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Hermann von Helmholtz

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Hermann von Helmholtz 1821–1894

Preface

This entry is based extensively on three biographies of Helmholtz, Cahan (2018), Koenigsberger (1902/1965), and Muelders (2001/2010), and on Boring (1950) for his emphasis on Helmholtz's relevance for Psychology. These four references overlap considerably on the facts of Helmholtz's life and many accomplishments relevant to physics, physiology, and psychology. Therefore, source citations for each and every fact presented here from these four sources will be limited generally to quotations or matters unique to a source. Other references are cited as needed to document particular points of interest.

Pre-University Years

Hermann Ludwig Ferdinand Helmholtz was born on August 31, 1821, in Potsdam, Germany. His father August Ferdinand Helmholtz was a teacher at the Potsdam Gymnasium (high school) and his mother (née Caroline Penne) was a remote descendent of William Penn, Founder of Pennsylvania (1681).

Helmholtz grew up in an upper-middle class home but enjoyed cultural advantages above his family's station, as his father was a teacher and a

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military veteran and his mother was the daughter of a military officer. Helmholtz learned and enjoyed playing piano. He took his piano with him to college and said later that it was beneficial when he wrote a treatise on the psychology of music.

In high school, Helmholtz followed a classical curriculum that included physics, mathematics, Latin, Greek, French, English, Italian, Hebrew, and rudiments of Arabic. He was said to be a good but not exceptional student.

University Education and Service as Physician-Surgeon in Prussian Army

Helmholtz's preference for advanced study in physics and mathematics was deemed impractical financially, so in autumn of 1838, he passed the entrance exam and enrolled in the Prussian Army's medical school, the Friedrich-Wilhelm Medicosurgical Institute in Berlin. The Medicosurgical Institute was affiliated with the University of Berlin's Medical Faculty. Room and instruction were free to all students, but Helmholtz had additional financial needs that compelled him to commit to 8 years' service upon graduation as a physician-surgeon in the Prussian Army.

Helmholtz was most impressed by Johannes Müller's lectures in physiology at the University of Berlin. Müller was Germany's most renowned physiologist based upon (among other accomplishments) having completed his 8-volume *Handbuch der Physiologie des Menchen* in 1840 (see Boring 1950, pp. 34–35 for brief summaries of each of the eight volumes or see "Müller, Johannes Peter" in this Encyclopedia). Müller supervised Helmholtz's doctoral thesis. Helmholtz received his diploma on November 2, 1842.

Helmholtz became friends with some of Müller's students and assistants, including Emil du Bois-Reymond, Ernst Wilhelm von Brücke, and Carl Ludwig. du Bois-Reymond became well known at the University of Berlin for his research in muscle electrophysiology. Brücke became an eminent physiologist at the University of Vienna where Sigmund Freud was his student for 5 years; Freud described Brücke as his greatest teacher. Carl Ludwig would become Chair of Physiology at the University of Leipzig where he influenced Wilhelm Wundt, founder of Experimental Psychology, and Ivan Pavlov, discoverer of the conditioned reflex.

Müller believed in vitalism (i.e., a "life force" in biology that could not be reduced to chemistry and physics). du Bois-Reymond, Brücke, Ludwig, and Helmholtz strongly opposed vitalism. du Bois-Reymond and Brücke pledged to compel the truth that "No other forces than common physical chemical ones are active within the organism" (Boring 1950, p. 708). Surely Ludwig and Helmholtz shared this view, but perhaps they were absent when the pledge was made. Below we shall see that two achievements by Helmholtz essentially demolished vitalism, although some biologists persisted in believing in vitalism decades later (see Guyer 1931, pp. 22–23).

After completing his dissertation in 1842, Helmholtz began to intern at the Charité Hospital, a teaching hospital in Berlin, and subsequently qualified to become a physician-surgeon. In October 1843, Helmholtz began his service as a Prussian Army physician. During his military service years, Helmholtz made two of his most important contributions, both of which refuted vitalism.

In 1847 (age 28), and based upon many experiments in physiology, especially, metabolism, Helmholtz formulated the law of conservation of energy which he published as *Ueber die Erhaltung der Kraft* (On the Conservation of Force). Cahan (2018, p. 151) summarized the law as follows:

> Nature as a whole contained a store of force . . . that could be neither Increased nor decreased; its total quantity was "eternal and unchangeable like the quantity of matter."

A passage from its philosophical introduction (approximately 1 3/4 pages) may be seen in English translation in Fulton and Wilson (1966, pp. 22–24).

Determining the Speed of Neural Conduction

On September 30, 1848, Helmholtz was released from his last 3 years of military service. He also abandoned the practice of medicine. On May 19, 1849, he was appointed Extraordinary Professor of Physiology at the University of Konigsberg.

Johannes Müller believed that the speed of neural conduction was on the order of the speed of light and that it would never be measured. In his *Handbuch*, Müller cited sources for three possible speeds, the highest being 60 times the speed of light (Boring 1950, p. 41). This, presumably, supernatural speed for neural transmission and Müller's belief that it could never be measured importantly influenced his belief in a "life force" (i.e., vitalism). On January 15, 1850, approximately 6 years after Müller's prediction that the speed of nerve conduction was immeasurable, Helmholtz sent to du Bois-Reymond a short report: "On the Rate of Transmission of Excitation in Nerve." Helmholtz also sent the report to Müller. Using a frog nerve-muscle preparation, Helmholtz had determined the speed of neural transmission to be on the order of 90 ft/s. Later, Helmholtz would find comparable results using sensory nerves.

Vitalism's Parallel in Psychology

In psychological science, most researchers show no hesitation in attributing "emergent properties" to phenomena being studied; such activity is now referred to as "emergentism." The readiest example of emergentism is the reification of fictional concepts, for example, "stress caused her illness." "Stress" can be neither a cause nor an effect (e.g., his impending final examination in calculus cause him "stress") because "stress" is fictional in the sense of having no material (i.e., chemical-physical) reference, a concept that merely names the condition it is purported to cause. It is far too common to reify such concepts in psychological research, and many examples could be cited easily. See related discussion of emergentism in animal cognition and the reification of concepts in the "▶ Morgan's Canon" and "▶ Müller, Johannes Peter" entries in this *Encyclopedia*.

Helmholtz's Other Academic Positions

After his years at the University of Konigsberg, 1849–1855, Helmholtz relocated to the University of Bonn, 1855–1858, where he was Professor of Physiology and Anatomy. From 1858–1871, Helmholtz was Professor of Physiology at the University of Heidelberg, and from 1871 to 1888 he was Professor of Physics at the University of Berlin. At the time he was appointed to them, the Professorships in Physiology at Heidelberg and in Physics at Berlin were Germany's most prestigious positions in those respective fields. Finally, Helmholtz served as Rector (President) of the Imperial Physico-Technical Institute in Charlottenburg from 1888 until his death in 1894.

Additional Accomplishments by Helmholtz

Helmholtz had so many scientific accomplishments that only a few can be included here. It is reasonable to suggest that, had the Nobel prize existed before Helmholtz died in 1894 (the first Nobel Prizes were awarded in 1901), he likely would have qualified for at least two, one for having developed the law of conservation of energy and one for measuring the speed of neural transmission, both of which were supported by numerous experiments in his laboratory. Two other areas of accomplishment will be discussed here, namely, Helmholtz's theoretical and experimental work in vision and audition, two fields to which his important contributions might also have qualified him for Nobel prizes.

Helmholtz's Research in Vision

Perhaps, the first accomplishment to be mentioned is his 3-volume, *Handbuch der Physiologikschen Optik: Vol. 1* (1856), *Vol. 2*, (1860), *Vol. 3* (1866) about which Boring in 1950 wrote, "It remains today a gospel in its field" (p. 302). The three volumes spanned physics, physiology, and psychology.

Invention of the ophthalmoscope. Helmholtz is recognized for inventing the ophthalmoscope, an instrument that enabled critical advancement in the study of visual optics. Helmholtz noted that Ernst Brücke had come within "a hair's breadth of the invention of the ophthalmoscope" (Helmholtz quoted in Cahan 2018, p. 96). Cahan (2018, p. 96) added:

> It was only Brücke's failure to inquire about the return path followed by the light sent to the observed eye and how an optical image is formed in the observer's receiving eye that prevented him (in principle) from becoming the ophthalmoscope's inventor.

Helmholtz commented further that there were five to ten other German scientists:

> . . . who doubtless would have performed in a completely logical way exactly the same as I if they had been put before the same tasks and under the same conditions. (Helmholtz quoted in Cahan 2018, p. 96)

It may be of interest to note that one of Helmholtz's primary motivations for inventing the ophthalmoscope was that he wanted a way to demonstrate the anatomy of the retina to his students.

Helmholtz formally published his invention of the ophthalmoscope in 1851. It was a handheld instrument designed to enable a physician or researcher to view the retina with focused illumination from the instrument and, in Helmholtz's time, with 20 times magnification. It remains an important instrument in the ophthalmologist's armamentarium, although many improvements have been made since Helmholtz's was introduced.

Next, Helmholtz turned his interest to the study of the accommodation of the lens of the eye and that led to his invention of the ophthalmometer (1852) to calculate the curvatures of the cornea and lens from measurements of the sizes of images reflected on their surfaces.

Color Vision

In 1801, British physicist Thomas Young lectured before the Royal Society of London "On the Theory of Light and Colours." The lecture was published as Young (1802). Drawing heavily on Isaac Newton and others, Young argued that sensitive points in the retina consisted of particles that undulate (Young preferred "undulate" to Newton's "vibrate") to provide the different sensations of color. For Young, red, yellow, and blue were primary, and other colors resulted from resonant undulations with the primaries.

Helmholtz rejected most of Young's theoretical foundations, but he embraced the general concept of Young's trichromatic theory of color vision. Helmholtz's contributions to the theory of color vision led others to label it the "Young-Helmholtz trichromatic theory of color vision." Young had not known of the cells of the retina, but Helmholtz (*Handbook of Physiological Optics Vol. 1,* 1856) distinguished among nerve fibers, ganglion cells, and rods and cones in the retina. However, the functional difference between rods and cones was determined later (1866) by Max Schultz who was Helmholtz's successor at the University of Bonn.

Through his psychophysical research, Helmholtz decided that cones reacted differently to different wavelengths of light, and he proposed three types of cones: (a) short-wavelength-preferring cones, blue; (b) middle-wavelength-preferring cones, green; and (c) long-wavelength-preferring cones, red. Technology was not yet sufficient to determine how the cones reacted differently to wavelength of light as measured with a diffraction grating. That would come nearly a century later with the identification of three types of cones containing chemicals within that varied in the range and peak wavelengths of light to which they best reacted, namely, cyanolabe (cyanopsin) for sensitivity to blue, chlorolabe (chloropsin) for sensitivity to green, and erythrolabe (erythopsin) for sensitivity to red. It was a century later that George Wald was awarded the Nobel Prize in 1966 for his research on the absorption spectra of the photopigments in the rods and cones of the retina.

Helmholtz and others studying color vision relied almost exclusively on human experimentation with psychophysical data (biochemical and electrophysiological data were still far into the future), Ewald Hering reported results that the Young-Helmholtz trichromatic theory could not explain, and Hering proposed an opponent-process theory of color vision that could account for his psychophysical research findings.

Christine Ladd-Franklin (1847–1930) and Helmholtz. Ladd-Franklin's name does not appear in the three Helmholtz biographies used here, but she may have been the only American (certainly the only American woman) to spend time in Helmholtz's laboratory and in Ewald Hering's laboratory to study color vision. This occurred when she accompanied her husband, Fabian Franklin, a mathematician, on his sabbatical from Johns Hopkins University to Germany in 1891–1892. Ladd-Franklin had earned a PhD in mathematics and logic at Johns Hopkins in 1882. However, women were not recognized formally, and she did not receive her doctorate until 1926. After her research experiences in both Helmholtz's and Hering's laboratories, Ladd-Franklin became a self-identified psychologist.

Ladd-Franklin developed a theory of color vision intended to account for both Helmholtz's trichromatic and Hering's opponent-process theories and to supersede them (Kargon 2014). Ladd-Franklin's theory was first presented at the International Congress of Psychology in London (1892) in a session on color vision. That evening, Helmholtz was part of a private discussion where he spoke disparagingly of one of the contributions (not Ladd-Franklin's). Someone asked Helmholtz what he thought of Dr. Ladd-Franklin's color theory. Helmholtz replied, "Ach, Fran Franklin, die versteht die Sache" (*Oh, Fran Franklin, she understands the matter*, quoted by an unidentified writer in Ladd-Franklin 1929, p. 148). This author has been unable to find a definition for "Fran" in German. There may have been a typographical error, and "Frau," "Mrs." in German, may have been intended.

Helmholtz's Research in Audition

Helmholtz's research on phenomena associated with sound and hearing overlapped his research on light and vision. His single volume about hearing, *Die Lehre von den Toneempfindungen al physiologische Grundlaga für die Theorie of Musik* (*On the Sensations of Tone as a Physiological Basis for the Theory of Music*), was published in 1863. It presented a "resonance-place theory" for how the ear processes sound; that is, he assumed that places along the basilar membrane of the cochlea resonated differently to frequencies of sound somewhat like the strings of a piano. Helmholtz's knowledge of the anatomy and physiology of the function of the cochlea did not have the benefit of more advanced technology later used by Georg von Bekesy who received the Nobel Prize in 1961 for his research showing the vital role of the basilar and tectorial membranes and the hair cells of the cochlea in auditory processing of different sound frequencies. However, in von Bekesy's Nobel address, he stated:

> For me the most stimulating book on hearing was Helmholtz's *Die Lehre von den Toneempfindungen* . . . Helmholtz's method of viewing physiology and psychology in physical terms is today just as fresh as the day it was written. (von Bekesy quoted in Muelders 2010, p. 154)

Three of Helmholtz's Most Notable Protégés

Helmholtz had many notable protégé's in physics, physiology, and psychology, but the three considered here were clearly among the most outstanding.

Physics

Heinrich Rudolph Hertz (1857–1894). Hertz was a devoted student perceived apparently by Helmholtz to be a rising star, and Helmholtz was a devoted mentor. Hertz provided some insight regarding social interactions with Helmholtz. On one occasion Helmholtz and his wife Anna invited Hertz to tea. Anna was the easier conversationalist. Hertz described Helmholtz as:

> . . . very charming . . .. but he speaks in such a slow and measured manner that, for me at least, it's impossible to keep one's attention on him, except when it's a matter of things in which every word must be weighed. Then, however, the conversation stops, since I don't want to put my opinion up against him. (Hertz quoted in Cahan 2018, p. 605)

Hertz was often invited to social events at the Helmholtz's, and, as time passed, such events became much more relaxed for Hertz.

As a mentor, Helmholtz supported Hertz's research fully, offering suggestions and guidance when useful but allowing Hertz the freedom to work as he preferred. Helmholtz saw to it that Hertz's research was well published and promoted. Related to Hertz's future accomplishments, Helmholtz was the most energetic German scientist in bringing James Clerk Maxwell's theoretical work on electromagnetism from Scotland to the Continent. Helmholtz arranged to have Maxwell's *A Treatise on Electricity and Magnetism* (1873) translated into German, and Helmholtz encouraged Hertz to bring experimental proof to Maxwell's theory. After some strong but preliminary work on proving Maxwell's theory, in 1888 Hertz hesitantly asked Helmholtz's assistance in publishing his latest work in *Sitzungsberichte,* which was the publication for the proceedings of the Prussian Academy of Sciences:

> Yet the work in question was Hertz's epochal experimental proof of the identity of electromagnetic and light waves, a work that Helmholtz called "absolutely genius." Helmholtz asked du Bois-Reymond to rush Hertz's manuscript into print in the academy's *Sitzungsberichte;* it appeared soon thereafter. (Cahan 2018, p. 609)

Hertz died relatively young at age 36, a result of surgeries associated with severe migraines that led to infection.

In 1930, in honor of Heinrich Hertz, the unit *hertz* (Hz) was established by the International Electrotechnical Commission as the standard unit for *frequency*, that is, the number of times that a cyclical event occurs per unit of time, i.e., cycles per second (cps). In 1960, the unit, Hz, was adopted by the General Conference on Weights and Measures, and although acceptance of Hz to replace cps was slow initially, by 1970 Hz had essentially replaced cps.

Neurobiology and Biophysics

Julius Bernstein (1839–1917). Bernstein earned his medical degree under Emil du Bois-Reymond's supervision at the University of Berlin in 1862 (Seyfarth 2006). Bernstein had succeeded Wilhelm Wundt (see below) as Helmholtz's assistant at the University of Heidelberg in 1864 and succeeded Helmholtz as Interim Head of Physiology when Helmholtz left the Chair in Physiology at Heidelberg in 1871 to become the Chair in Physics at the University of Berlin. This writer has seen relatively little about Helmholtz's and Bernstein's personal relationship, but from what is available, it is clear that Bernstein was appreciative of Helmholtz.

It was during his time as Helmholtz's assistant that Bernstein accomplished that for which he is best remembered, namely, being the first to record the action potential of neurons (1866). He was able to do so using a special instrument (the *differential rheotome*) that he designed and constructed. Much later (1902) Bernstein published his membrane theory (see Seyfarth 2006, pp. 5–7), which enabled an understanding of the electrochemical basis for the action potential. In 1912, Bernstein published a treatise titled *Elektrobiologie*, which Seyfarth (2006, p. 7) summarized as follows:

> His treatise amounts to the first quantitative theory of nerve- and muscle action based on solid experiments, exact measurements, and biophysical models that finally led to a paradigm shift in the understanding and further investigation of bioelectrical processes.

Bernstein was the first Jewish Rector (President) of a German university (the University of Halle).

Although antisemitism was widespread, Seyfarth (2006) found no evidence to indicate any discrimination against Bernstein. Such was not the case for Bernstein's sons. In 1933 when the Nazis came into power, Bernstein's two sons who held university faculty positions, respectively, at the University of Halle and at the University of Göttingen, were dismissed from their positions, and they and their families were forced into exile.

Psychology

Wilhelm Wundt 1832–1920. Wundt is well remembered as the founder of Experimental Psychology at the University of Leipzig in 1879, that being the year he was assigned half a building for his research laboratory. Educated as a physiologist, it was as Professor of Philosophy that Wundt went to Leipzig. As "Wilhelm Wundt" is the subject of another entry in this Encyclopedia, information about Wundt here will be limited mostly to his association with Hermann von Helmholtz.

While earning his doctorate in medicine at the University of Heidelberg in 1856, Wundt also spent a semester studying with Johannes Müller in Berlin. After receiving his doctorate, Wundt remained at Heidelberg as a Dozent (lecturer). In 1858 Helmholtz arrived at Heidelberg as the Chair in Physiology. Wundt became Helmholtz's assistant. Regarding Helmholtz's and Wundt's relationship, Boring (1950, p. 319) wrote:

> Altogether there seems to have been respect and mutual admiration between Helmholtz, 11 years senior, and Wundt, the junior, but no great personal intimacy.

Helmholtz and Wundt overlapped at Heidelberg for 14 years, but when it involved their research, each preferred to work independently. Nevertheless, Cahan (2018, p. 253) wrote:

> They had a good working relationship, though, and Wundt greatly admired Helmholtz. [Paragraph Break] Helmholtz for his part, had a quite positive view of Wundt both as a teacher and as a researcher . . .. [Paragraph Break] Helmholtz also tried to help Wundt get Heidelberg to name him Extraordinary Professor of anthropology and medical psychology in the Medical Faculty . . .. Wundt received the Extraordinary Professorship the following year.

Wundt hoped to succeed Helmholtz in Heidelberg's Chair in Physiology, but as noted above, that appointment went to Julius Bernstein. Wundt stayed on at Heidelberg until he accepted a position in Philosophy at the University of Zurich in 1874. By then, part 1 (1873) and part 2 (1874) of Wundt's *Grundzüge der physiologischen Psychologie* (*Textbook of Physiological Psychology*) were published, and Wundt was leading the effort to have Psychology recognized as an independent discipline.

Regarding Psychology as a discipline, Helmholtz's research over his career has been described as physics, physiology, and psychology, but he believed firmly that the scientific aspects of psychology belonged in physiology, and the rest of psychology belonged in philosophy. Interestingly, in 1868, Helmholtz had written to du Bois-Reymond that "Philosophy is, incidentally, a dreadful wasp's nest, which one should never touch" (Cahan 2018, p. 533).

Closing Remarks

Helmholtz's Wives

It would be remiss to fail to mention Helmholtz's wives, both of whom Helmholtz clearly loved and respected. He married Olga von Velton in 1849 and with her had two children. However, after several years of failing health, she died in December 1859. About a year later, Helmholtz met Anna von Mohl. Despite their age difference (Anna, 26; Helmholtz, 39), they quickly realized they would be a good match. They were married in May 1861, approximately 18 months after Olga's death. Some saw it as an insult to Olga's memory, but most friends and family saw it as a good marriage, in part, because Anna was happy to assume the care of Helmholtz's children. Helmholtz and Anna were also a close match intellectually, and he named her to be his Literary Executor following his death. That duty included finalizing some of his unpublished manuscripts.

Helmholtz's Ill Fated Voyage to the United States

In 1892, the Reich government asked Helmholtz to represent Germany at the International Electrical Congress in August in Chicago, USA. Being in less than optimal health, Helmholtz resisted initially but eventually agreed. Also being much concerned about Helmholtz, Anna requested and received funds from Germany's Chancellor to accompany him. The trip lasted from early August to early October. They visited many of the famous tourist sites (e.g., the Rockies and Niagara Falls) and were hosted and honored at several major universities, especially Columbia University where one of Helmholtz's students was an influential ophthalmologist. On the voyage home, while Anna was resting in their cabin, Helmholtz fell down a long set of stairs. He retained consciousness but was conveyed to the more comfortable captain's cabin where, according to Anna, he was ably attended by the ship's doctor. Helmholtz resumed his duties in November as Rector at the Imperial Physico-Technical Institute in Charlottenburg, but he never fully recovered. He died on September 8, 1894. Anna died in 1899 at age 66.

Honors and Awards

It is fitting to end this brief biography of Helmholtz by listing a few of his major awards and honors.

- 1873. He received The Order of Merit for the Arts and Sciences. The award was established by Frederick Wilhelm IV (King of Prussia from 1840 to 1861) in 1842 to honor extraordinarily distinguished persons, and it was intended to be Germany's highest civilian award.
- 1883. Helmholtz attained nobility (viz., the title "von") at the instigation of the Crown Prince and Princess. Hereafter, he would be Hermann von Helmholtz. Such a title placed Helmholtz above most of his fellow scientists which caused him some concern, but he realized he could not deny the benefits of nobility to his family and descendants.
- 1889, June 6. Helmholtz's statue in front of the main building at University of Humboldt was dedicated (see below).
- In Charlottenburg, Berlin, the street *Helmholtzstraße* is named after von Helmholtz.

Statue of Hermann von Helmholtz at the University of Humboldt

Cross-References

- ▶ Action Potentials
- ▶ Auditory Processing and Perception
- ▶ Auditory Signals
- ▶ Color Changes
- ▶ Electromagnetic Fields
- ▶ Energy
- ▶ Müller, Johannes Peter
- ▶ Neural Impulse
- ▶ Sensory Receptors
- ▶ Wundt, Wilhelm

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