Encyclopedia of Philosophy (Summer 2003 Edition)*, Edward N. Zalta (ed.), 1–19, on 6; URL = <http://plato.stanford.edu/archives/sum2003/entries/episteme-techne/>. Parry's discussion includes also relevant reflections of Xenophon, Aristotle, the Stoics, Alexander of Aphrodisias, and Plotinus.

[44] Compare Helmholtz, "Optisches über Malerei," 97, with "Messungen über den Zeitlichen Verlauf," 837.

copy of nature, the goal of the translation was rather to produce an idealized image of essential qualities of the natural object. The curve of energy was just such an idealized universal image. It was a curve of an abstract concept, energy, which had to be made understandable through the *Technik* associated with the mechanical instruments that made its representation possible, while eliminating any extraneous effects. Only as this idealized and translated image was the curve capable of displaying directly the *Form* of the muscle contraction and with it the propagation time of the nerve impulse.

It seems appropriate to conclude with the suggestion that Helmholtz saw himself in the role of an accomplished artist, a master of the *Technik* that enabled one of nature's *Forms* to be revealed. Symbolically he ascribed that role to himself when he signed the refined drawings of his instruments in the lower left corner, like any other artist (**figure 20**).

Figure 20. *Like a professional draftsman, Helmholtz signed his drawings in the lower left corner (from "Messungen über den Zeitlichen Verlauf," Tafel V).*

Author's biographical sketch

M. Norton Wise teaches history of science at the University of California, Los Angeles, where he is Distinguished Professor of History and Co-director of the Center for Society and Genetics. With Ph.D. degrees in both physics and history, Wise focuses on the ways in which science is embedded in its socio-cultural context, such that they co-evolve. In this process, technologies play a fundamental role as mediators. That theme appears in *Energy and Empire* (1989, with Crosbie Smith), *The Values of Precision* (1995, edited), and *Bourgeois Berlin and Laboratory Science* (in progress). Wise has also investigated how ideals of scientific explanation have changed dramatically in recent decades in *Growing Explanations* (2005, edited) and *Science without Laws* (2007, co-edited). His other interests include landscape gardens, the gendering of scientific concepts, and automata in history.

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