The year 2000 coincides with the 150th anniversary of the invention of the ophthalmoscope. In 1850, Hermann von Helmholtz (1821-1894) inaugurated the modern era in ophthalmology with his magnificent instrument, which has done more to revolutionize the development of ophthalmology than any other invention or discovery. Before Helmholtz's invention, it was not possible to visualize the posterior pole of the eye in a living subject. The ophthalmoscope permitted the clinical correlation of signs and symptoms with findings in the retina, vitreous, and optic nerve. The ophthalmoscope became the model for all forms of endoscopy that followed. It is often compared in importance with 2 earlier inventions, the telescope (17th century) and the stethoscope (early 19th century). All of these instruments made dramatic new information available to the human mind.

Although Hermann von Helmholtz (Figure 1) was educated as a physician, he spent most of his career as a basic scientist. From an early age, he was interested in solving scientific problems. His father was a professor of philology and philosophy at the best secondary school in Prussia, the Potsdam Gymnasium, but his relatively low salary did not allow the senior Helmholtz to subsidize his son's interests for long. Instead, he encouraged him to study medicine. At that time, few opportunities were available for a physiologist or physicist, but a career in medicine offered relatively secure future prospects. Helmholtz took advantage of free tuition at the military medical school in Berlin, Germany, graduating in 1843.

Helmholtz never regretted his years spent in medicine. After fulfilling his obligation to serve as an army physician for several years, he turned to an academic career in the natural sciences, primarily physiology. At the relatively young age of 29 years, as a professor at the University of Königsberg, Königsberg, Germany, he invented the ophthalmoscope while preparing a lecture on ocular physiology.

Helmholtz's first communication concerning his remarkable instrument occurred on December 6, 1850. To establish his claim as the inventor, he gave an oral presentation to the Physical Society of Berlin, a small group of scientists that had been established a few years earlier. Eleven days after this presentation, Helmholtz described his invention in a letter to his father. A sense of pride and excitement, tempered by a Prussian sense of propriety, is apparent:

I have on the occasion of my lecture on physiology made an invention which could possibly be of considerable use to ophthalmology. Actually, this invention was obvious, did not need any more knowledge than I had learned at the gymnasium. It now seems ridiculous to me that others and I myself could be so obtuse not to have found it earlier. It is a combination of glasses by which it is possible to illuminate the dark fundus of the eye through the pupil without using a glaring light, and at the same time to see details of the retina much more precisely than we can see the external eye without magnification. The transparent parts of the eye are seen as if through a loupe of 20x magnification. One can see the blood vessels, the branches of arteries and veins, the entrance of the optic nerve head into the eye, etc.
Up to now a large number of important eye diseases were lumped together under the name of “black cataract,” a terra incognita, because we knew nothing about the pathologic changes in the living eye, not even after autopsy. Thanks to my invention the most detailed examination of the inner structure of the eye is possible.\textsuperscript{1(p105)}

Actually, the invention was not as self-evident as Helmholtz rather modestly put it. The concept required a sophisticated understanding of optics and an inquiring mind.

His father replied, “The instrument is immediately practical and the question will arise whether you should not obtain a patent for this diagnostic instrument.”\textsuperscript{1(p105),2} The senior Helmholtz realized that the invention might have significant economic potential. The inventor did not respond to his father’s idea and never patented the ophthalmoscope. Although he and his family could have used the additional income, he preferred to see his instrument widely used to benefit humanity than to make him a fortune. But he was not opposed to the manufacturer of the instrument profiting from the invention. Shortly after his article on the new instrument appeared, he wrote his father that 18 orders for the new instrument had already come in, including requests from Holland, France, and England, “so that my mechanic will make quite a profit.”\textsuperscript{1(p106)}

Helmholtz’s first public announcement of the ophthalmoscope occurred on November 11, 1851, at a meeting of the Society for Scientific Medicine of Königsberg. This society had been founded just a few days earlier, and Helmholtz was its first president. At nearly the same time, his 43-page monograph on the ophthalmoscope was published.\textsuperscript{3} Because Helmholtz’s first public description of the instrument, as well as his first publication concerning it, occurred in 1851, that year is sometimes erroneously given as the date of his invention, rather than his presentation to the Physical Society of Berlin the previous year.

The monograph clearly presents the optical problems of viewing the ocular fundus and the need for the observer to look into the subject’s eye in the same direction as the incoming light is directed. His solution to the problem involved a transparent mirror made of 3 thin parallel sheets of glass angled to reflect the maximum light into the eye (Figure 2). It proved to be difficult to use and was soon replaced by a concave mirror with a central opening.

Helmholtz recognized the clinical importance of his invention in this publication: “I believe I may hold the expectation, not to be exaggerated, that all the alterations of the vitreous body and of the retina, which until now have been found in cadavers, will also be recognizable in the living eye, a possibility which appears to give promise of the greatest advances in the hitherto undeveloped pathology of these structures.”\textsuperscript{4}

As the ophthalmic historian Thomas Shastid aptly stated in a footnote to the first translation of Helmholtz’s monograph, this is “probably the most significant sentence ever penned” by anyone working in the field of ophthalmology. Shastid elaborated:

How the great man’s prophecy has been fulfilled is known not merely to specialists and general practitioners, but even, in some degree, to first year medical students and the educated portion of the laity. In fact, there are just two kinds of ophthalmology, that which came before and that which followed after Helmholtz’s Beschreibung eines Augenspiegels [Description of an Ophthalmoscope].\textsuperscript{3(p29)}
Helmholtz called his instrument an Augenspiegel (eye mirror) because the glass plates of his invention reflected light into the eye being examined. The word ophthalmoscope was introduced in 1852 by Maressal de Marsilly. This was a modification of an earlier word, ophthalmoscopy, a general term for examination of the eye.

NEAR-INVENTORS

As early as 1703, Jean Me´ry in Paris, France, became the first person to observe details of the fundus in a live subject. He saw the optic nerve of a cat, but to do so he had to submerge the cat’s head under water to neutralize the effect of the cornea. Adolf Kussmaul, who is remembered today for his work on respiration, did animal experiments as a medical student at Heidelberg, Germany, in 1844 in an attempt to visualize the retina, but he did not know how to illuminate the fundus. William Cumming, working in England in 1846, and Ernst Brucke in Vienna, Austria, in 1847, were even closer. They were able to illuminate the fundus, but could not visualize it.

There is a British claim for precedence. In 1854, the ophthalmologist Thomas Wharton Jones published his “Report on the Ophthalmoscope,” writing, “It is but justice that I should here state, however, that 7 years ago Mr Babbage showed me the model of an instrument that he had contrived for the purpose of looking into the interior of the eye.” That instrument was a mirror with a central opening. No other bit of information corroborates Jones’ statement. Charles Babbage, a well-known and eccentric mathematician, is generally recognized as the father of the modern computer. Neither his autobiography nor the 11 volumes of his published works contain anything related to examination of the eye. Apparently Babbage kept a diary, which has been kept private by his descendants. Perhaps someday its contents will be made public. Until that time, as the eminent ophthalmic historian Julius Hirschberg has written, the retrospective claim for Babbage “cannot be taken seriously.”

One other person may have visualized the retina before Helmholtz. This is the Czech physiologist, Jan Purkinje, who is remembered today for the catoptric images formed by reflection from the lens and cornea. In a book that was published 27 years before Helmholtz’s first description, Purkinje made these interesting statements:

I was also by coincidence capable of observing the interior of the eye where the vitreous is present when a suitable method is used. I examined the eye of a dog by using the spectacle lens of a myope [ie, a concave mirror] and placing a candle behind the dog’s back. . . . I found the light as the source which is reflected from the concavity of the spectacle lens into the interior of the eye. From there it is again reflected. I immediately repeated the experiment on a human eye and found the same phenomenon.

Purkinje constructed an artificial eye to verify these findings. He was still alive nearly 20 years after Helmholtz described his ophthalmoscope and appears never to have claimed priority for himself. As in many other fields, the credit is most often awarded to the person who made the invention known.

POPULARIZATION OF THE INSTRUMENT

The ophthalmoscope was accepted quickly by nearly every prominent...
European ophthalmologist. One notable advocate was Albrecht von Graefe, who obtained a copy of Helmholtz’s monograph shortly after it was published. von Graefe was only 23 years of age in 1851, and Helmholtz was 30. When von Graefe first visualized the fundus with the new invention, he shouted out enthusiastically, “Helmholtz has unveiled a new world to us.” He ordered several ophthalmoscopes from Helmholtz’s manufacturer and sent 1 to Desmarres in Paris and another to Bowman in London. Soon there was a flood of publications describing observations using the ophthalmoscope, most notably those of Ruete, Coccius, von Graefe, Liebreich, Stellwag, Jaeger, Donders, Wells, and Bowman. A further improvement, indirect ophthalmoscopy, was devised by Ruete in 1852. Elkanah Williams of Cincinnati brought ophthalmoscopy to America in 1855. He had already published one of the earliest reports in English on the new instrument in 1854 while working at Moorfields Eye Hospital in London.

Often there is some resistance to innovation in medicine, and not surprisingly, this new instrument proved to be no exception. A few ophthalmologists did not want to learn a new technique. Others were concerned about the potential for light damage to the retina, particularly in a diseased eye. Ophthalmologists were well aware of the temporary scotomas and sensitivity that can be induced by light and the potential for permanent damage from the sun. In 1853, a British ophthalmologist made the interesting comment, “Prolonged illumination of the retina in order to draw the fundus could cause amaurosis.” However, the risks of ophthalmoscopy were soon shown to be negligible, and the instrument was quickly incorporated into medical practice.

The first ophthalmoscopes were certainly not easy to use. The source of light was a reflected flame that was far less intense than the electric bulbs used today. Glare from the cornea was an important impediment. If the pupil was not dilated, visualization of the fundus could be difficult. Atropine was commonly used to dilate the pupil, but the long-lasting mydriasis and cyclopia from this medication were significant disadvantages. Despite the difficulties, some humorous anecdotes have been passed down to us. Helmholtz received a dozen letters from one ophthalmologist, who repeatedly wrote, “Your ophthalmoscope is excellent, but I cannot see anything with it.” Helmholtz always answered, “Practice.” The 13th letter finally stated, “I can see.”

Visitors to von Graefe’s clinic in Berlin were often shown a spot on the ceiling of a darkroom used for ophthalmoscopy. The mark was said to have been made by an ophthalmoscope thrown by an excited ophthalmologist who had seen the optic nerve for the first time.

HELMHOLTZ’S OTHER SCIENTIFIC ACHIEVEMENTS

Helmholtz proved to be one of the greatest scientists of the 19th century. Ophthalmologists know him for his magnificent textbook, *Handbook of Physiological Optics*, and the ophthalmometer, as well as the ophthalmoscope. To the rest of the scientific world, however, he is best known for the law of the conservation of energy. In the same year that he created the ophthalmoscope, he was able to perform a scientific feat that experts had said was impossible—to measure the speed of conduction of a nerve impulse. He also made valuable contributions to our understanding of the ear, music, and aesthetics.

His intellect was so well respected that at his autopsy, the structure of his brain was studied in a search for unusual development. There is a long tradition of seeking the origin of genius by examining the brains of famous scientists. Unfortunately, gross and microscopic studies of the cerebral cortex of men such as Helmholtz, Osler, and Einstein have provided equivocal answers.

HONORS TO THE INNOVATOR

As early as 1858, the Heidelberg, Germany, Ophthalmological Society honored Helmholtz at its annual banquet with a silver cup inscribed, “To the creator of a new science, to the benefactor of mankind, in thankful remembrance of the invention of the ophthalmoscope.” von Graefe himself made the presentation. Helmholtz was particularly grateful for this recognition, as he revealed to his wife, because it was “a decoration from the experts.” The general public knew of his accomplishments, but he was most touched when his colleagues recognized his contributions.

Helmholtz’s innovation is sometimes termed an invention and at other times a discovery. Actually, he used both words. Initially, he used the word invention, as in the letter to his father in 1851 mentioned previously. He was a modest man, uncomfortable with flattery, and came to use the word discovery to avoid ostentation. He first used the word discovery more than 30 years after the fact, in 1882. In his words, the ophthalmoscope was “more a discovery” than an invention.

When I review the history of my ophthalmoscopic invention, I have to admit part of it was luck and the other part was only the work of a trained laborer who had learned to use the means and knowledge acquired by his predecessors. I have expressed the same thoughts in an after-dinner speech given at a memorial celebration to Graefe when his statue in Berlin was unveiled: “The ophthalmoscope was more a discovery than an invention,” ie, when a well-trained physicist arrived and recognized the importance of such an instrument, all optical means and all knowledge had been developed which were necessary in order to design such an instrument.

The ophthalmoscope was so important that Helmholtz was often asked to describe how he came to invent it. The last occasion occurred in 1893, the year before he died, during his only visit to the United States. The German Emperor Wilhelm II had prevailed upon him to visit America as a scientific emissary to the World’s Columbian Exposition, which was held in Chicago, Illinois. Also encouraging
him was Professor Herman Knapp, the head of ophthalmology at Columbia University’s College of Physicians and Surgeons, New York, NY, and editor of the Archives of Ophthalmology. They had been friends for many years, dating from Knapp’s student years in Heidelberg. Knapp had been inviting Helmholtz to come to America for 20 years. In a letter to Knapp describing his travel plans, Helmholtz wrote this fascinating comment: “I am convinced that America represents the future of civilized humanity and that it includes a vast number of interesting men, or the supremacy of Russia to look forward to.”

Helmholtz was treated as a magnificent celebrity by the scientific communities and socialites of New York and Chicago. Among others, he met the inventors Thomas Edison and Alexander Graham Bell, the architect Charles McKim, and the banker J. Pierpoint Morgan.

He spoke at the dedication of Knapp’s new ophthalmology clinic at Columbia and described the creation of the ophthalmoscope: “I think that no physiologist doubted, until the end of the last century, that the eyes of cats, dogs, oxen, and other mammals, and of birds, developed light of their own which shown forth at night.” He described how this was disproved early in the 19th century when the eyes of animals that appeared luminous were found to have a reflecting layer, the tapetum, and light could reflect from the tapetum of a dead animal as well as a live one. About 1846, an English ophthalmologist, Cumming, found that any eye could be made luminous in a dark room if a light is shined in and the observer is nearly on line with it.

Helmholtz continued,

Using a blackboard, Helmholtz traced the path of rays that create an image in the observer’s eye.

He emphasized,

All that was original with me in the matter was that I went to ask how the optic images could be produced by the light coming back from the illuminated eye. All my predecessors had failed to put this question to themselves. They had stopped in the middle of their way instead of going on to the end. As soon as I had answered that question I saw how an ophthalmoscope could be constructed, and it took me only 2 days to do it and successfully experiment with the new instrument. I say this to impress upon you how necessary and how useful it is to go on to the end when investigating natural phenomena. You must not go half-way and then stand still or go back.

One hundred fifty years after the fact, we can only admire Helmholtz’s ability to ask the relevant question and to come up with the innovative solution.

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