MILESTONES IN OPHTHALMIC IMAGING

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The Early Days of Fundus Photography

Introduction

There is a compelling connection between the eye and camera that goes beyond the obvious parallels between cornea and lens, iris and aperture, retina and film. As early as the 16th century, Leonardo DaVinci and others drew comparisons between the camera obscura and the human eye. It is not surprising, then, that from the earliest days of photography, several investigators sought to use the camera to document the condition of the eye. Due to the technical limitations of available photosensitive materials and the difficulty in illuminating the interior of the eye, fundus photography became the holy grail of medical imaging. In the decades immediately following the introduction of photography in 1839 by Daguerre, Fox-Talbot, and others, there were incremental advances toward achieving this elusive goal. In 1851, Hermann von Helmholtz introduced the ophthalmoscope. That same year, Frederick Scott Archer described the collodion photographic process, a significant improvement over the calotype and Daguerrotype. In the 1860's Henry Noyes of New York, and A.M. Rosebrugh of Toronto, both constructed fundus cameras and attempted fundus photography on animals.[1,2] Although this news was encouraging, Helmholtz was skeptical and commented on Rosebrugh's technique in the correspondence column of *The Ophthalmic Review*,[3] "I must confess I cannot yet believe that it (photographing the fundus oculi) will succeed in the human subject; the chief difficulty is evidently the use of sufficiently powerful sun-light, which would only be admissible with a completely blind eye."

He was right. Early results were severely compromised by insufficient light, long exposures, eye movement, and prominent corneal reflexes that obscured detail. Spectral sensitivity of available photographic emulsions had very little red sensitivity, adding to the difficulty of adequate exposure. It would be several decades before these problems could be conquered. Even as advances were made, results were often disappointing. In 1894, Lucien Howe, one of the early pioneers in fundus photography stated, "It is so easy, in theory, to photograph the interior of the eye, that it has undoubtedly been attempted many times. It is so difficult, however, in fact to accomplish this, that no satisfactory results have been obtained, in spite of the great value of this method of recording observations if it could be brought to perfection."[4]

The First Fundus Photograph

When it comes to the first successful human fundus photo, different historical accounts assign priority to different investigators. Lucien Howe, Jackman and Webster, and E Barr have all been mentioned in texts and historical reviews as being among the first to photograph the

fundus of a living human being.[5-10] Most accounts give Jackman and Webster priority, since they published their technique along with a reproduction of a fundus image in two photography periodicals in 1886.[11-12]

The article from the June 1886 *Philadelphia Photographer* described a 2½ minute exposure resulting in an image with a prominent corneal reflex, but a faintly visible optic disc.[11] The *Philadelphia Photographer* at that time was sparsely illustrated, mostly with line drawings, low quality engravings, and woodblock prints. Photogravure was too expensive a process for a periodical like this and halftone reproduction had not yet been widely adopted. The reproduction of the fundus photograph in the *Philadelphia Photographer* was an engraving which only simulated the original photograph. There is no doubt however, that Jackman and Webster were the first to publish a fundus "image" of a living human subject (Figure 1).

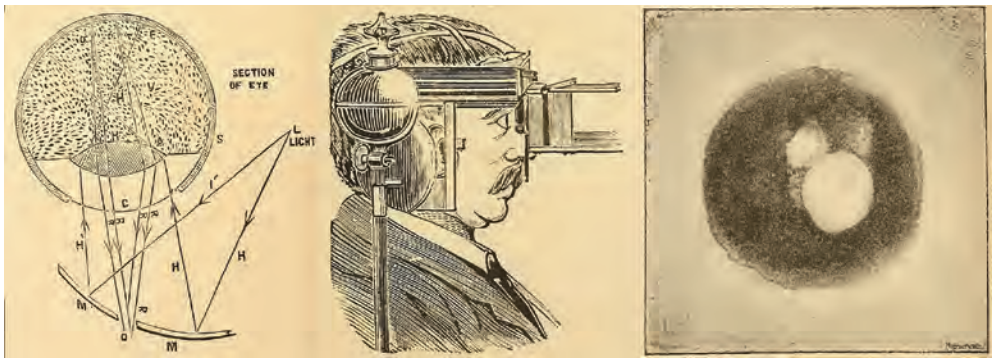


Figure 1: Illustrations from the Jackman and Webster article in the June 1886 *Philadelphia Photographer*. Historians most often cite this reproduction as the first successful fundus photograph of a human eye. *Reproduced from Jackman and Webster 1886.*

Howe, Starr, and "Barr"

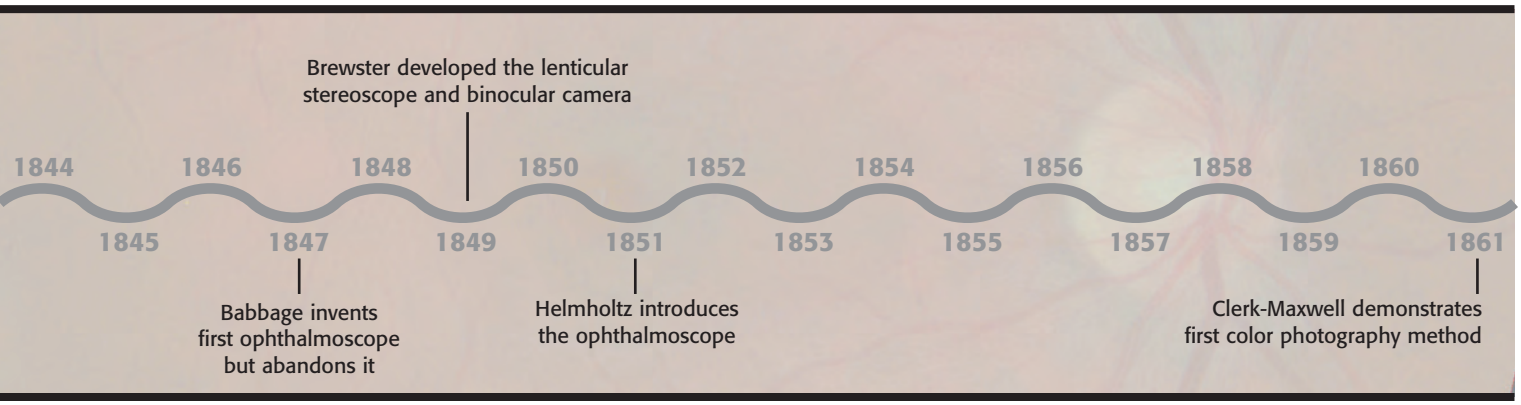
Three other names played a prominent role in early fundus photography. According to some historical accounts, Elmer Barr and Lucien Howe may have been first to photograph the human retina. A literature search for these authors turned up two articles with similar sounding titles. They are both available in online archives and interestingly they are both from researchers in Buffalo, NY, and were published the same month.

Photography of the Interior of the Eye.
Trans Amer Ophth Soc. 23:568-71 July 1887
Lucien Howe, MD of Buffalo, N.Y.

On Photographing the Interior of the Human Eyeball
Amer J Ophth 4:181-3 July, 1887
Elmer Barr, MD of Buffalo, N.Y

Howe's 1887 report to the American Ophthalmological Society[13] credited the work as that of his assistant, "Dr Elmer Starr of Buffalo, N.Y.", while the name on the *American Journal of Ophthalmology* article was Elmer Barr.[14] What's the likelihood that there was both an Elmer Barr and an Elmer Starr, working independently in Buffalo, NY to photograph the living human retina? An odd coincidence? Starr's name didn't turn up in a traditional literature search of the medical journals. I suspected that either the name Barr or Starr might be a typographical error. Since corrections aren't indexed in journal search databases, it was a challenge to turn up any evidence of a typographic error using a search engine, but a manual search of the next few issues of the *AJO* turned up this correction: "The name of the author of the paper on 'Photographing the Interior of the Human Eyeball,' published in our last number is not, as printed, Dr. E Barr, but Dr. Elmer Starr. *Am. J. Ophthalmol.* 4:240, 1887."

Sure enough, it really was Elmer Starr, not Elmer Barr! A similar correction appeared for an article in the *Scientific American* of the following year that had also been mislabeled as Elmer Barr. A further search of the popular science and photography periodicals from the late 1800's turned up another paper by Elmer Starr: "Photographing the human eye." in the *Philadelphia Photographer* 1887.[15] It was essentially the same content and technique as the Howe and Barr papers. Indeed



they all came from the same lab and described the same image (Figure 2). Typographical errors were not uncommon in the literature of the time and Starr fell victim to this several times. An early historical review from the turn of the century misspelled Starr's first name as Elemer multiple times, while another review mentioned the work of "Lowe in 1887" (they were referring to Howe).

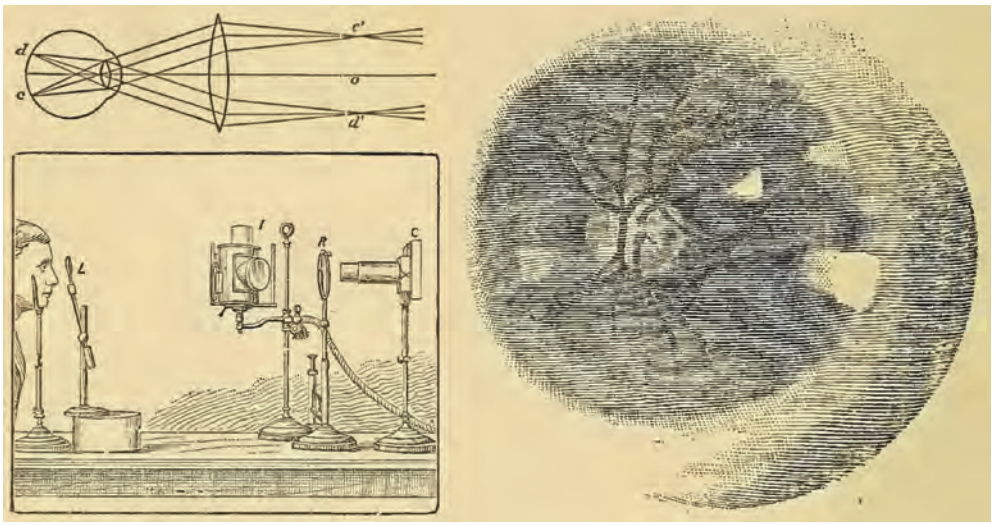
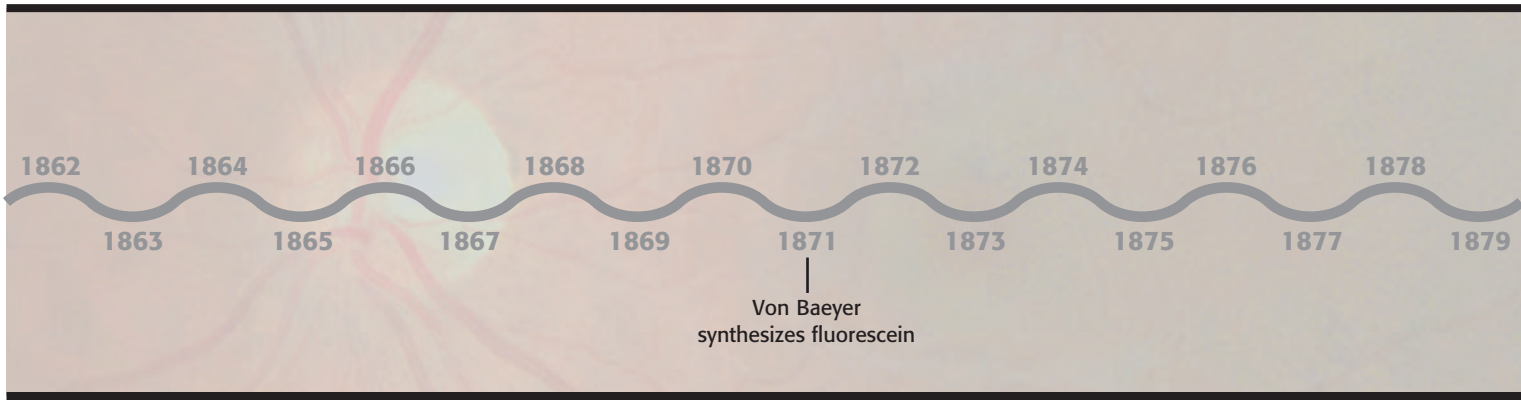


Figure 2: The *Philadelphia Photographer* published an article, Photographing the Human Eye by Elmer Starr, MD in 1887 that included an artist's woodcut rendition of a fundus photograph. The article was one of several reports by Starr and Lucien Howe from that year describing their success in obtaining the first recognizable image of a human fundus. Several of the articles incorrectly listed the author as Elmer Barr. *Reproduced from Starr 1887.*

Lucien Howe is a well-known name in ophthalmology. Howe was educated in the United States and Europe, having spent time studying and conducting research with Lister in Edinburgh, Helmholtz in Heidelberg, and others before returning to the United States and establishing the Buffalo Eye and Ear Infirmary. He was a Professor of Ophthalmology at the University of Buffalo, served as President of the American Ophthalmological Society, established the Howe Laboratory of Ophthalmology at Harvard University, and has had several prestigious awards and medals established in his name.

Starr was one of Howe's assistants in Buffalo and they collaborated on the fundus photography project in 1886-88. Howe described their results as the first "recognizable" fundus photograph, apparently a nod to Jackman and Webster being the first to "publish" a fundus photograph. Based on the written accounts, Howe and Starr's image was in fact more "recognizable" as a fundus, but it's difficult to tell from the published illustrations which were woodcut reproductions.

Interestingly, Howe's account was delivered as a third-person report, while both the "Barr" and Starr papers are written in the first person. All of this suggests that Starr was the actual principal investigator and took the photographs himself. Yet there is almost no mention in historical reviews of him being among the first to obtain a recognizable photograph of the living human retina. Starr seems to have missed his place in history simply because of repeated typographical errors. After initial publication in 1887, Howe didn't pursue fundus photography any further, but did present on the topic to the Ophthalmological Society of the UK in 1893.[16] It was essentially a repeat of the same material he presented six years earlier. He was no longer investigating fundus photography but hoped to "incite others to do better work…" In reviewing the limited progress to date, he listed Rosebrugh, Fick, and Gerloff as "the only three other attempts which as far as I can ascertain, have thus far been published." He conspicuously left out any mention of Jackman and Webster, which is curious because all of the previous Howe/Barr/Starr papers referred to the published Jackman and Webster photograph. Was this omission a mistake or done on purpose? He again thanked Starr for his assistance, but fell short of thoroughly crediting him as he had in



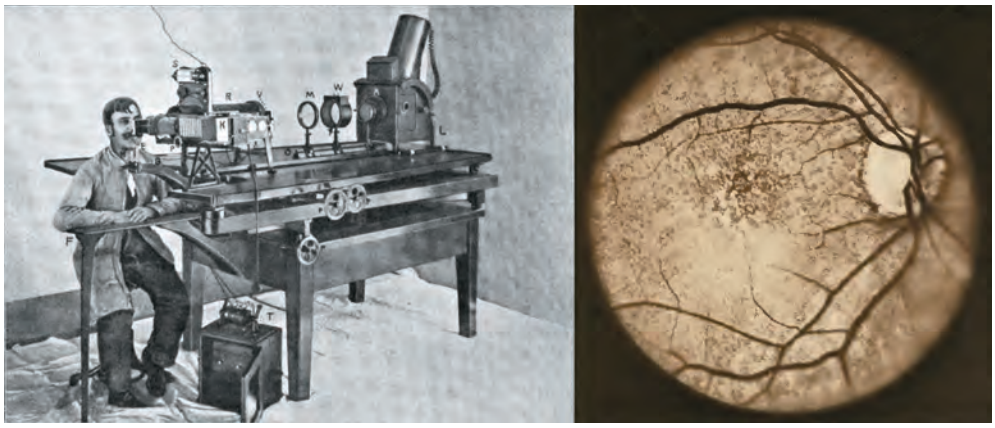


Figure 3: Friedrich Dimmer collaborated with Zeiss Jena to design and build a complex, one of a kind, reflex-free fundus camera that was capable of obtaining stunning results. *Reproduced from Dimmer 1907.*

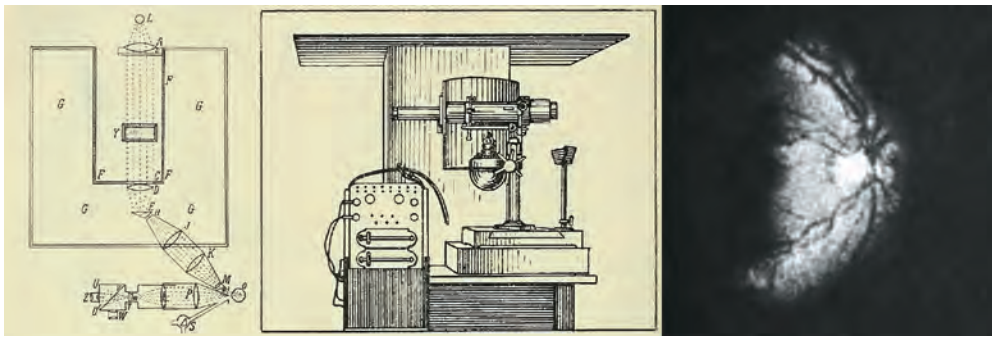


Figure 4: Walther Thorner developed a reflex-free ophthalmoscope in 1898 and over the next several years adapted the same principles to fundus camera design. Unfortunately, the images were small and unevenly illuminated. *Reproduced from Dimmer 1907.*

the past. In an 1895 address to the American Otological Society Howe reported on his attempts to photograph the eardrum.[17] In his address, he again took credit for having "showed the first photographs made of the human fundus oculi." It seems that as time went by, Howe began to assert a claim of priority and chose to ignore the prior work of Jackman and Webster.

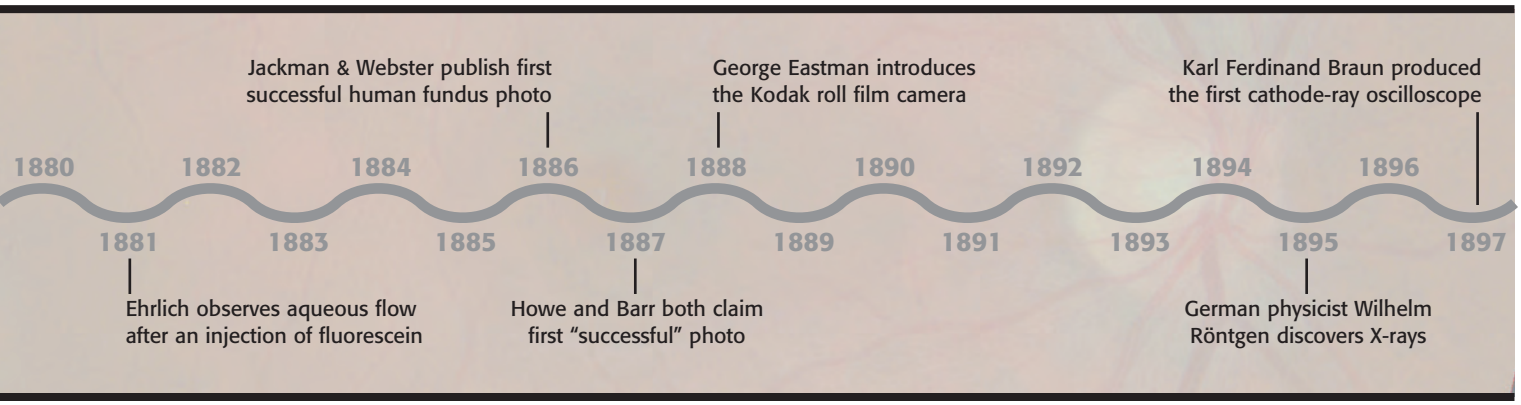
Thorner vs. Dimmer

Over the next decade there were improvements in both film and instrumentation that significantly improved photographic results. Bagneris, Guilloz, Gerloff, Wolff, Thorner, and Dimmer all made improvements in photographing the fundus oculi around this time. Tactics such as water bath immersion, corneal cover plates, and polarized light were used to reduce unwanted corneal reflexes but these techniques were ultimately deemed impractical.

In 1898, Walter Thorner of Berlin designed the first reflex-free ophthalmoscope based on the simple principle of transmitting the illuminating beam through one half of the dilated pupil and viewing the light reflected through the other half.[18] The following year Friedrich Dimmer of Vienna showed reflex-free photographs at the Ninth International Congress of Ophthalmology that caused quite a stir, and another controversy was born.

Dimmer continued to refine his technique and collaborated with Zeiss Jena to design and build a complex reflex-free fundus camera (Figure 3). It was so large and expensive that only one was ever built.[19-20] Thorner used a camera of his own design (Figure 4), but his images were smaller, had a limited field of view, and were unevenly illuminated compared with Dimmer's.[7]

A report from the Tenth International Congress of Ophthalmology in *The Ophthalmoscope* from 1904 compared their images,[21] "Professor Dimmer, of Gratz, showed twenty beautiful photographs of the fundus oculi, normal and abnormal. The photographs were so good as to allow one to recognize, literally at a glance, the conditions they depicted. The apparatus by which



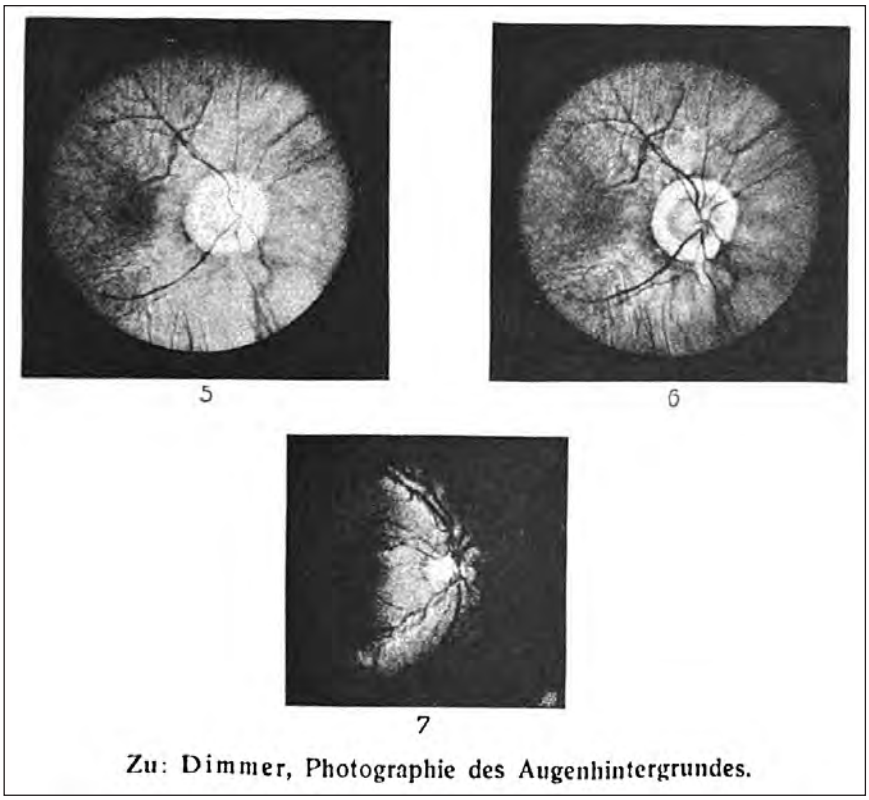


Figure 5: Dimmer published an article describing the use of a printing mask to improve detail in his fundus photographs in 1908. Image 5 is printed without a mask. Image 6 shows improved detail in both the macula and optic nerve. Dimmer included one of Thorner's images for comparison (image 7). Although Dimmer stressed that the mask was used only to maximize detail contained in the negatives, perhaps this technique is what led Thorner to accuse him of retouching his photos. *Reproduced from Dimmer 1908.*

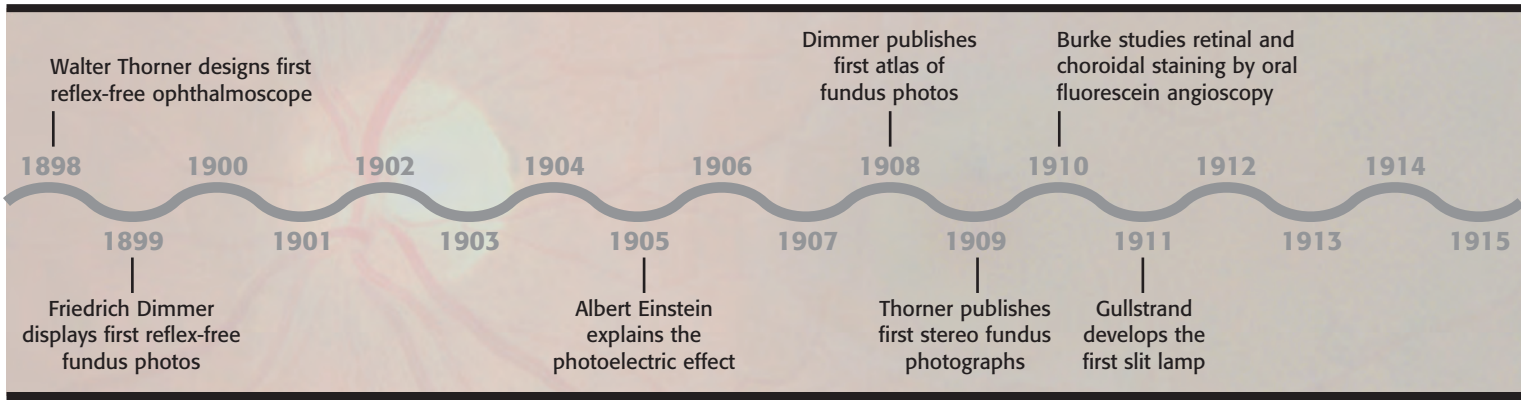
these extraordinary photographs were taken was also on view. It is, unfortunately, almost as big as a grand piano, and is stated to be correspondingly expensive. Dr. Walter Thorner, of Berlin, also showed photographs of the fundus oculi, but for beauty and detail they could not be compared with those of Professor Dimmer."

Dimmer's instrument incorporated the reflex-free principles introduced by Thorner, but Thorner was skeptical of the Dimmer's results and accused him of retouching the photographs to remove the central corneal reflex (Figure 5). This resulted in a feud that lasted several years.[5-7] Keeler and co-authors[22] recently summarized the controversy, "By 1908 Dimmer had produced exceptional black and white images which were published in an atlas. Thorner was so impressed that he wrongly accused Dimmer, of "touching up" the results. Thorner however took comfort in the knowledge that only one instrument, the size of a small car, could take these photographs and the instrument could not be commercialised."

20th Century Milestones

Thorner later designed a stereoscopic camera and may have published the first stereo fundus photographs in 1909.[6,23-24] The following year, Allvar Gullstrand improved upon Thorner's reflex-free ophthalmoscope and invented the slit lamp. Gullstrand was celebrated for these accomplishments and won the 1911 Nobel Prize for his work on the dioptrics of the eye. As early as 1915, Nordenson described a new camera that combined carbon arc illumination and Gullstrand's principle of reflex-free ophthalmoscopy. The Zeiss Nordenson camera was introduced commercially in 1925 and finally made fundus photography more practical (Figure 6).

An atlas of retinal images by Dimmer and Pillat was published in 1927, two years after Dimmer's death. Arthur J Bedell published an important atlas of fundus images taken with the new Nordenson camera in 1929. Over the next several decades, Bedell was recognized around the world as a tireless advocate for fundus imaging. He published numerous cases and articles on fundus photography. He documented several patients with serial photography for as many as forty years and amassed a slide collection numbered in the tens of thousands. He was celebrated throughout ophthalmology for his lifelong contributions



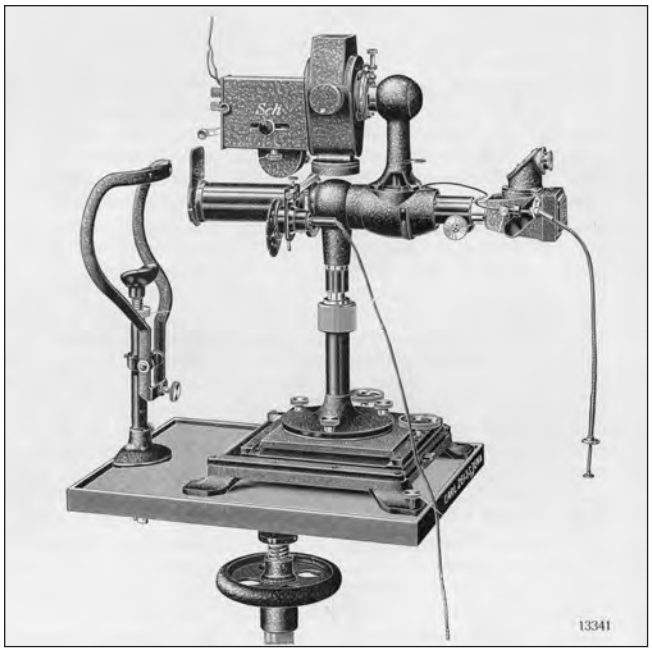


Figure 6: The Zeiss Nordenson camera was introduced commercially in 1925. The original design utilized a carbon arc lamp that was later replaced by an electric lamp. *Image courtesy of the Carl Zeiss Archives.*

and received numerous academic honors, fellowships, and awards including all three Lucien Howe medals.

On more than one occasion, Bedell claimed to have been the first to produce stereoscopic fundus images.[9,25] He wrote that although Metzger was first to mention stereo fundus photography in the literature in 1927, his own series of stereo images were taken and submitted for publication first. Of course this ignores Thorner's published work on stereo fundus photography from 1909. That seemed to be a recurring theme for Thorner. He was the first to describe reflex-free ophthalmoscopy, reflex-free fundus photography, and stereo fundus photography. But in all cases his work was overlooked or soon eclipsed by others.

In the 1930's, Hartinger made several modifications to the Nordenson camera, replacing the carbon arc illumination with a high intensity electric lamp, and adding a small black dot in the optical path to eliminate

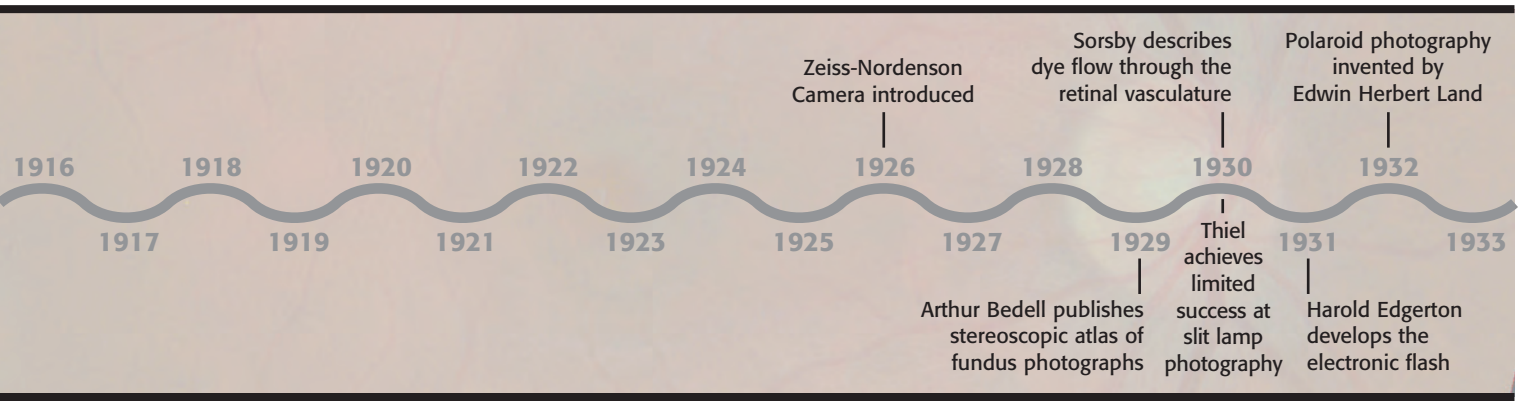
Figure 7: The Zeiss Littman fundus camera with electronic flash illumination ushered in the era of modern fundus photography. *Image courtesy of the Carl Zeiss Archives.*

a small reflective artifact. In the early 1950's, Meyer-Schwickerath, Ogle and Rucker, and Hansell and Beeson, all adapted electronic flash tubes to fundus cameras.[7-8] In 1955, the Zeiss-Littman fundus camera was introduced. With an improved optical design and electronic flash illumination it quickly became the workhorse for modern fundus photography (Figure 7).

Lee Allen was a pioneer in electrophysiology, ocular prosthetics, and fundus photography. He made several modifications to the Zeiss Littman camera in the 1960's including the Allen Dot based on the concept previously described by Hartinger and Boeghold. He authored a series of best practices in fundus photography and stereo photography, designed the Allen Stereo Separator, and adapted Polaroid film cameras.[26-27] Allen was held in high regard throughout ophthalmology for his many contributions to the field, and went on to become a founding member and the first President of the Ophthalmic Photographers Society in 1969.

The Foundation of a Profession

Many of the significant milestones in photography, fundus photography, and stereo imaging occurred during the nineteenth and early twentieth centuries' great enthusiasm for science and innovation. Several of the pioneers



in this nascent field were competitive rivals who craved recognition for their contributions. History has certainly smiled on some of them and been unkind to others. Collectively however, their contributions reinforced the innate connection between eye and camera, and provided the foundation for a profession that we now celebrate on the 50th anniversary of the founding of the Ophthalmic Photographers' Society.

Over these last five decades, our profession has witnessed some incredible technological advances. As a result there is an ever increasing reliance on ophthalmic imaging to diagnose and treat patients. As we look to the future, our profession continues to advance the analogy that inspired the invention and evolution of fundus photography.

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