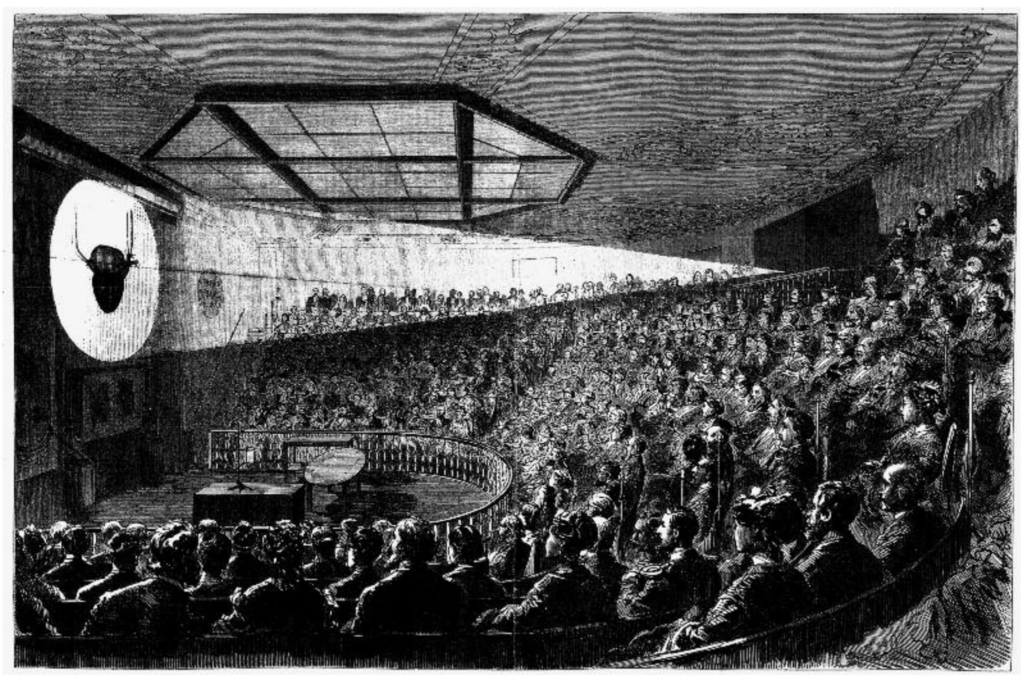
Czermak's frog heart projection in the Leipzig Spectatorium, 1872.



1900—The Spectatorium: On Biology's Audiovisual Archive

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"In order to give a sense of the viewability of this surprising demonstration, I only mention that the diameter of the silhouette of the still-beating heart appearing on the wall was about two meters."[1] Johann Nepomuk Czermak was satisfied, probably even proud. On December 21, 1872, the physiologist had inaugurated his Private Laboratory at the University of Leipzig. The visual climax of the ceremony was the extremely enlarged projection of an isolated, still-contracting frog heart in the darkened lecture hall. As Czermak underlined in his opening speech, more than 400 spectators were enabled, by means of this "surprising demonstration," to observe minute details in the contraction of the frog heart "that escape or are hardly visible to the unassisted gaze."[2]

The "viewability" (*Schaubarkeit*) Czermak referred to was part of a comprehensive conception of visual instruction in experimental physiology. At the beginning of his speech, Czermak had emphasized the crucial role of "visual perception," or *Anschauung*, in the teaching of physiology. Since the late eighteenth century, *Anschauung* had played a crucial role in German philosophical idealism and romantic biology. In the writings of Immanuel Kant, Johann Wolfgang von Goethe, and Alexander von Humboldt, the meaning of *Anschauung* oscillated between "visual perception" and "intuition." For example, Humboldt aimed at a comprehensive "view" of nature as embodied in perceptible totalities or concrete "arche-types" that were apt to sum up empirical knowledge and at the same time stimulate further research.[3]

Once experimental physiology had established itself as a leading discipline of the late nineteenth century, such idealist notions of *Anschauung* were radically transformed by means of laboratory technologies. Starting in the 1870s, physiologists turned their new institutes into sites of sophisticated sensorial stimulation. In particular, their auditoriums became *spectatoriums*; that is, viewing halls. Using complex assemblages of machines and organisms and specifically designed projection devices, leading physiologists such as Emil du Bois-Reymond in Berlin and Étienne-Jules Marey in Paris created a new dynamic image of life. Highlighting movement over stability, this image was meant to display the functioning of entire organisms or single organs in vivo. These physiologists confronted their audiences with "movement images" (to borrow a term from Gilles Deleuze) of the living body and its parts. One of the striking features of these movement images was that they were moving themselves. Carefully orchestrated by and synchronized with the speech of the lecturing physiologist, these dynamic and immersive images were crucial contributions to the definition of biology's audiovisual archive around 1900. In its center stood a fragmentary "cinematographic apparatus" consisting of projector, screen, and rows of seats. Cells, tissues, and organs functioned in the place of recordings on celluloid. Thus, before the advent of the cinema, the spectatorium housed something like a cinematography without film, a *cinema of bare life*.[4]

Czermak was the pioneering figure in this area. As early as 1872 he had explained that the decisive challenge for the teaching physiologist was

> to create and acquire the means for physiological demonstrations of a hitherto unachieved completeness and extension, so that—once this was accomplished—it would become possible to treat physiology for the first time by means of authentic and generally conceivable representations based on immediate visual perception [*unmittelbarer Anschauung*].[5]

He then listed the special features of the laboratory building he himself had paid for, emphasizing the architectural design and technological equipment of the lecture hall. Introducing the term *spectatorium*, Czermak highlighted the fact that this hall was not a mere auditorium. Its seat rows were arranged in the form of a horseshoe around the lecturer so that the distance between the "experimenter's arena" and the audience was reduced to a minimum. Because the ascending seat rows had been arranged according to strict geometrical principles, spectators could focus their gaze on the arena without obstructing one another. In the "Optical Room," situated at the top and behind the last row of the seats, were installed two limestone light projectors. These projected upon a circular screen located behind and well above the lecturer photographs of embryos, polished sections of bones, a colored photograph of a dog's knee, a cross section of human skin tissue, as well as the still-contracting frog heart that had formed the climactic moment of the opening ceremony.[6]

The visual archive of experimental physiology has often been identified and equated with the "graphical method." In 1847, physiologist Karl Ludwig introduced the use of rotating drums for registering, in curve-like form, the organic movements that result from respiration, circulation, and other vital processes. Shortly thereafter, Hermann von Helmholtz applied a refined version of this method to the problem of measuring the speed of muscle contractions and 0 nervous stimulations. Starting in the 1860s, Marey considerably broadened the scope of "*la méthode graphique*"—that is, the use of kymographs (Ludwig) and myographs (Helmholtz) as well as visual representations of data by means of graphs, tables, and diagrams.[7]

In the late 1940s, art historian Sigfried Giedion evocatively juxtaposed physiological and artistic movement images—on the one side, the Weber brothers and Marey; on the other, Marcel Duchamp, Wassily Kandinsky, and Umberto Boccioni. Ever since, historians of art and of science have investigated the corresponding traces, curves, and graphs that nineteenth-century scholars had produced in order to explore the living functions of individuals and their organs in the physiological laboratory.[8] Whereas notations à la Ludwig and Marey have found an obvious place in the history of social and cultural modernity, other aspects of physiological imagery have not received comparable attention and contextualization. For example, the visual practices of physiological work after Marey were profoundly transformed by the advent of cinematography and its use for scientific purposes.[9] But this also holds true for the variety of optical and acoustical experiences that, before *and* after Marey, were created in the lecture hall in order to propagate physiological knowledge.

Even before the foundation of the first large-scale institutes for physiology in the late 1860s, physiologists such as Czermak and Jan Evangelista Purkyně (one of Czermak's academic teachers) used phenakistoscopes, mirrors, magic lanterns, and other optical media to create a novel image of life in front of academic and general audiences.[10] This image was neither a fixation of organic kinematics by means of relatively stable lines and points (as in the graphical method) nor the cinematography of body action characteristic of the early history of motion pictures (according to Deleuze).[11] Instead it formed a dynamic representation of the equally dynamic movements of the living body. By means of animated drawings and the projection of stimulated preparations, organs, and organisms, the basic facts of physiology were made *anschaulich*, or visually evident, during lectures in order to foster recognition and respect for the emerging new science. The eighteenth century had conceived of physiology as animated anatomy, or *anatomia animata*. The late nineteenth century witnessed the emergence of cinematographic physiology and physiological spectacles.

In the 1870s, when laboratories of physiology were being established in growing numbers, the architecture of their lecture halls and the available technologies for visual instruction received heightened attention. In their teaching facilities, physiologists created a thoroughly temporalized visual representation of the functions of life. Through movable screens and powerful projectors and by the use of flags, rolling tables, as well as entire series of specifically designed demonstration devices—for example, the "contraction telegraph"—physiologists immersed their audiences in a cinema of life. In 1879, Granville Stanley Hall was studying physiology in Berlin and other German cities. To Hall, the innovative projections and demonstrations transformed the physiological lecture hall into "a sort of theater."[12]

To many physiologists, this turn away from mere lectures to carefully prepared spectacles was a logical step in the development of their discipline. As Friedrich Kittler has suggested, the modern history of German universities is closely tied to a regime of the spoken word. According to Kittler, the discourse network of the university around 1800 functioned as highly efficient "textual apparatuses" that, by means of precise utterances, turned subjects into servants.[13] While this holds true for discursive disciplines such as philosophy, theology, and law, the natural sciences opened up different channels for communication and perception. Following chemistry, physics and physiology gradually turned from verbal discourse to material practices firmly grounded in experiential knowledge. With the opening of Justus von Liebig's chemistry laboratory in the late 1830s in Giessen, hand and eye became organs of teaching and learning as important as had been mouth and ear. Assessing this development, physiologist Emil du Bois-Reymond declared at the opening of his Berlin physiological institute in 1877, "The physiological lecture hall, just like those of the physical and chemical sciences, had to become a show stage [*Schaubühne*] for natural phenomena, and from there on physiologists needed a teaching and research laboratory fitted to their specific needs."[14]

A New Image of Life

This paper investigates a specific form of image production in the physiological spectatoriums of the late nineteenth and early twentieth centuries; it focuses on the images of living frog hearts that were projected during physiological and pharmacological lectures. From the days of Czermak, such images were part of the standard repertoire of physiological instruction. Around 1900, however, frog heart projections took on increasing importance in the teaching of the emergent discipline of pharmacology. In his *Introduction to the Study of Experimental Medicine*, French physiologist Claude Bernard called the frog "the Job of physiology, that is to say, the animal most maltreated by experimenters."[15] Hardly any other model organism of nineteenth-century biology was used in such broad and diverse ways: to study the physiology of nerves and muscles, circulation, the senses, and so on. One reason for this widespread use is the relative ease with which the frog could be handled and made to produce and reproduce.[16] Another is the iconographic resemblance of the hanging frog and the bipedal posture of human beings.[17] However, the entire frog was not always used in research; its specific parts had model characteristics as well. For example, in the early 1850s its legs played an eminent role in Helmholtz's pioneering investigations concerning the velocity of the nervous impulse.[18]

From the 1860s on, another part of the frog became an increasingly important actor in physiological research. In this period, physiological scholars such as Elias von Cyon, Henry Bowditch, and Luigi Lucian became interested in the innervation of the frog heart, its irritability and rhythmic action and the problem of its nutrition and fatigue. In 1870, Oswald Schmiedeberg, one of the future "founding fathers" of experimental pharmacology in the German-speaking countries, published his path-breaking "Investigations into Some Effects of Poison in the Frog Heart" in the *Arbeiten aus der Physiologischen Anstalt zu Leipzig* (edited by Ludwig), and between 1880 and 1900, German physiology journals published numerous studies exploring the effects of ether, strychnine, and other substances on the functions of the frog heart.[19]

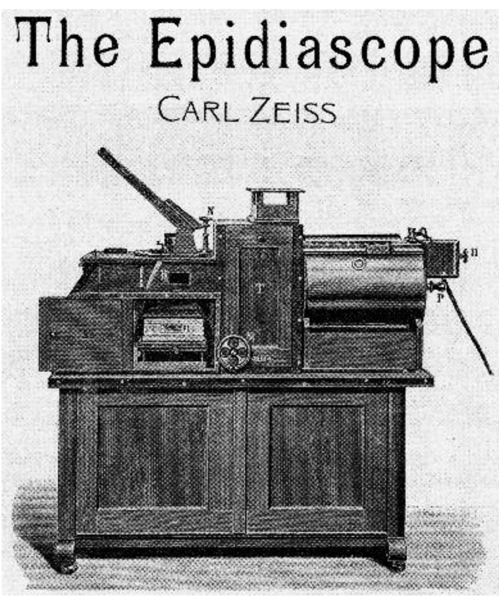
The growing interest in the physiology and pharmacology of the frog heart was paralleled by the development of new techniques for representing its activities; for example, devices for registering changes in volume of the isolated heart, instruments for pumping various kinds of fluids through it, manometers for measuring pressure, and apparatuses for the graphical recording of heart movements. However, the majority of these instruments were designed for laboratory use, not for demonstrations in the lecture hall. In the late 1860s, Czermak introduced such demonstration devices into the teaching of physiology. While giving popular lectures on the physiology of the heart in the Jena Rosensaal, he demonstrated the rhythmic movements of the organ by means of a "heart mirror," a cardioscope specifically designed for this purpose. A still-contracting heart cut out of a frog was placed on a small stand. Small pieces of cork connected with angled steel rods were placed on the two heart chambers. Attached to the end of each rod was a light mirror plate that moved backward and forward as the corresponding heart chamber contracted. By means of a device "similar to a magic lantern," a ray of light was directed at both mirror plates. The moving plates reflected the light onto a screen. In the darkened lecture hall the audience could thus see an enlarged image of the heart's movements.[20]

A decade later, Czermak's cardioscope was part of physiology reference works for research and teaching.[21] However, even thirty years later—that is, after the advent of cinematography—advanced projection technologies were used in order to create movement images of the frog heart that were meant to accompany physiological instruction in the lecture hall. In contrast to Czermak's projection of the contracting heart silhouette, the advanced technologies were designed to project *color* images of demonstration experiments in frog hearts that were "laid bare"; that is, fully exposed but connected to the rest of the body. The emergence of these projection techniques relied on improved technologies of illumination. Around 1900, the emergence and distribution of powerful light sources—in particular, the carbon arc lamp—permitted the creation of projections not only by passing a light ray through an object (transparent or diascopic projection) but also onto an object; that is, so the object directly reflected the light ray (opaque or episcopic projection).

In physiology, experimental pathology, and the emerging discipline of pharmacology, episcopic projection was used to show, as directly as possible, simple experiments on frogs and other model organisms to a growing number of students. Around the turn of the century, manufacturers of optical instruments in Europe and the United States offered an increasing number of devices for episcopic projection. In most cases, these devices could be used for both episcopic and diascopic projections, a double function often reflected in the names given to the devices by their manufacturers—for example, Universal Projection Apparatus (Leitz), Epidiascope (Zeiss), Universal Projectoscope (Stoelting). However, the use of such devices in the teaching of biology presented numerous challenges. For example, in many cases the heat of the light ray threatened the structure and function of the projected organs and organisms—a difficulty that was often coped with by placing a cooling chamber filled with water between the light source and the projected object.[22] Another difficulty lay in synchronizing the presentation of the visible and the audible; that is, aligning biological images with their biological terms or descriptions.

The Case of Carl Jacobj

The specific possibilities and problems implied in the use of episcopic projections during lectures are illustrated by the case of the Tübingen physiologist and pharmacologist Carl Jacobj (1857–1944).[23] In the 1880s, Jacobj studied medicine in Göttingen, Leipzig, Tübingen, and Strasbourg, with Karl Ludwig and Oswald Schmiedeberg among others. Under the direction of Schmiedeberg, he received his MD in Strasbourg in 1887 for a study "On the Excretion of Iron from the Animal Body after Subcutaneous and Intravenous Injection." In the following decade,



Epidiascope by Zeiss, 1906.

Jacobj was Schmiedeberg's assistant in the newly established Institute for Pharmacology in Strasbourg. After a brief interlude at the National Institute of Health in Berlin, Jacobj was professor of pharmacology at the University of Göttingen between 1897 and 1907. Shortly afterward, he was promoted to full professorship and became director of the new pharmacological institute in Tübingen, where he remained until his retirement in 1927.

Jacobj's reputation as an excellent teacher played a decisive role in his promotion from Göttingen to Tübingen.[24] In planning and organizing his new institute, he placed special emphasis on the design of the lecture hall and its technical equipment. In particular, Jacobj wanted to create a "lecture projection facility" (*Vorlesungsprojektionseinrichtung*) that served the special needs of pharmacological teaching. The architecture and technology of this facility was meant to allow for a kind of visual instruction that would no longer be interrupted by static illustrations (e.g., the presentation of charts and slides) but could be structured by the seamless integration of dynamic projections (e.g., the living frog heart).

Jacobj based his pedagogical conception on a physiological theory of the primacy of the visual in the emergence and distribution of knowledge. As a result, a rationalized conception of teaching replaced the idea of *Anschauung* that for many nineteenth-century physiologists still carried romantic overtones. In Czermak's visual practices, the crucial issue had been to demonstrate that the means of experimental physiology were capable of creating an image of life as visually evident as the images provided by natural history or embryology. In Jacobj's practice, the central problem became how an increasing number of students would be able to absorb in a limited period of time the rapidly growing body of knowledge produced in and by the experimental life sciences. Jacobj's presentation of movement images of the living was not an end in itself. Rather, it served a specifically modern economy of time and attention.[25]

Jacobj's projection images consisted of a cinematography without film that was accompanied by lectures and vice versa. Well before Jacobj, pioneers of the graphical method had attempted to set their chronophotographic images in motion. In the early 1880s, Eadweard Muybridge created a device called the "zoopraxiscope" in order to project such images from rotating glass disks and give the impression of motion. By contrast, Marey was not interested in projection per se but in the application of this technique for analyzing movements by "slowing down some movements and speeding up others."[26] After the advent of cinematography around 1895, scientists such as Charles-Emile François-Franck, Lucienne Chevroton, and Charles Richet used chronophotography and cinematography to capture the pulsing of the heart in various kinds of organisms.[27] However, not until the 1930s were similar films—for example, by René Lutembacher and Emil von Skramlik—made for use in the academic teaching of biology.[28]

What appeared on the screen of Jacobj's lecture hall in Tübingen around 1910 was altogether different. During his courses, Jacobj presented colored movement images. However, their repeated projection did not rely on chronophotographic or cinematographic shots that had been made beforehand but on the renewed presence of a living being that was "directly" projected. Technologically, the Tübingen lecture projection facility was based on the Universal Projection Apparatus by Leitz. When used for the projection of simple animal experiments, this apparatus was transformed into a complex assemblage of organic and mechanical parts, electrical current and light rays, lenses, carbon rods and mirrors, frogs, wooden boards, and water jars. In his writings Jacobj often used the term *Anordnung* (arrangement) to describe the complexity of this assemblage. Other historical actors even spoke of their projection devices as "complex organisms." Tied together by means of a cast iron frame, the combined elements of these image-producing assemblages reached their maximum effect within architectural conditions that allowed for rear projection—a technique often used in magic lantern shows (phantasmagorias in particular) and early cinema. Jacobj was convinced that only this kind of screen practice guaranteed the synchronicity of word and image, concept and object, that he believed to be the decisive feature of all efficient visual instruction.[29]

The Tübingen projection technology and architecture hybridized two distinct traditions in the material culture of science: on the one side, the architectural separation between the lecture hall and an adjacent preparation room that emerged in experimental physiology in the 1870s; on the other side, the use of episcopic projection technologies for creating images of macroscopic organ preparations in experimental pathology in the 1880s. From the late 1870s, physiological institutes in Budapest, Strasbourg, and other cities were provided with preparation rooms behind the lecture halls. These rooms were used for arranging demonstration experiments that were brought into the lecture hall on rolling tables. In contrast, institutes of pathology—for example, those in Vienna and Berlin—were pioneering episcopic projections of preparations and experiments.[30] Jacobj's pharmacology lecture projection facility brought together the architectures of the physiology institute and the apparatuses of the pathology institute. At Tübingen he could, by means of episcopic projection, project simple experiments out of the preparation room into a lecture hall where the corresponding images became visible on a screen. At the level of material culture, Jacobj's pharmacological demonstrations look back from the first decades of the twentieth century to the physiology and pathology of the late nineteenth century.

Visual Instruction and the Management of Time

In the 1860s and 1870s, Czermak advocated "immediate visual perception" (*unmittelbare Anschauung*) as a primary way of acquiring the knowledge of experimental physiology. In addition, he believed that "visual instruction" (*Anschauungsunterricht*) could elevate physiology to the rank of a "core component of *Bildung*."[31] Du Bois-Reymond emphasized the primary role of the visual in teaching experimental physiology. In 1877, he stated, "To see for himself and to convince himself" are the most important tasks for the beginning physiologist, even if this initially should require "some self-conquest."[32] To du Bois-Reymond, "the phenomena" of life ought to be "demonstrated as obviously as possible" during academic and public lectures. Without demonstrations and experiments, he explained, the teaching of physiology remained "fruitless."[33]

Jacobj placed comparable emphasis on the role played by visual perception in the process of creating and distributing objective knowledge. According to him, it was not by accident that the teaching methods of German high schools and universities increasingly relied on visual means such as inserting figures into textbooks or using wall charts and demonstrations in the classroom. As he explained, this kind of *Anschauungsunterricht* "facilitated" the acquisition of new knowledge while at the same time—and this was decisive for him—"accelerating" that acquisition. However, the acoustical and the optical aids (i.e., lecture and projection) had to be presented simultaneously. Only then could verbal instruction restrict itself to explaining the image in question:

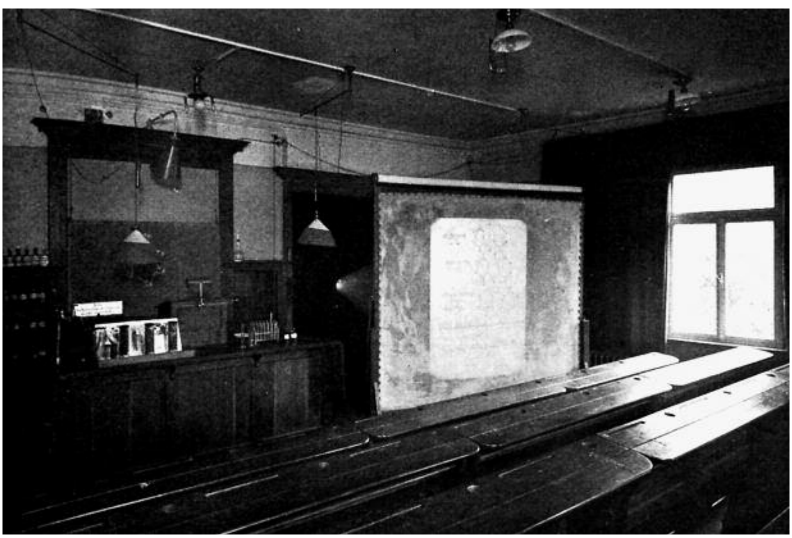
> Symbolically descriptive word images [*Wortbilder*] of concepts can be replaced by the simultaneously created visual image [*Anschauungsbild*] that represents the factual object of observation immediately and in all its details, so that it [the visual image] is imprinted in a faster, stronger, and more sustainable way on the conscious mind and, as a consequence, on memory.[34]

Through "immediate visual perception" of an object discussed in the oral presentation, the permanent understanding of this object became less difficult. More important, "immediate" visual perception saved time because the instructor could simply direct the students' attention to the details of the image being shown. As a result, Jacobj no longer understood *Anschauungsunterricht* within the framework of a romantic aesthetics of science. For him it had become a question of efficient time management.

For Purkyně and even Czermak, "immediacy" referred to the spatial closeness of the spectator to an object possessing visual clarity or, as Czermak put it, "intense viewability." For Jacobj, the same term, *unmittelbar*, designated a temporal relation, a momentariness or synchronicity of what was seen and heard. Precisely along these lines Jacobj underscored that, "by means of simultaneous co-action of the two sense impressions of hearing and viewing," instructors were able to achieve "a swifter and easier absorption of the stuff in shorter time."[35] According to Jacobj, the "immediate, simultaneous presentation" of concept and object was the only possible way to transfer the "vast amount of knowledge required by the profession and by life in the short time period of academic training"—a strategy that hints at the growing numbers of students in Jacobj's classes: before 1919, he taught 45–75 students per class; from 1919 until 1923, class sizes were between 100 and 215.[36]

Jacobj offered a detailed criticism of the traditional methods of demonstration and projection. The basic pattern of this criticism is unsurprising. The spatial and temporal separation between general lectures and specific demonstrations; the handing around of images, books, preparations, and instruments in the lecture hall; and the use of wall charts or hanging drawings, diagrams, and tables—none of this corresponded to the "principle of unity of word and visual image" that, according to Jacobj, was the basic principle of all *Anschauungsunterricht*. Preparations or instruments had to be handed around slowly from seat to seat. Wall charts were even worse, since they remained permanently visible, even after the verbal explanation had come to its end. Jacobj also criticized the attempt to integrate standard projections into lectures. The usual "intermediary pauses" (*Zwischenpausen*) resulted in a decoupling of concept and image that was to be avoided: "It is above all the darkening of the auditorium that precedes each presentation of images which is felt as an utterly annoying disturbance."[37]

This led Jacobj to another point. In addition to various forms of asynchronicity, visual instruction could be severely impaired by various ways of disturbing and distracting attention. He argued that the prompt hanging and taking away of charts was not a solution, because the corresponding handling of the charts by the lecturer or his assistant would distract the students. In projections, the noises of the darkening mechanisms, the operation of curtains and shades, the "disappearance" of students and professors in the dark, the working noise of the projector in the lecture hall, the unavoidable calls—"More focus, please! Too much! Wrong! Stop!"—and the "blinding" of the eyes when returning to



Interior view of the lecture hall, Tübingen Institute for Pharmacology, 1928.

daylight were distractions, disturbances, and irritations.[38]

To Jacobj, visual instruction that proceeded along these lines was nothing but a waste of time. In contrast, the visual instruction method he developed in Tübingen—based on the "principle of placing the apparatus in an adjacent room while using a transparent screen"—appeared to be much more promising.[39] At the Tübingen Institute, a preparation room situated behind the lecturer and his experimenting table allowed for projections from this darkened room into the lecture hall. The temporal unification of the spoken word and the projected image was thus produced by means of spatial separation.

Beside the experimenting table was a large window connecting the lecture hall and the preparation room. The interior of the latter was painted black to avoid reflection. The window was in fact a two-meter-square screen of fine linen covered with paraffin. Jacobj reported that the required semipermeability of the linen screen was achieved by means of a special procedure developed "after a long series of preliminary trials" (*Vorversuchen*).[40] The screen, an interface between front- and backstage, was of prime importance in Jacobj's lecture projection facility: it separated the image production by the assistant backstage from the image consumption by the students sitting close to the front stage, while at the same time connecting them to each other. Jacobj, standing next to the screen, controlled the circulation of the images.

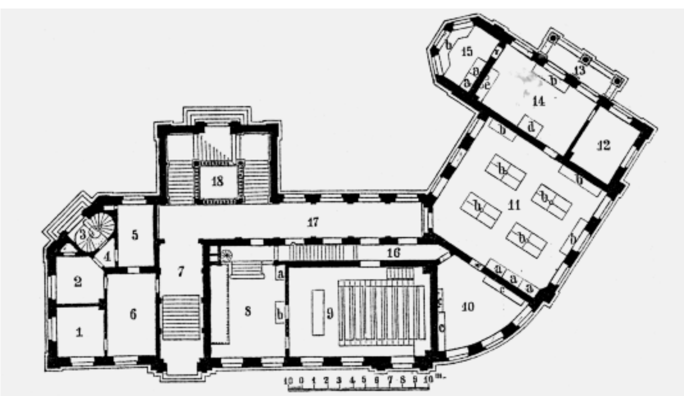
According to Jacobj, by projecting on the rear of the screen the lecture hall could remain lit. At the same time, a moveable blind allowed the images prepared by the assistant to be shown at exactly the moment the instructor needed them. Frontal projection presented clear disadvantages, "since it means drawing curtains, arranging the projector, and having the speaker's personal contact with the students disappear, on account of their losing sight of each other."[41] In the Tübingen facility, an assistant placed in the preparation room made all necessary preparations for the projection, including the changing of images and their focusing. The assistant would follow the lecture and swiftly react to what the instructor was saying or suggesting. The advantages of the system were clear: "There is no disturbance attendant upon the projecting itself, no interruption of the speaker's flow of thought, all the students can see the image at the same time, at exactly the proper moment, and when this image has served its purpose, it can be made to disappear."[42] At this point, the auditorium existed as a spectatorium.

Preparation Rooms

Jacobj acknowledged that a comparable lecture projection facility had been used "probably for the first time" at the Strasbourg Institute for Pharmacology.[43] The institute, constructed between 1883 and 1887 according to plans by architect Otto Warth, had a preparation room directly behind its auditorium. For ten years, Jacobj worked at the institute as lecture assistant to Schmiedeberg, and his long-term experience "behind the scenes" influenced his design of the Tübingen devices and the arrangement of its lecture hall. A contemporary description of the Strasbourg institute notes that its preparation room could store the "animals meant for demonstration" for as long as they were needed for a lecture. The room was also used as a storage site for other demonstration objects—"such as drugs, chemicals, medicinal products, figures, and so on."[44]

Jacobj does not mention in his writings that other physiological institutes included similar spatial structures even earlier than did Strasbourg. Sometimes these structures were explicitly embedded in ambitious projects for visual instruction. This was the case at the Budapest Institute for Physiology. The physiologist Andreas Eugen Jendrassik had planned the building, erected between 1873 and 1876, in cooperation with architect Antal Szkalnitzi. Like other physiologists before him, Jendrassik was eager to offer "immediate visual perceptions [*unmittelbare Anschauungen*] of the object" of physiological science.[45] Similar to du Bois-Reymond, Jendrassik assumed that physiology, like chemistry and physics, was capable of "making sensual" (*versinnlichen*) oral presentations by means of experimental demonstrations, thus turning the latter into the "experiential basis" (*Erfahrungsgrundlage*) for all theoretical considerations.[46] Implicitly alluding to Czermak, Jendrassik added that, when planning the new institute, his aim had been to integrate not just an auditorium but specifically a "spectatorium." Jendrassik also touched upon issues of time management: "As soon as physiology aims at communicating experience-based knowledge to larger circles, it has to strive for appropriate means in order to guarantee that for large groups it gives simultaneous insight into the articulated complex of organic processes."[47]

The "appropriate means" Jendrassik alluded to were: first, the generous layout of the auditorium, with space for 200 students; second, the calculated arrangement of the rows of seats with respect to the large experimenting table; third, the illumination of the lecture hall by gas lamps that could be switched on by means of electricity; and fourth, the presence of blackboards and other equipment for presenting large drawings, as well as projection devices and automatic shutters. A "preparation room for experiments," adjacent to the back of the lecture hall, served the purposes of his *Anschauungsunterricht*. The preparation room was connected to the auditorium by a door so that "tables with the animals prepared for experiment or other apparatus . . . can be transferred to the lecture hall."[48] A system of tracks fixed to the floor allowed the rolling tables on which the



Left: Plan of the Strasbourg Institute for Pharmacology, ca. 1887. Lecture hall (9) and preparation room (8).

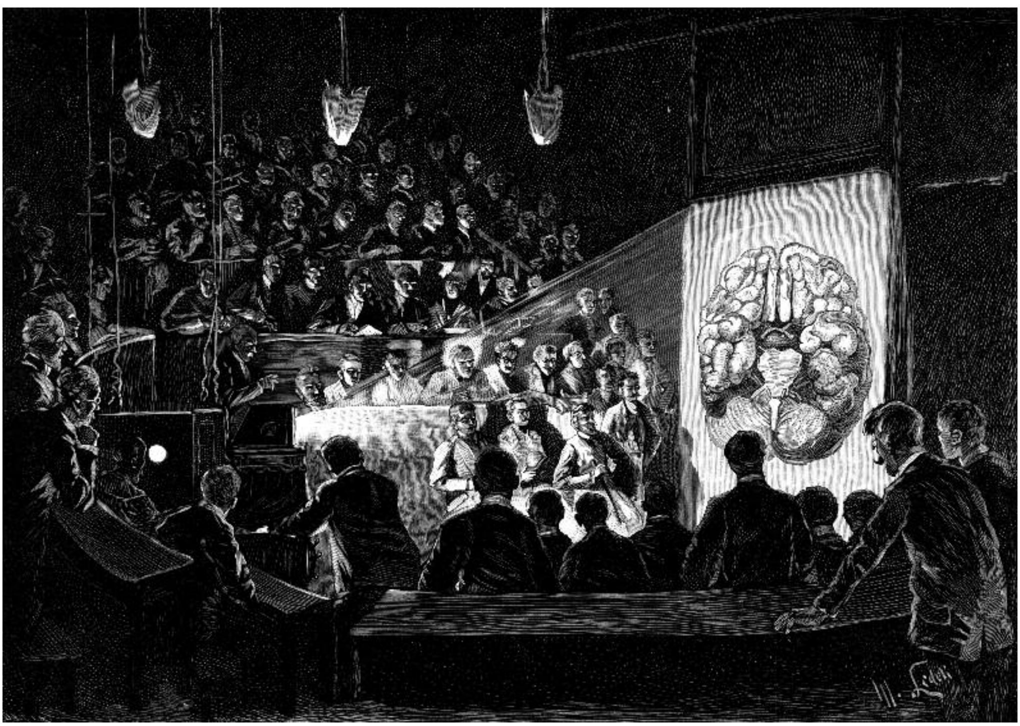
Opposite: Stricker's use of episcopic projection technology in his lecture hall at Vienna, 1890.

animals were prepared to be pushed back and forth. A revolving disk allowed them to move left and right before the rows of seats so that the largest number of students could see the experiment. The surfaces of some of the tables could even be inclined so that "the vivisection board with the animal fixed onto it [could be turned] toward the spectators as any given case requires it."[49] The door connecting the lecture hall and preparation room was covered with boards that could be moved horizontally—including large opal glass plates that could be used for "light projections from the preparation room situated behind."[50]

Similar separations between front- and backstage could be found in other physiological institutes of the period; for example, in Würzburg (founded in 1892) and Turin (1894). Their common spatial arrangements served not only the preparation of demonstration experiments. In Würzburg, for example, a "sciopticon," an early form of the slide projector, projected images onto the backside of a 1.3-square-meter frame covered with a specially prepared canvas. One of the main advantages of this arrangement was that the projector could be placed on a vibration-free stone table in the backroom. In addition, the projector could be handled without disturbing the students.[51]

Episcopes

The projections realized in the physiological institutes at Budapest, Würzburg, and Turin were mainly diascopic. In contrast, episcopic projections were made primarily at institutes for pathology. In these institutes, however, the separation between lecture room and preparation room often did not exist. Instead, all devices required for episcopic projection were placed in the auditorium itself. The pioneer of this technique was former Ernst Brücke student Salomon Stricker, who in 1868 had become director of the Institute for General and Experimental Pathology at the University of Vienna. His starting point was the projection of microscopic preparations, which, since the early 1880s, he had projected by means of a Dubosq lantern and a vertically mounted microscope. With an enhanced



"projection microscope" manufactured to his specifications by the optical workshop of Simon Plössl in Vienna, Stricker presented, in the 1880s and 1890s, improved projections of microscopic preparations during his lectures and at scientific meetings and congresses—for example, the 1886 annual meeting of German naturalists and physicians in Berlin.

During the same period, Stricker started to use projection and other technologies to show animal experiments in the lecture hall. In experiments on respiration, he worked with enlarged shadows and flags fixed to the chest wall of the experimental organism, while the kymographic registration of the animal's circulation took place on a glass plate that, during the experiment, moved horizontally through a sciopticon. In this way, "even students on the remotest seats [were able] to perceive all the details of the pulse curve with the highest precision."[52] In addition, Stricker used episcopic projection when demonstrating in vivo experiments in the lecture hall. His assistant Max Reiner developed the episcopic projection device that he used. As did Jacobj in the field of pharmacology, Stricker used the device mainly for showing heart movements. In reviewing the history of physiology since Harvey, Stricker underscored the importance of this kind of demonstration: "This form of observation [i.e., the observation of the heart laid bare] might be one of the simplest, but it has allowed us the highest achievements."[53] He also noted the importance to his institution of being able "to show the pulsating heart to the future physician."[54]

By means of episcopic projection, Stricker demonstrated in his lectures such physiological phenomena as the influence of the heart nerves on cardiac inhibition and acceleration or the behavior of the heart in suffocation. As his assistant Gärtner noted, Stricker's demonstrations were done "in the most visible and instructive [*anschaulichen*] way."[55] Stricker himself chose a different register when describing the effects of his heart projections: "The pulsing heart appears on the white wall as an enlarged, modeled [*plastisch*], and, if I may dare to say, living image that in all its details is well visible for hundreds of listeners."[56] Stricker alludes here to the genre of *tableaux vivants*, highly popular in the nineteenth century. At the same time he refers to the suggestive, lifelike power of the new, dynamic image of physiological processes and phenomena.

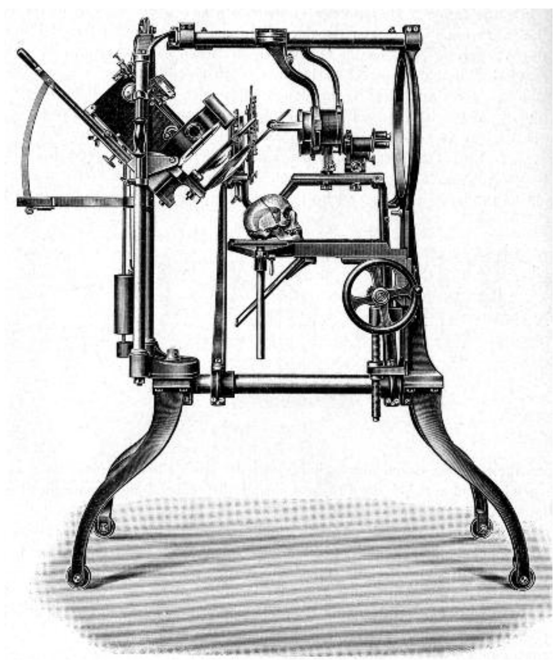
Shortly thereafter, episcopic projections were used in the lectures given at Rudolf Virchow's institute for pathology at the Charité hospital in Berlin. As in Stricker's institute, the starting point was diascopic projections of microscopic preparations. In order to bring the macroscopic preparations of Virchow's substantial collection before the eyes of large groups of students, the curator of the pathological museum, Carl Kaiserling, devised a Universal Projection Apparatus, closely cooperating with the optical manufacturer Leitz in Wetzlar. Kaiserling published the first description of the new projection device in 1906. The device was meant for both episcopic and diascopic projections. Within a large cast-iron frame, its main components included a collapsible carbon arc lamp with perpendicular carbon rods, an optical bench to which various kinds of attachments could be fixed (e.g., slide changers), and a small table that held objects under the beam of light. Kaiserling used the surface of this table to produce projections of macroscopic preparations during the lectures of the institute's director, Johannes Orth. One method consisted in taking the preparations out of their jars and reducing their glossiness "by dabbing away the fluid." At other times the light beam would be directed through the jar and the fluid surrounding the preparation.[57]

Kaiserling described his projection device as a "complex organism that one has to know precisely." To use it appropriately during lectures required "quite a bit of good will, lots of patience, and long practice." Despite these complications, use of the device was necessary if one wanted to offer effective training in pathology. For Kaiserling, academic training in pathology was dominated by external factors: "lack of time and large number of listeners."[58] Jacobj in Tübingen was confronted with similar circumstances, and in both places episcopic projection proved to be an efficient technology for quickly teaching a growing number of listeners "how to see" as physicians and scientists.

Jacobj and His "Pandidascope"

Technically, the lecture projection facility that Jacobj used at the Tübingen institute from 1908 on was based on Kaiserling's Universal Projection Apparatus. Leitz had supplied a projection apparatus modified to Jacobj's specifications, "with specific arrangements for all projections that are important in the teaching of pharmacology, e.g. the projection of the living frog heart and frog muscles."[59] The modifications mostly concerned the size of the table inside the projection apparatus. Jacobj later made other minor modifications in cooperation with the "well-known Tübingen workshop for precision mechanics, E. Albrecht."[60] In order to highlight his contributions to the Kaiserling apparatus, Jacobj named his Tübingen device the "Pandidascope." The striking feature of this apparatus was its "extraordinarily powerful lamp," which resulted in the projected images being displayed with "excellent brightness."[61]

As in Kaiserling's apparatus, the lamp consisted of perpendicular carbon rods. The



Kaiserling's Universal Projection Apparatus, prepared for use in episcope projection of a human skull.

lamp and its lenses were movable on an optical bench and permitted a stream of light to be directed upon almost any kind of object without any change in the direction of the optical axis. To the same axis, one could attach optical devices such as microscopes or slide changers. This arrangement allowed for various kinds of projections: under direct light the projection of vertical slides, spectra, and microscopic objects; under reflected light the projection of large horizontal slides and opaque objects. Mimicking the design of Jendrassik's lecture hall in Budapest, the Tübingen projection apparatus was mounted on fixed tracks so that the distance to the screen, and hence the size of the projected image, could easily be varied.

For projecting the functioning of a frog heart, the following arrangement was used. Twenty centimeters behind the third and fourth lenses Jacobj placed a glass-fronted water container into a horizontal plate raised on two small pillars:

> A frog whose chest wall has been opened so as to lay bare the heart is spread upon a small piece of board and the whole is immersed in the water, with the board so attached to two flat springs screwed into the sides of the container that the heart is directly in front of the opening of a tube that comes up at an angle from below and that terminates near the middle of the container and close to its glass front. A flow of neutral salt solution is carried to the heart by this tube from a second container above the first one to prevent the heart from being injured by the strong heat generated by the light.[62]

The results of this arrangement were remarkable. Evoking Czermak, Jacobj explained that his assemblage "makes it possible to project the tiny frog heart, hardly one centimeter square, with such brilliancy that even magnified over 400 times its life processes can be directly seen with the naked eye by sixty to eighty spectators."[63] In other words, the experimenting life scientist in the lecture hall not only controlled the central functions of organic life; he also, and at the same time, made them visible to large audiences.

Conclusion

The imagery of experimental physiology cannot be reduced to the graphical method. As impressive as the epistemic productivity of that method was, and as attractive as its aesthetic aspects remain today, the traces, curves, and graphs of bodily functions have blocked from view a highly diversified collection of physiological images produced in the late nineteenth century and early twentieth century in order to bring the functioning of organs and organisms to "immediate visual perception." From the 1870s, phenakistoscopes, magic lanterns, and rolling tables transformed the physiological lecture hall into a spectatorium, a kind of theater where the contractions and pulsations of organic life were shown by means of various kinds of movement images—animated drawings, shadow projections, "contraction telegraphs"—to growing audiences. At the turn of the twentieth century, improved lamp technology made possible episcopic projections of in vivo experiments. Leitz's Universal Projection Apparatus, Zeiss's Epidiascope, and similar devices were used for this purpose in various contexts: physiology, pathology, and pharmacology.

The reoccurring motif of these projections was the heart of a frog laid bare—a "simple" demonstration, as one of the historical actors admitted, but still one that was deemed to be crucial in the training of future scientists and physicians. The persistence of this motif over a period of more than sixty years reflects the central importance of heart, circulation, and respiration in all forms of animal and human life. The motif also persisted because of the relative ease with which the effect of physiological and pharmacological interventions could be demonstrated in the frog heart. However, the respective publications by Czermak, Jacobj, and other physiologists also speak of the gaze as a means of power over the organism. Episcopic projections in the lecture hall made it possible to share this gaze with a large group of spectators *and* listeners—or even to impose it on them. Jacobj presented the multiplication and control of eyes and ears during lectures as a process rooted in physiology. To him, it was a physiological fact that seeing and simultaneous hearing were the keys to objective knowledge. In a sense, not only the body of the frog was subjected to the lecturing process. Jacobj's students were meant to be part and parcel of this spectacular strategy.

The graphical method has often been described as a means of "picturing time." Something similar can be said about the architectures and technologies of biological instruction around 1900. The projection of the contracting frog heart illustrates as well as embodies the pulse of time. The change from systole to diastole marks duration for the eye just as the ticking of a clock marks it for the ear. In contrast with the products of the graphical method, however, the projected heart images do not leave a durable trace. Time in these images is not only pictured but manifested itself, and it was "felt" by the historical actors in various forms and formats: as the time of a lecture during which the functioning heart was offered to the gaze; as the time that was needed for the preparation of the organism, the projection device, and their mutual adjustment; and, equally, as the time that went into the production of the screen tissue, the time that was required for the technical development of universal projection apparatuses and for the building of institutes, and eventually the time that was available for the emergence and the transfer of scientific knowledge.

What the history of the heterogeneous projection assemblages devised in the experimental life sciences of the early twentieth century makes clear is that time becomes *palpable* in various ways. As a consequence, the history of these assemblages inscribes itself into the history of cinematic time and modernity.[64] Because their emergence and evolution is largely independent of the rising technology of cinematography, they are not simply part of the "prehistory" of the cinema. What the optical machines of Czermak, Jacobj, and other scholars embody is a deconstructive history of cinematography, a history that disassembles the black box of the "basic cinematographic apparatus," in order to redistribute its elements—the movement image, the projector, the screen, the seat rows, and so on—without making any claim to be complete.[65] In the place of a filmstrip that can be shown again and again without any substantial alteration, the projection assemblages used in the spectatorium integrate a living object. This object has to be exchanged and replaced by a new, similar living object if the projection is to start again. The result can be understood as a cinema of life in which the repetition of the spectacle relies on the productivity of organic differences.

Notes

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61. Jacobj, "Anschauungsunterricht und Projektion," 299.

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