Listening to the Body Electric. Electrophysiology and the Telephone in the Late 19th Century.

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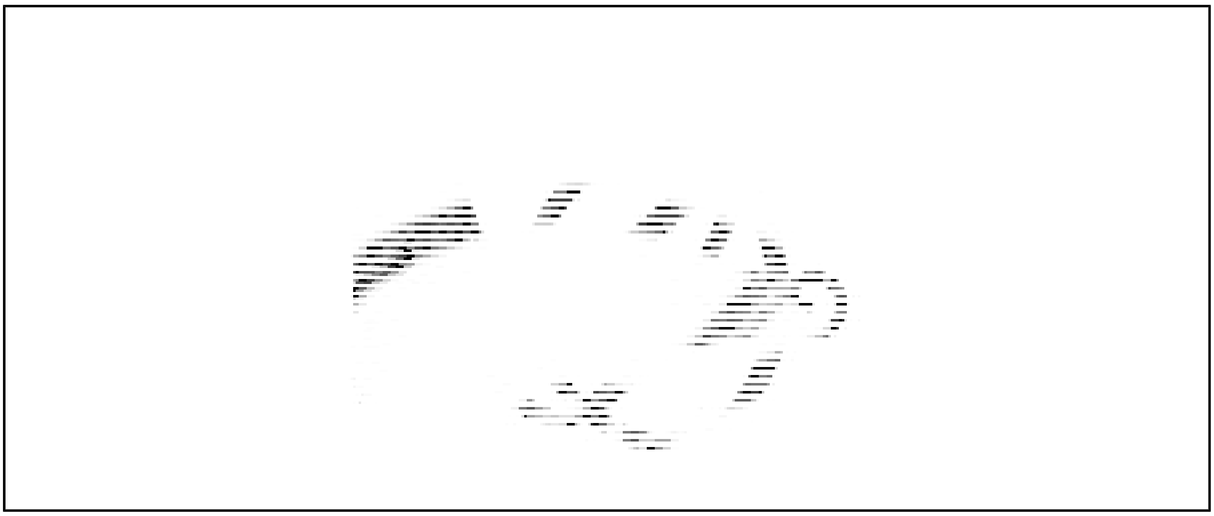
Images and visualization technologies are important factors in producing and circulating scientific knowledge. Numerous studies in historical epistemology, visual studies, and art history have been devoted to this subject. However, scientists also employed non-visual techniques in order to broaden their knowledge about specific epistemic objects. To emphasize this point, this essay presents and discusses some methods and instruments of auditory knowledge production that were used in the experimental life sciences of the 19th century.



Early telephone. Taken from: Peyer et Favarger. 1897. Prix-Courant de la Fabrique de Télégraphes & Appareils électriques.

Part 1: Sounding bodies

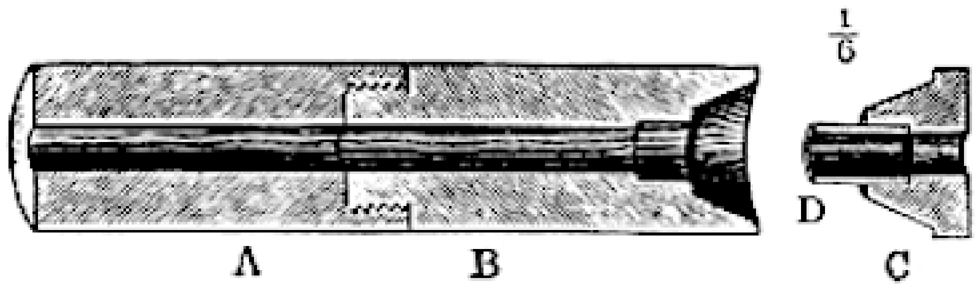
Today the use of auditory techniques in medical examinations is a common practice. The history of this method goes back to the 1750's, when the Viennese physician, Joseph Leopold von Auenbrugger (1722 - 1809), presented the percussion of the chest as a diagnostic tool. In his treatise, *Inveritum novum ex percussione thoracis huinani ut signo abstrusos iriterni pectoris morbos detegendi* (1761), Auenbrugger showed that percussion sounds convey useful information about the physical condition of the patient. He writes, "I here present the Reader with a new sign I have discovered for detecting diseases of the chest. This consists in the Percussion of the human thorax, whereby, according to the character of the particular sounds thence elicited, an opinion is formed of the internal state of that cavity" (quoted after Forbes 1936, p. 7).

Some historians of medicine consider Auenbrugger to have "initiated modern scientific medicine" (Clendening 1960, p. 306). As convincing as his method of using percussion may seem today, it did not gain immediate recognition. Only when Jean-Nicolas Corvisart (1755 - 1821) published a French translation of Auenbrugger's treatise in 1808, did this state of affairs start to change.

At the end of the 18th century medical knowledge underwent profound changes. Nosology, the old classification system of pathological signs, was about to be replaced by the emerging discourse of pathological anatomy and physiology. Both of them built heavily on the dissection of the body. The obvious disadvantage of autopsy was that it could only be performed on the dead. As a visual examination into the living body was impossible, other means of investigation were developed. As a result, the dialogue with the patient, i.e. the patient's 'case history,' which formerly had been the basis for medical diagnosis, was considered less important. Gradually, it was replaced by the physical examination of the body (Foucault 1973).

Focusing on the "story" the body tells, Corvisart promoted what he called the "*éducation médical des senses*," i.e. the refining of the clinician's senses in order to locate and identify diseases. Based on this concept, he strongly recommended techniques such as palpation, percussion, and direct auscultation which is listening to the body by placing one's ear on the patient's thorax.

Inspired by his teacher, Corvisart, René Théophile Hyacinthe Laënnec (1781 - 1826) invented a tube-shaped listening device around 1816/17. Shortly thereafter, Laënnec called this device a stethoscope, i.e. "chest-explorer." The purpose of the wooden tube was straight forward, it allowed for "mediated auscultations" (*auscultations médiates*). One could say it offered an auditory "glimpse" into the human body.



Stethoscope acc. to Laënnec. Taken from: Gscheidlen, Richard. 1876. Physiologische Methodik, p. 611/612

At that time, Laënnec was working in one of the public hospitals in Paris. This fact was crucial to the development of his technique. The clinic became a laboratory space allowing for an empirical approach to medical knowledge. During his work at Necker hospital, Laënnec started to auscultate about one hundred patients every day. He was able to develop a vocabulary for abnormal and pathological sounds which he linked to physical alterations of the body (lesions) found by dissection, i. e. tubercles in the lungs. As a consequence, Laënnec transformed sounds characterized by distinct acoustical properties into positive facts or as he put it, "pathognomonic signs" (Duffin 1998, p. 138). In other words, the sounds identified by Laënnec shed light on a domain that had been inaccessible beforehand.

In 1819, Laënnec published the results of his studies in *De l'auscultation médiate ou traité du diagnostic des maladies des poumons et du cœur*. Shortly thereafter, bodily sounds were widely discussed. Laënnec's treatise was widely read and translated into several languages. His auscultation technique was regarded as an objective method of medical diagnosis and as a means to apply pathological anatomy to the diagnosis of the living. In fact, mediate auscultation proved to be an extremely successful medical practice during the entire 19th century (see also Duffin 1998; Lachmund 1997).

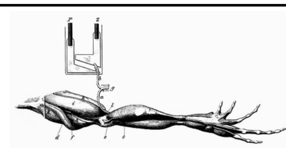
Laënnec examines a consumptive patient with a stethoscope in front of his students at the Necker Hospital. Painting by Théobald Chartran, 1816

Part 2: Using Telephones in Electrophysiology

One of the fields in which scientific listening resurfaces in the 19th century is experimental physiology, in particular electrophysiology. While studying the activity of electricity in muscle-tissue and nerves, physiologists found themselves in a situation similar to that of the young Laënnec. Around 1850, they were clearly lacking methods for displaying their epistemic objects. Since electricity itself is neither visual nor audible, the situation was particularly difficult. Electricity entirely belongs to the sphere of the "real." One could even say it is a "negative real" since it seems to be out of reach for the human senses. Therefore, one of the major challenges of electrophysiology consisted in the proper design of experimental settings and the conception of display technologies (Lenoir 1986).

One of the common instruments used in this study was the frog galvanoscope, a vivisected and isolated frog leg displaying weak currents of electricity by twitching when current is passed through it. Since physiologists were often trained as physicians, most of them were familiar with the technique of medical auscultation. Not surprisingly, the stethoscope was soon adopted in electrophysiology to trace the movements of muscle contractions in various experiments. It is interesting to note, shortly after the first demonstration of the electric telephone by Alexander Graham Bell in 1876, physiologists began to integrate this novel device into their laboratory environments. According to Florian Dombois, this telephone-based research can be regarded to be the "first audifications" of electrical currents (Dombois 2008a, 42; see also 2008b).

As is well known, the German physiologist Emil Heinrich Du Bois-Reymond (1818 - 1896) was one of the pioneers of electrophysiological research. As early as 1877, Du Bois-Reymond reported on experiments he had conducted by using a telephone. By connecting the telephone to a frog-leg galvanoscope, he managed to excite the muscle through his own voice and thereby created an almost mystical situation:
"It is easy to achieve a twitch by the current of the telephone. [...] Evidently, the nerve seems to be more sensitive to some sounds than to others. If one calls out to him: "Jerk!" the limb will jerk; on the first "i" in "lie still" it does not react. The sounds with deeper characteristic overtones are thus more effective than those with higher ones." (Du Bois-Reymond 1877, p. 576).

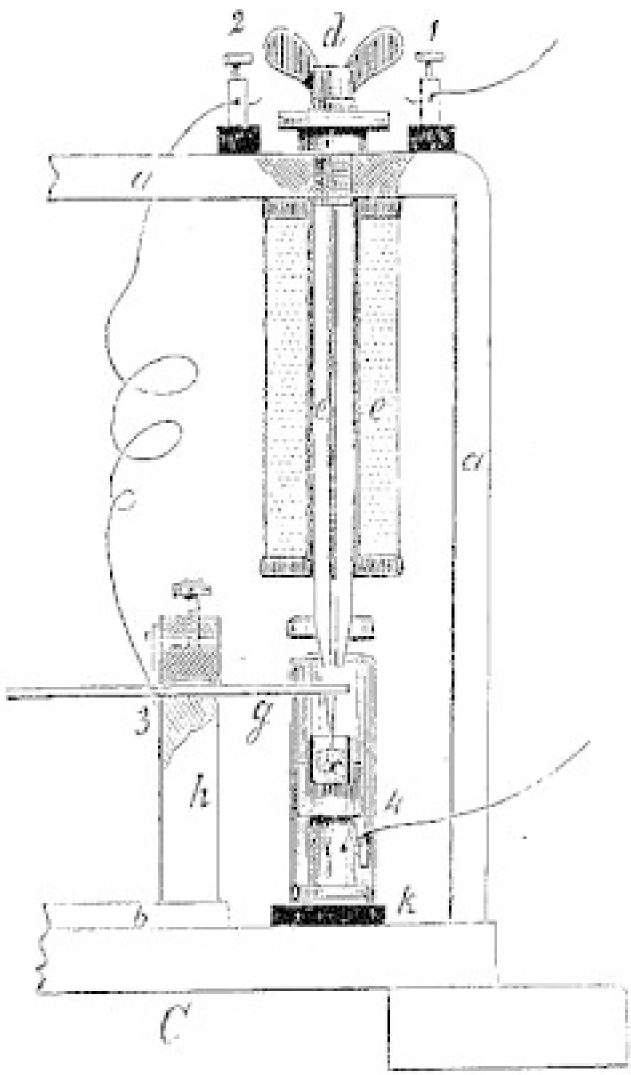


Frog-leg galvanoscope, taken from Du Bois-Reymond. 1860.
Untersuchungen über thierische Elektricität, vol. II, table V, fig. 141

While Du Bois-Reymond had only used the telephone to *produce* currents in muscles, his students Julius Bernstein (1839 - 1917) and Ludimar Hermann (1838 - 1914) undertook various experiments in which they used the telephone as a auditory display. In 1878, Bernstein applied the novel device for testing the reliability of his "acoustic interruptor," an instrument used to produce rapid electrical stimulations by connecting it to the telephone (Bernstein 1878).

Meanwhile, Hermann compared the respective abilities of the galvanoscope and the telephone to detect and display weak electrical currents that were conducted through the muscle tissue. One of Hermann’s motivations was the possibility of gaining new information that could not be attained otherwise. Unfortunately, his first results were negative because the Bell telephone that he used was unable to make any of the weak "action currents" audible (Hermann 1878).

In the same year, the Russian physiologist Ivan Tarchanov (1846 - 1908) conducted a series of experiments in which he displayed various sounds of electric currents that he had induced in muscles. The title of Tarchanov's paper *The Telephone as Display for Nerve and Muscle Currents in Man and Animal* (Tarchanow 1878, my emphasis) clearly indicates that a display is not necessarily of a visual nature. It is neutral with respect to sense modalities.



Acoustic Interruptor acc. to Bernstein. Taken from: Cyon, Elie de. 1876. Methodik der Physiologischen Experimente, Atlas

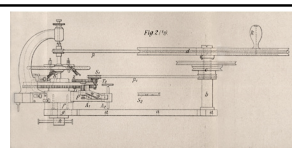
In 1881, Bernstein reported having perceived "a distinct rattle" while stimulating muscles of a dissected frog with a train of electrical pulses stemming from the acoustic interrupter. In addition, he had noted "a deep singing tone" after causing tetanus in a rabbit's leg by poisoning it with strychnine (Bernstein 1881, pp. 19 and 22). By focusing primarily on the pitch of the sound, Bernstein determined the upper limit of possible contractions that the muscle could perform in a specific time. Shortly thereafter, other researchers would repeat Bernstein’s experiments in their own laboratories.

Although Bernstein’s descriptions of the perceived sounds were limited by the ability to fully describe sound in written word, his notes about muscle sounds triggered a scientific discourse concerning electrophysiological phenomena that were displayed to the ear. In fact, in the 1880s, the telephone had become a common device in the technological world of the electrophysiological laboratory. Part of this success was the fact that the newly available model from Siemens & Halske was much more sensitive with respect to weak electrical currents than the original device marketed by Bell.

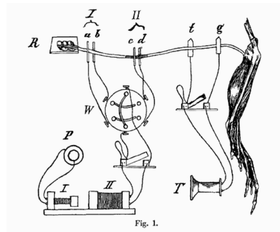
Part 3: Optical vs. Acoustical Display

Around 1890, another development led to major changes in the economy of display devices in the lab. Hermann, Bernstein, and others invented photographic methods for recording the weak currents they were dealing with. The new instruments were hybrid instruments using the telephone as a transducer. This transducer was attached to an optical apparatus casting a beam of light onto a drum holding photographic paper as a recording surface. Experiments relying on this half optical, half acoustical display technique were initially called "phonophotographic studies" (Hermann) or "phototelephonic studies" (Bernstein).

One year later, Hermann explained his efforts to construct an optical recorder called rheo-tachygraph by making reference to "a growing desire for the graphic recording of the procedures" he observed in the experiments (Hermann 1891, p. 539). In the same context, the myograph would also become a common device. Within a few years, similar solutions to the problem were presented, resulting in an increase of illustrations containing photographically derived curves of electric oscillations published in journals of electrophysiology in the 1890s.



Rheo-Tachygraph acc. to Hermann, taken from F. Matthias (assistant of Hermann). 1892. Ueber graphische Darstellung der Actionsströme des Muskels. *Archiv für die gesammte Physiologie des Menschen und der Thiere* 53, table III



The telephone (T) as part of the experimentational setup of electrophysiology, taken from Wedensky. 1900. Die fundamentalen Eigenschaften des Nerven unter Einwirkung einiger Gifte. *Pflügers Archiv für die gesammte Physiologie des Menschen und der Thiere* 82, p. 140

However, the telephone was not sent into immediate retirement. In 1900, the Russian researcher Nikolai Wedensky (1852 - 1922) continued to defend "the telephonic method" as "virtually irreplaceable" (Wedensky 1900, p. 139). According to Wedensky, the telephone provided the unique possibility of quickly comparing action currents in different locations of the muscle or nerve under observation. "In the study of every complicated process in the nerve fiber it is necessary to use the muscle, the telephone, and the galvanometer. Every one of these devices is speaking in its own language and appears to be a good witness under certain conditions and a weak one under others" (Wedensky 1900, p. 189).

As this statement makes clear, physiologists did not care much about the actual modality of the data obtained in the course of their experiments, as long as the phenomena proved to be interesting. The telephone was used to verify whether or not electrical instruments worked, to determine the appropriate place for attaching the electrodes, to identify errors in the setup of the experiment, and to display electrical data. It was multi-functional and incorporated significant practical knowledge.

Part 4: Electron-tube Amplification and the Electrostethoscope

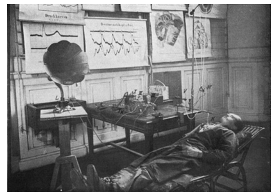
After the First World War, the dissemination of tube-based amplifiers contributed to improve the graphical recording of weak currents. But even then, scientists did not completely turn away from listening.

In 1919, Rudolf Höber (1873 - 1953) repeated the sonic mapping of electrical activity in muscles and nerves with the help of a tube amplifier and a telephone. At the same time, Höber discussed the sounds described by Bernstein and Wedensky some thirty years earlier. He listened to the sounds of contractions in patients suffering from certain diseases that affected their muscular or nervous activity, and produced graphic recordings of the corresponding currents. Höber concluded that these recordings were "largely concordant" with the facts he had established through listening (Höber 1919, p. 310).

In addition, Höber launched an innovative sonic pedagogy. He proposed to amplify body sounds like the heartbeat for demonstrative purposes and suggested the use of similar technologies for teaching medical auscultation and other techniques of scientific listening to larger groups of students.

The Austrian electrophysiologist Ferdinand Scheminzky (1899 - 1973) seized upon Höber's suggestion and constructed what he called an electrostethoscope in the mid#1920s. Scheminsky’s device consisted of an amplifier and several telephones which was used to investigate bodily sounds. At the same time, it served for the transmission of amplified signals to a graphical recording device and the study of bioelectrical phenomena in muscles and nerves (Scheminzky 1927). As a result, the electrostethoscope unified two fields of scientific listening that had been important in the 19th century, i.e. medical diagnosis through mediate auscultation and electrophysiological research with the aid of the telephone.

Conclusion



Apparatus for the electro-acoustic amplification of heart sounds (K recording capsule, M microphone, TK microphone transformer, I, II, III amplifier stages, L speaker, V valve). Taken from: Scheminsky. 1927. Untersuchungen über die Verstärkung und graphische Registrierung von Schallerscheinungen über Herz und Lunge mittels Elektronenröhren, p. 480

The use of telephones in 19th-century electrophysiology exemplifies the productive power of the ambiguous notion of the "sounding body." In an emerging world of technologies for sound reproduction and sound transmission, "sounding bodies" do not have to actively sound by themselves; instead, various sources of oscillations can be transformed into a "virtual sounding body" and can then be analyzed by listening scientists. As we have seen, in electrophysiology, there is no sound in muscular and nervous activity. However, coupled with the phenomeno-technology of the electric telephone, "bodies" begin to aurally express themselves through a mediated form of electrical auscultation. Therefore, the use of the telephone as an auditory display challenges our understanding of sight and sound and their respective roles in the history of science. Sound is obviously able to provide answers to scientific questions and thus can form a sound knowledge – in both senses of the word "sound."

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