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Hermann von Helmholtz:

The Ophthalmoscope and some of his other Contributions to Ophthalmology

Chu Luan Nguyen & Jean-Paul Wayenborgh

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.

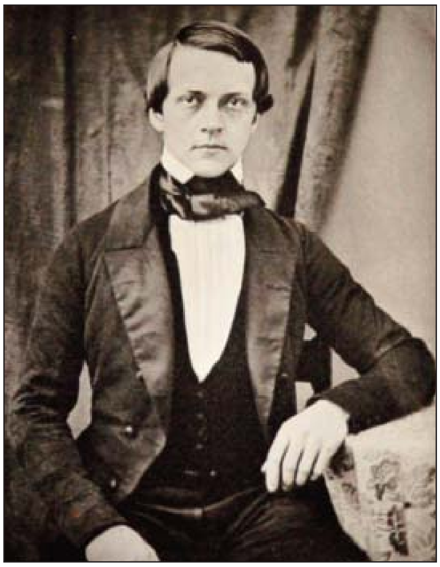
Introduction

Hermann von Helmholtz was a German physiologist and physicist, and one of the most important individuals in the history of physics and medicine of the 19th century. 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]

Chu Luan Nguyen, B.Optom, MBBS
Department of Ophthalmology,
Royal North Shore Hospital, Sydney;
Reserve Rd,
St Leonards NSW 2065,
Australia
chuluannguyen@gmail.com

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]



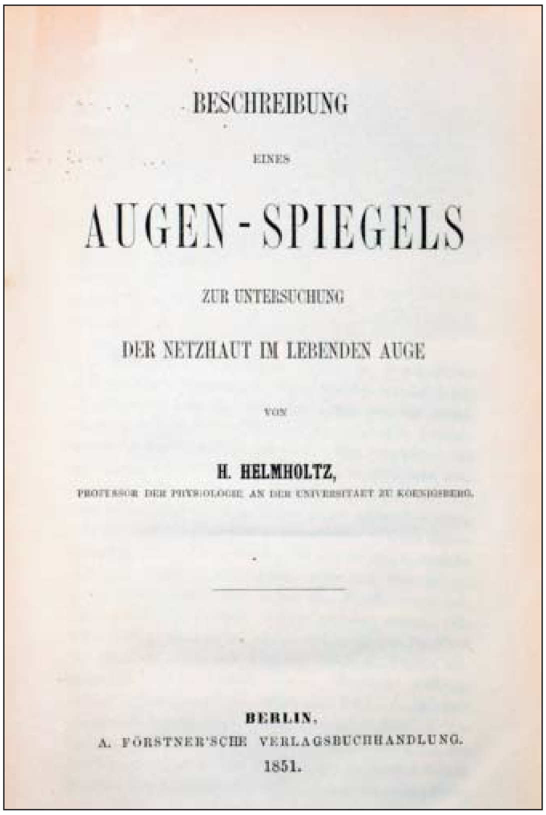
von Helmholtz aged 27
Daguerrotype from the legacy of the French physiologist Emile Dubois-Raymond

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.



BESCHREIBUNG
EINES
AUGEN-SPIEGELS
ZUR UNTERSUCHUNG
DER NETZHAUT IM LEBENDEN AUGE
VON
H. HELMHOLTZ,
PROFESSOR DER PHYSIOLOGIE AN DER UNIVERSITAET ZU KOENIGSBERG.

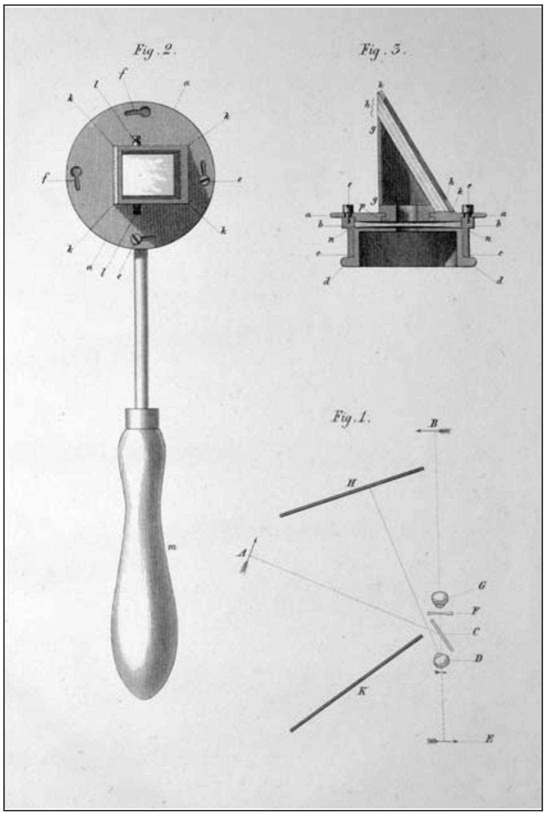
BERLIN,
A. FÖRSTNER'SCHE VERLAGSBUCHHANDLUNG.
1851.

First edition of Helmholtz´s epoch making invention of the ophthalmoscope
Wayenborgh Collection

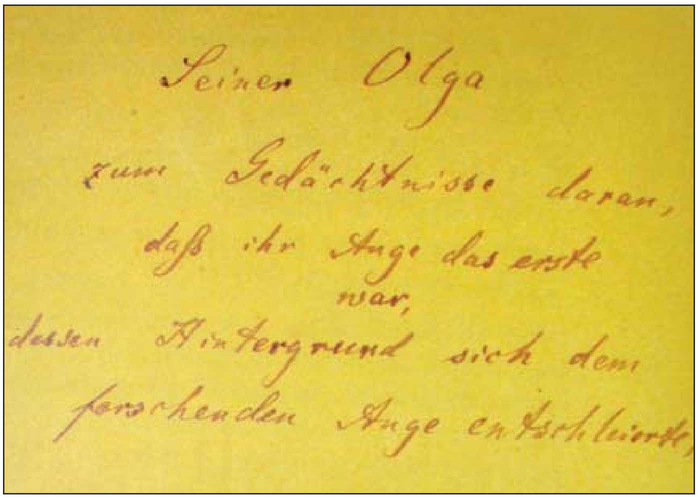
Swedish ophthalmologist, Alvar Gullstrand, would later modify Helmholtz's eye model which is used today.

His *Handbuch der physiologischen Opti*k (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.[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.[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.[2,3,7-13]



Engraving from Helmholtz´s *Augenspiegel (see opposite page)*

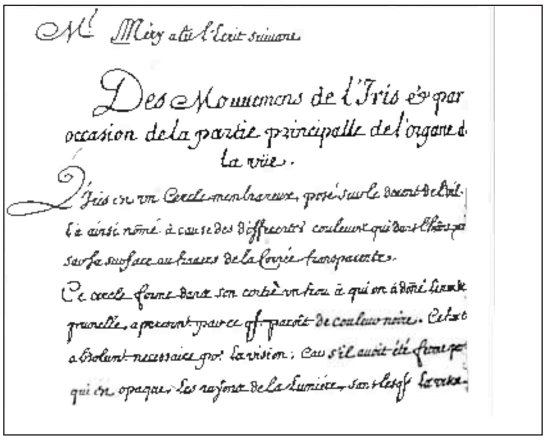

Seinen Olga
zum Gedächtnisse daran,
daß ihr Auge das erste
war,
dessen Hintergrund sich dem
forschenden Auge entschleierte,

Helmholtz´s touching dedication on the cover of Augen-Spiegel (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)

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.

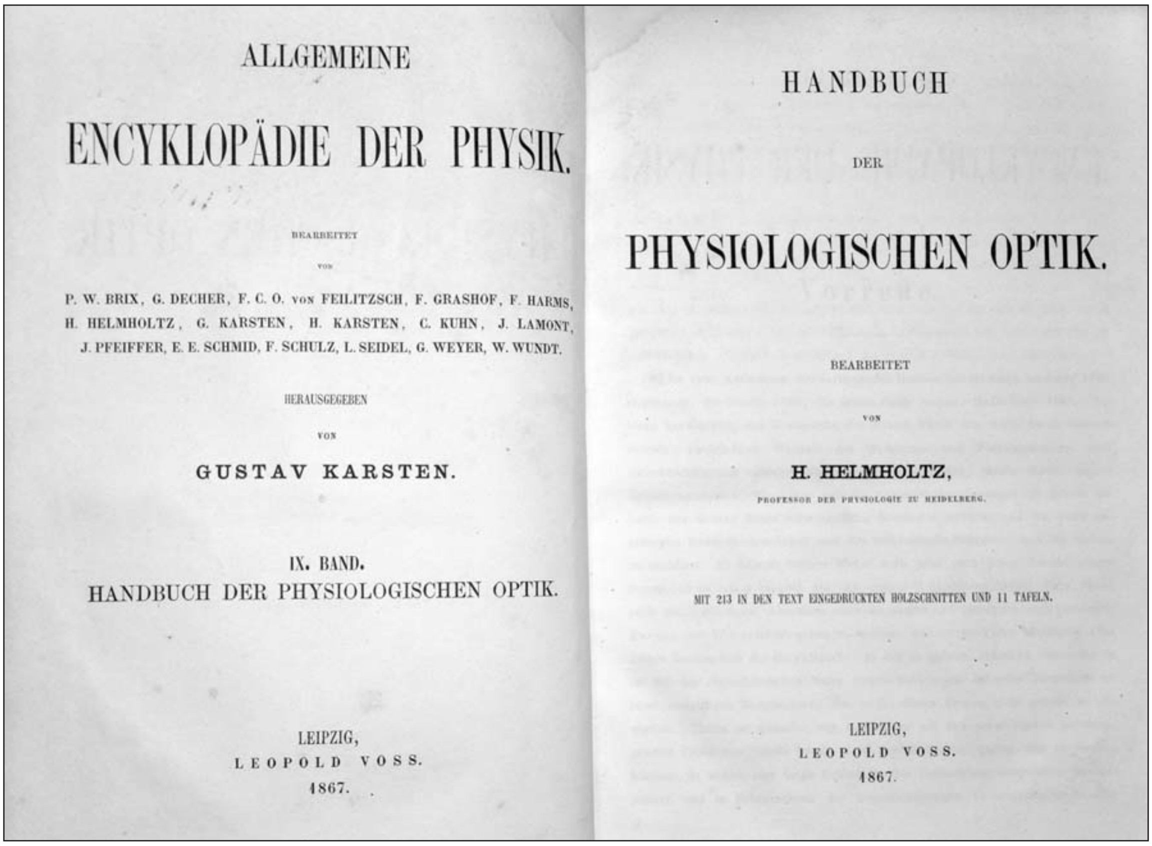

Mr. Méry a lû l'Ecrit suivant.

Des Mouvemens de l'Iris & par occasion de la partie principalle de l'organe de la vue.

Extract from the record of the Proceedings of the Royal Academy of Sciences for the year 1704, volume 23, page 277 verso (Session of Wednesday I2th November 1704). Minute of Jean Méry's lecture : " Mr. Méry a lu l'Écrit suivant: " Des Mouvemens de l´iris & par Occasion de la Partie Principale de l'Organe de la Vue' "
(*transl: Mr. Méry read the following paper: "On the Movements of the Iris and on Occasion of the Principal Part of the Organ of Sight* ")

(Archives o f the Academy of Sciences, Paris)

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.



ALLGEMEINE

ENCYKLOPÄDIE DER PHYSIK.

BEARBEITET

VON

P. W. BRIX, G. DECHER, F. C. O. VON FEILITZSCH, F. GRASHOF, F. HARMS, H. HELMHOLTZ, G. KARSTEN, H. KARSTEN, C. KUHN, J. LAMONT, J. PFEIFFER, E. E. SCHMID, F. SCHULZ, L. SEIDEL, G. WEYER, W. WUNDT.

HERAUSGEGEBEN

VON

GUSTAV KARSTEN.

IX. BAND.

HANDBUCH DER PHYSIOLOGISCHEN OPTIK.

LEIPZIG,

LEOPOLD VOSS.

1867.

HANDBUCH

DER

PHYSIOLOGISCHEN OPTIK.

BEARBEITET

VON

H. HELMHOLTZ,

PROFESSOR DER PHYSIOLOGIE ZU HEIDELBERG.

MIT 213 IN DEN TEXT EINGEDRUCKTEN HOLZSCHNITTEN UND 11 TAFELN.

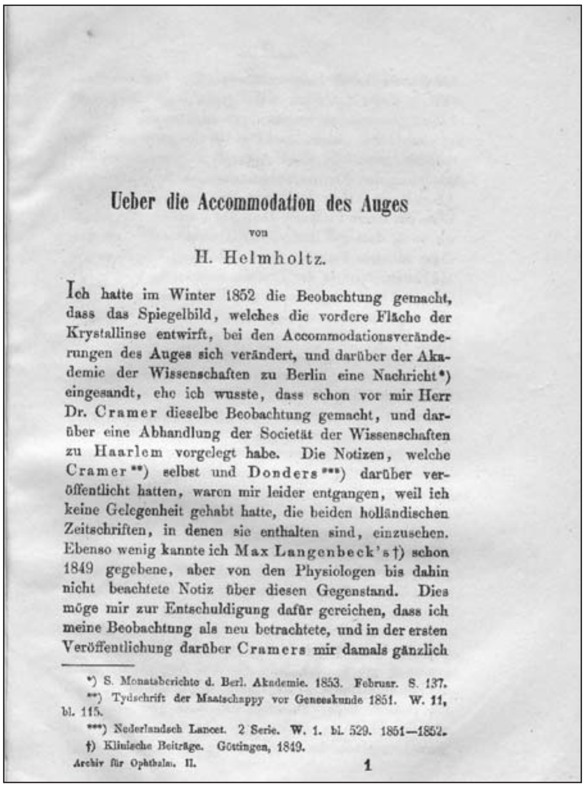
LEIPZIG,

LEOPOLD VOSS.

1867.

Original edition of the Physiologischen Optik. The foundation of modern physiological optics containing also Helmholtz revival of Young´s theory of color vision

Wayenborgh Collection



Ueber die Accommodation des Auges

von

H. Helmholtz.

Ich hatte im Winter 1852 die Beobachtung gemacht, dass das Spiegelbild, welches die vordere Fläche der Krystallinse entwirft, bei den Accommodationsveränderungen des Auges sich verändert, und darüber der Akademie der Wissenschaften zu Berlin eine Nachricht*) eingesandt, ehe ich wusste, dass schon vor mir Herr Dr. Cramer dieselbe Beobachtung gemacht, und darüber eine Abhandlung der Societät der Wissenschaften zu Haarlem vorgelegt habe. Die Notizen, welche Cramer**) selbst und Donders***) darüber veröffentlicht hatten, waren mir leider entgangen, weil ich keine Gelegenheit gehabt hatte, die beiden holländischen Zeitschriften, in denen sie enthalten sind, einzusehen. Ebenso wenig kannte ich Max Langenbeck's†) schon 1849 gegebene, aber von den Physiologen bis dahin nicht beachtete Notiz über diesen Gegenstand. Dies möge mir zur Entschuldigung dafür gereichen, dass ich meine Beobachtung als neu betrachtete, und in der ersten Veröffentlichung darüber Cramers mir damals gänzlich

*) S. Monatsberichte d. Berl. Akademie. 1853. Februar. S. 137.

**) Tydschrift der Maatschappy vor Geneeskunde 1851. W. 11, bl. 115.

***) Nederlandsch Lancet. 2 Serie. W. 1. bl. 529. 1851—1852.

†) Klinische Beiträge. Göttingen, 1849.

Archiv für Ophthalm. II. 1

In this paper, published in Graefe´s Archiv Vol.1 pp.1-74, Helmholtz explains the mechanism of accommodation with the help of the ophthalmometer invented by himself three years before, in 1852. Wayenborgh Collection

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.[1,20,21]

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

ON A

LUMINOUS APPEARANCE

OF

THE HUMAN EYE,

AND ITS APPLICATION TO THE DETECTION OF DISEASE OF THE RETINA AND POSTERIOR PART OF THE EYE.

BY WILLIAM CUMMING,

LATE HOUSE-SURGEON TO THE LONDON HOSPITAL.

COMMUNICATED BY T. B. CURLING,

ASSISTANT-SURGEON TO THE LONDON HOSPITAL.

Received June 1st—Read June 23rd, 1846.

THE luminous appearance of the eyes of cats, dogs, rabbits, oxen, sheep, and other animals, has been long known, and referred to the reflection of light by the tapetum; as also the reflection from the eye of the Albino, the reflection produced by morbid deposits in, and other changes of, the retina; and from the deficiency of pigment in persons not Albinoes.

Müller, (page 93, by Baly,) in a paragraph on the development of light in the higher animals, says, "The luminous appearance of the eyes of some animals arises from the reflection of the light from a brilliant tapetum which is devoid of black pigment; for which reason the eye of the white rabbit is especially brilliant, and the eyes of the Albino Sachs are said to have been luminous. Prevost was the first to explain the phenomenon: he showed that it could never be seen in complete darkness, and is dependent neither on the will, nor on the passions, but is the effect of the reflection of light which enters the eye from without."

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´Medical Biography 5861

Wayenborgh Collection

Reconstruction of Babage´s instrument which can be considered as a precursor of Helmholtz´ ophthalmoscope.
Wayenborgh Collection

Charles Babbage. by William H.F.Talbot

instrument. 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.[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.[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'.[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-

Early model of Helmholtz´s ophthalmoscope,

Royal College of Ophthalmologists Collection, London

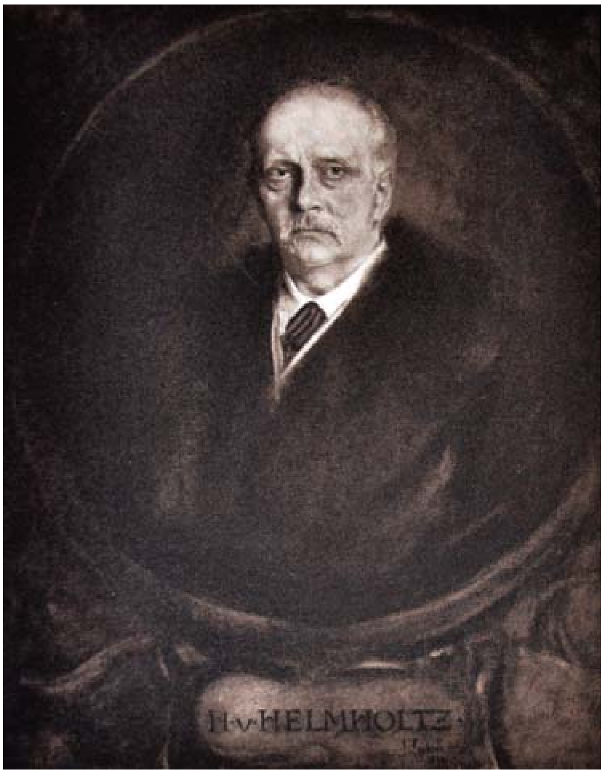
tation of fundus diseases by ophthalmologists. In 1853, Earnest Adolph Coccius described retinal detachment and retinitis pigmentosa. In 1855, Richard Liebreich described central retinal vein occlusion and would go on to publish the first atlas of ophthalmoscopy. Albrecht von Graefe would describe retinal artery occlusion and glaucoma.[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.[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.

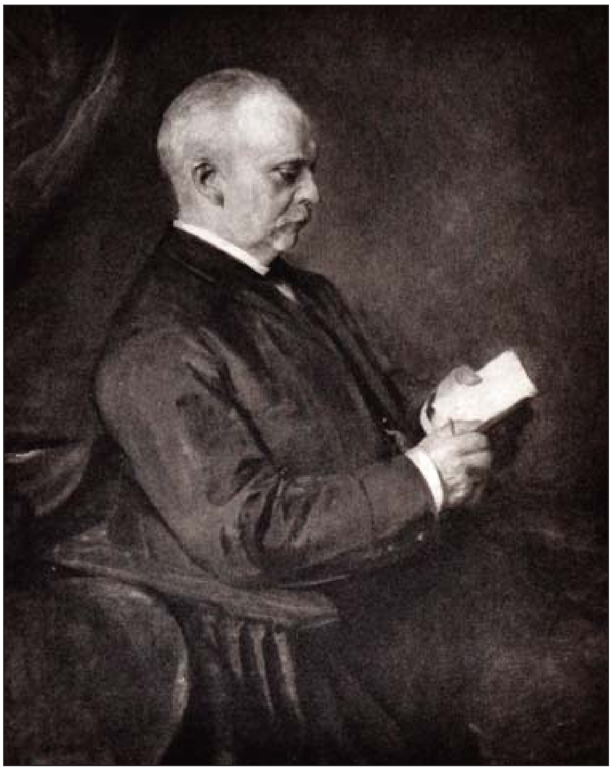
Conclusion

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[29]

von Helmholtz on an English copperplate, dated 1867

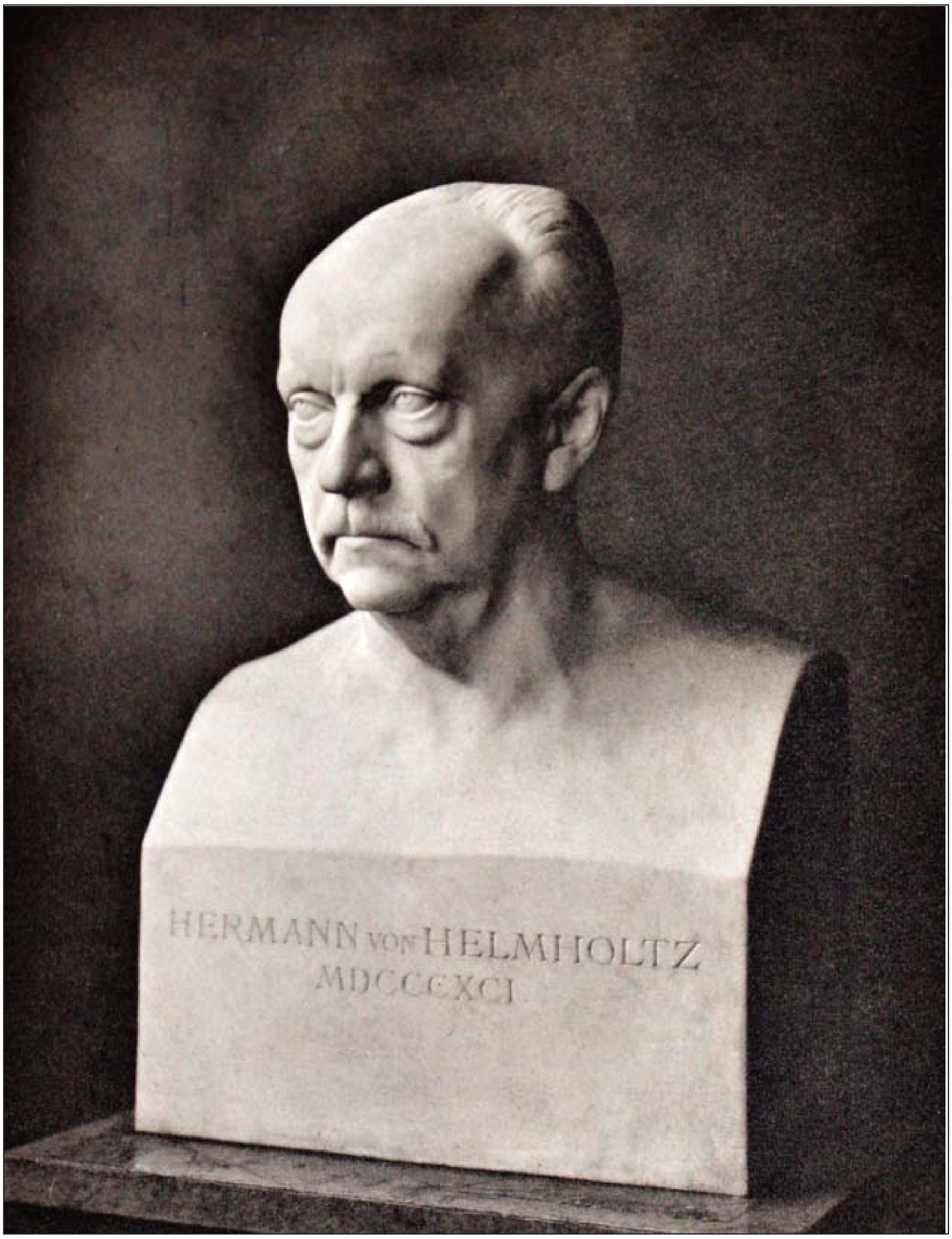




Above and left:
Hermann von Helmholtz painted 1884 by the German artist Franz von Lenbach (1836-1904)

Hermann von Helmholtz 1894 (Pastel drawing by F. von Lenbach, dedicated to Helmholtz by the artist 29 April 1894)

Hermann von Helmholtz 1894 by Franz von Lenbach (Pastel drawing)



Hermann von Helmholtz 1891, marble bust by Adolf Hildebrand 1847-1921

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