Hermann von Helmholtz:

THE OPHTHALMOSCOPE AND SOME OF HIS OTHER CONTRIBUTIONS TO OPHTHALMOLOGY

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Abstract

Hermann von Helmholtz was a German, and one of the most important individuals in the history of physics and medicine. He made important findings in muscle and nerve physiology, physiological acoustics, and thermodynamics. In addition, his contributions to ophthalmology were enormous. He invented the ophthalmoscope in 1850, developed the ophthalmometer in 1853, and his major publication, ‘Handbook of physiological optics’ in 1856 explained the mechanism of accommodation and produced the first accurate model eye among numerous other things. The invention of the ophthalmoscope can be considered as the single most important advancement in the history of ophthalmology. Prior to the ophthalmoscope, examining the posterior pole of the eye in a living human was not possible. The ophthalmoscope allowed for diseases that were previously unknown to be recognised, making the invention of the ophthalmoscope one of the greatest triumphs in ophthalmology. This report provides a brief biographical account of Helmholtz’s life, and reviews his major contributions to ophthalmology, in particular the ophthalmoscope and it’s impact on ophthalmology.

Introduction

Hermann von Helmholtz was a German physiologist and physicist, and one of the most important individuals in the history of physics and medicine. He made important findings in muscle and nerve physiology, thermodynamics, and physiological acoustics. In addition, his contributions to ophthalmology were enormous. He invented the ophthalmoscope in 1850, developed the ophthalmometer in 1853, and his major publication, ‘Handbook of physiological optics’ in 1856 explained the mechanism of accommodation and produced the first accurate model eye among numerous other things. The invention of the ophthalmoscope can be considered as the single most important advancement in the history of ophthalmology. Prior to the ophthalmoscope, examining the posterior pole of the eye in a living human was not possible. The ophthalmoscope allowed for diseases that were previously unknown to be recognised, making its invention one of the greatest triumphs in ophthalmology.1,2

Biography

Hermann Ludwig Ferdinand Helmholtz was born on August 31, 1821 in Potsdam, Germany. He was the first-born child of four children. His mother was a descendent of William Penn, the founder of Pennsylvania. His father was in the Prussian army and would later become a teacher at the Gymnasium in Potsdam where Helmholtz attended. Helmholtz was passionate about physics and wanted to become a physicist, but his father could not afford to send him to university. Instead in 1838, with a scholarship, he studied medicine at the Royal Medical and Surgical Friedrich-Wilhelm Institute in Berlin, where he was able to combine physics with his medical degree. As a medical student, he made his first contribution to medicine when he discovered that nerve fibres originated in ganglia through his research on the nervous system of invertebrates. After graduation from medical school, he was assigned to eight years of service in the military. During his time as a surgeon in the Prussian army in Potsdam, he devoted time to conducting experiments on heat production during muscle contraction. This resulted in the development of the conservation of force principle that was crucial to underpinning the law of conservation of energy, and the first law of thermodynamics.1,3-14

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In 1848, after his early release from military duty, Helmholtz would dedicate his life to research, and would not practice medicine again. A year later he was appointed professor of physiology at the University of Konigsberg in Germany. He worked there for six years and while there he was able to measure the propagation speed of nervous stimuli.

He started his research on physiological optics, and invented the ophthalmoscope in 1850. This revolutionized the practice of ophthalmology, allowing for visualization and understanding of diseases of the posterior pole of the eye.\(^2\)\(^,\)\(^3\)\(^,\)\(^5\)

He also explained the mechanism of accommodation by demonstrating the changes in lens surface curvature during accommodation. Individuals had attempted to develop methods to measure corneal curvature using rulers and compasses, but these were inaccurate. In 1853, Helmholtz created his ophthalmometer that doubled images with two glass plates. His ophthalmometer was largely for research but its use as an important clinical tool would develop later on.\(^15\)\(^,\)\(^16\)

In 1855, Helmholtz moved to the University of Bonn, in Germany where he was professor of anatomy and physiology. Helmholtz’s extensive work on the eye and optics resulted in the publication of, ‘Handbook of physiological optics’ in 1856. This publication described eye physiology and anatomy, accommodation, and contained descriptions of his ophthalmoscope. There would be two more volumes published later on, which described visual acuity, binocular vision, and perception of vision, along with numerous other topics on optics. His work also produced the first accurate eye model.

Swedish ophthalmologist, Alvar Gullstrand, would later modify Helmholtz’s eye model which is used today.

His *Handbuch der physiologischen Optik* (Handbook of physiological optics) is considered to be the foundation of the specialty of ophthalmology that was becoming more prominent at that time (see p.168).\(^1\)\(^,\)\(^4\)\(^,\)\(^17\) After three years at Bonn, Helmholtz moved to the University of Heidelberg, in Germany where he was professor of physiology. Here he published his major piece on physiological acoustics, ‘On the sensations of tone as a physiological basis for the theory of music’. This work is the foundation of what current understanding of hearing and acoustics are based on.\(^1\)\(^,\)\(^18\)\(^,\)\(^19\) In 1871, Helmholtz was appointed professor of physics at the University of Berlin, in Germany where he would focus
his research on physics. After several years of research he would end up chairing administrative positions at the university.\textsuperscript{1}

Helmholtz suffered from migraines as an adult. Nevertheless, he was an avid mountaineer and traveller, often making trips to the Alps and traveling throughout Europe for recreation and respite. Helmholtz was married twice, first in 1849 and then in 1861, and had four children.\textsuperscript{1-5,11,13} In 1893, Helmholtz visited Chicago in the United States to represent Germany at the Science World Fair. Unfortunately on the journey back home, he fell down a flight of stairs and sustained a cerebral hemorrhage. He passed away from complications several months later on September 8, 1894 at 73 years of age.\textsuperscript{2,3,7-13}

The ophthalmoscope

Prior to 1850 when Helmholtz invented the ophthalmoscope, there was documentation from several individuals who attempted to view the fundus but were unable to adequately observe it. In 1704, French surgeon and anatomist, Jean Méry noticed that a cat’s pupil would be observed to illuminate when the cat was placed under water. Méry showed that it was an optical phenomenon but was unable to explain it at that time.

In 1823, Czech physiologist, Jan Evangelista Purkinje, tried to examine the fundus of humans by placing a candle behind the patient’s back and using a concave spectacle lens.

In 1851 to his first wife Olga, saying: "To his Olga to remember that her eye it was of which retina was unveiled to the investigating eye..."

Formerly from the Haskell E. Norman Library (Christies cat.8922)
In the 1840s, English ophthalmologist, William Cumming (1812-1886) in 1846, and German physiologist, Ernst Wilhelm Ritter von Brücke (1819-1892) in 1845, explained that the axis of illumination and observation had to coincide to be able to view the fundus. However, although all these individuals recognised the red reflex, they were not able to view the fundus successfully.

Interestingly, three years prior to Helmholtz’s invention, English mathematician Charles Babbage (1791-1871) nearly invented the ophthalmoscope. Babbage is renowned for pioneering the calculating engine, which is the precursor of the modern computer. His ophthalmoscope consisted of a tube and a plain mirror with the silvering scraped off at three small spots in the centre. Light rays falling through an opening in the tube would reflect into the patient’s eye. In 1847, Babbage showed prominent English ophthalmologist, Thomas Wharton Jones, his ophthalmoscope. However, Jones was unable to view the fundus with the instrument, possibly due to being a myope. Babbage accepted Jones’ judgment and stopped developing his.
While a student at the London Hospital, Cumming, by shading the eye of a fellow student from the light was able to look directly into it and obtain both the retinal reflex and the white light from the entrance of the optic nerve. He made the first suggestion for the construction of a device for examining the fundus. Garrison & Morton \textit{Medical Biography} 5861 Wayenborgh Collection
Helmholtz noted that if Babbage had added a concave lens to correct the convergent light rays, his instrument would have provided a view of the fundus.\textsuperscript{22,23}

Helmholtz understood that the emitted light rays from the eye formed optical images that if visualised, would allow the fundus to be seen. He presented his working ophthalmoscope to the Berlin Physical Society on December 6, 1850. He demonstrated that there were three essential components to the ophthalmoscope, including a correcting lens, an illumination source, and a method of reflecting the light into the eye. His ophthalmoscope consisted of superimposed plain glass plates, one on top of the other. These were at an angle of incidence that produced the maximum illumination to achieve light reflection into the eye. He found that by using three or more plates, he could achieve partial polarisation of the bright, distracting corneal reflex. His early ophthalmoscope used a naked candle as an illumination source. Instrument-maker, Egbert Rekoss, from the university of Konigsberg constructed Helmholtz’s early ophthalmoscopes. Helmholtz’s early model used only concave lenses, which had to be changed depending on the refractive errors of the patient and examiner. In 1852, Rekoss added a revolving disc that conveniently carried a series of correcting concave and convex lenses. Helmholtz’s ophthalmoscope produced an upright image, with magnification of 15 times, and a small field of view. Since his invention, there have been numerous ophthalmoscopes developed with modifications made. The reflecting surface progressed from superimposed plain glass plates, to mirrors, and then to solid glass prism. Of all the changes to the ophthalmoscope, the most significant changes have been made to the illumination source, which progressed from a naked candle, to oil lamps, gas lamps, and electricity.

In 1879, American inventor, Thomas Edison began developing his incandescent light bulb and this would significantly improve the reliability of the illumination source.\textsuperscript{1,24-26}

Helmholtz reported his invention in his paper, ‘Beschreibung eines augen-spiegels: zur Untersuchung der Netzhaut im lebenden Auge’, which means, ‘Description of an eye-mirror: to examine the retina in the living eye’.\textsuperscript{27} Soon after Helmholtz’s invention of the ophthalmoscope, he sent copies of the instrument to prominent ophthalmologists of the 19th century for their judgment. Several German ophthalmologists of that time helped with the introduction of the ophthalmoscope to ophthalmology. As a result of the ophthalmoscope, there was an explosion in documen-
tation of fundus diseases by ophthalmologists. In 1853, Earnest Adolph Coccius described retinal detachment and retinitis pigmentosa. In 1855, Richard Liebreich described central retinal vein occlusion and would go on to publish the first atlas of ophthalmoscopy. Albrecht von Graefe would describe retinal artery occlusion and glaucoma.\textsuperscript{1,24-26} The immediate impact of the ophthalmoscope is seen in the dramatic increase in the volume of literature. Historical research, using ‘n-gram frequency’, which is the annual frequency of phrases based on analysis of millions of documents, has shown that the impact of the ophthalmoscope exceeded that of the invention of the otoscope, and stethoscope.\textsuperscript{28} Since the revolutionary birth of Helmholtz’s ophthalmoscope, the specialty of ophthalmology progressed as symptoms previously unexplained could be correlated with the fundus findings, opening up a new field of ophthalmology.

**Conclusion**

Helmholtz’s work was significant as well as diverse with contributions to both physics and medicine. His invention of the ophthalmoscope is possibly the most important single advance in the history of ophthalmology. Before its invention, diseases of the posterior
pole of the eye were largely unknown. His, ‘Handbook of physiological optics’ was the foundation for much of ophthalmology. Helmholtz’s contributions are important to recognise and have helped add to the success of ophthalmology.

**SOME PORTRAITS OF HELMHOLTZ MADE BETWEEN 1867 AND 1894**

von Helmholtz on an English copperplate, dated 1867

Above and left:
Hermann von Helmholtz painted 1884 by the German artist Franz von Lenbach (1836-1904)
Hermann von Helmholtz 1894 (Pastel drawing by F. von Lenbach, dedicated to Helmholtz by the artist 29 April 1894)
Hermann von Helmholtz 1891, marble bust by Adolf Hildebrand 1847-1921
References


7. Schumann WP. One hundred years of the ophthalmoscope-Von Helmholtz, the man, his life and work. *Am J Optom Arch Am Acad Optom.* 1951; 28(7): 357-368.


27. von Helmholtz H. *Beschreibung eines Augen-Spiegels: zur Untersuchung der Netzhaut im lebenden Auge.* Berlin: A. Först-