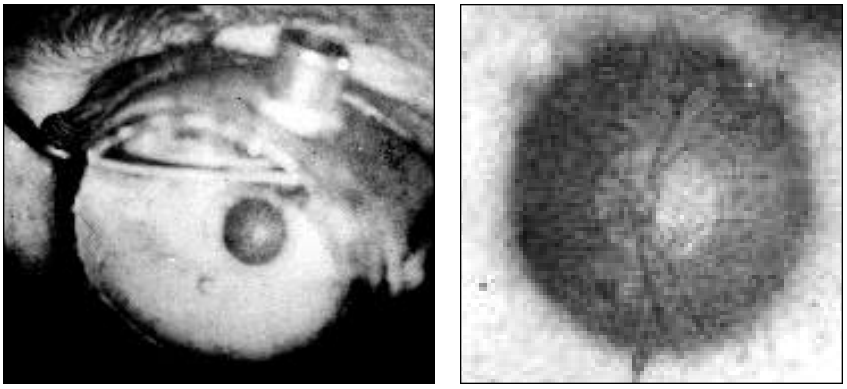


FIGURE 1-5
In 1891, Gerloff published a low-magnification retinal photograph that was much clearer than earlier efforts. (Reproduced from O Gerloff. ***Ueber die Photographie des Augenhintergrundes***. Klin Monatf Augenheil 1891;29:397.)

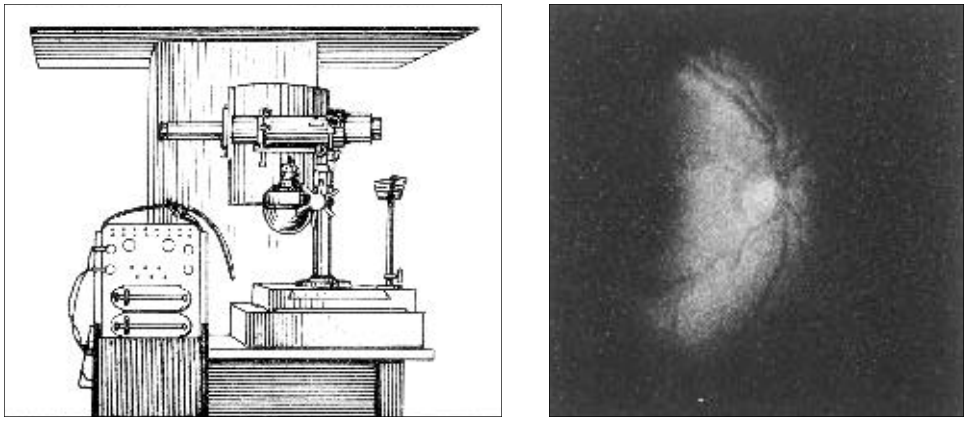


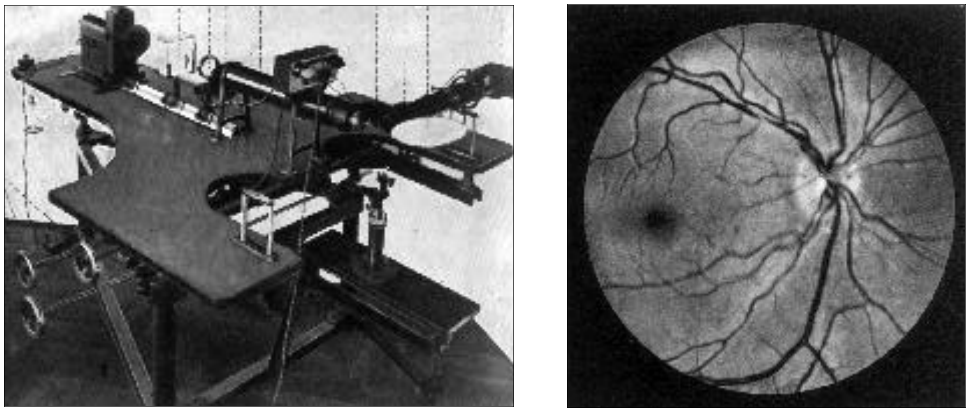
FIGURE 1-6
Thorner's camera (A) provided fundus photographs (B) with adequate detail but lacking even illumination. (Reproduced from F Dimmer. ***Ueber die Photographie des Augenhintergrundes.*** Wiesbaden, Germany: Bergmann, 1907.)

In 1891, Gerhoff used flash powder to illuminate a low-magnification fundus photograph (Figure 1-5).[15] Thorner wrote a 1903 book outlining his fundus photography techniques (Figure 1-6).[16]

Accurate, high-quality fundus photography began at the turn of the twentieth century with the work of Frederick Dimmer. Bedell wrote that Dimmer "electrified the 9th International Congress (1899) with his marvelous pictures...."[5] Dimmer's 1907 treatise on fundus photography described his cumbersome apparatus, which used carbon arc illumination (Figure 1-7).[12] He was the first to incorporate fundus photography into a basic ophthalmic textbook and the first to publish a photographic atlas.[17, 18]

Only one of Dimmer's cameras was ever produced. Modern fundus camera design grew from the work of Helmholtz, who introduced the direct ophthalmoscope in 1851.[19] Its design was improved by Thorner in 1899 and Gullstrand in 1910.[20, 21] Nordenson introduced a camera based on Gullstrand's principles in 1925.[22] The Carl Zeiss Company marketed Nordenson's design as the first commercially available fundus camera in 1926 (Figure 1-8).[23] This camera had a 10-degree field of view and required a one-half second exposure with color film.[24]

Color fundus photography was attempted as early as 1929, the same year Bedell published the first stereo atlas of fundus photographs.[25, 26] In



A B

FIGURE 1-7
Dimmer's fundus camera (A) was used to create this fine retinal photograph of a normal eye (B). (Reproduced from F Dimmer, APillat. ***Atlas photographischer Bilder des Menschlichen Augenhintergrundes***. Leipzig, Germany: F Deuticke, 1927.)

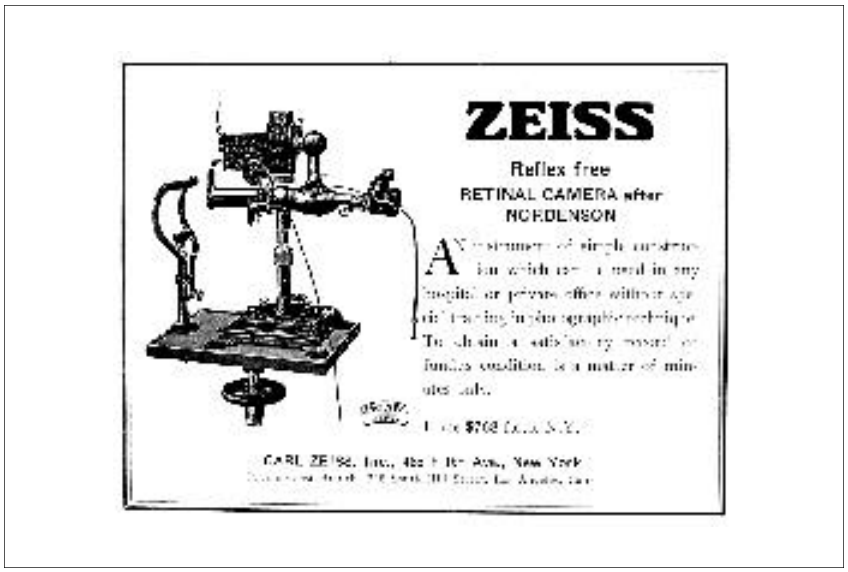


FIGURE 1-8
An advertisement for the Zeiss fundus camera from 1932. Fundus cameras have changed dramatically in the last 50 years. Advertising copy has not. (Reproduced from ***Am J Ophthalmol*** 1932;32:1214.)

June 1935, Bedell delivered the chairman's address at the Eighty-Sixth Annual Session of the American Medical Association[5] and described the current state of fundus imaging:

> *Direct color photography has attracted attention and some excellent pictures have been presented, but because of the expense and the difficulty of reproduction, it is not as yet popular. Eventually, drawings will be supplanted and even the most skillful artist will be forced to admit the superiority of photographs. For several years I have been taking colored photographs.*[5]

Limitations in clinical use of fundus photography in the 1930s and 1940s can be directly attributed to the difficulty in obtaining quality images. Slow film speeds and long shutter speeds were the rule with the then current carbon arc illumination system. Although Hartinger described a modification of the fundus camera by the addition of an electrical lamp, carbon arc fundus cameras continued to be used through the 1940s.[27, 28] Abright, instantaneous light source was needed for high-quality, routine fundus photography. External eye photographs taken with

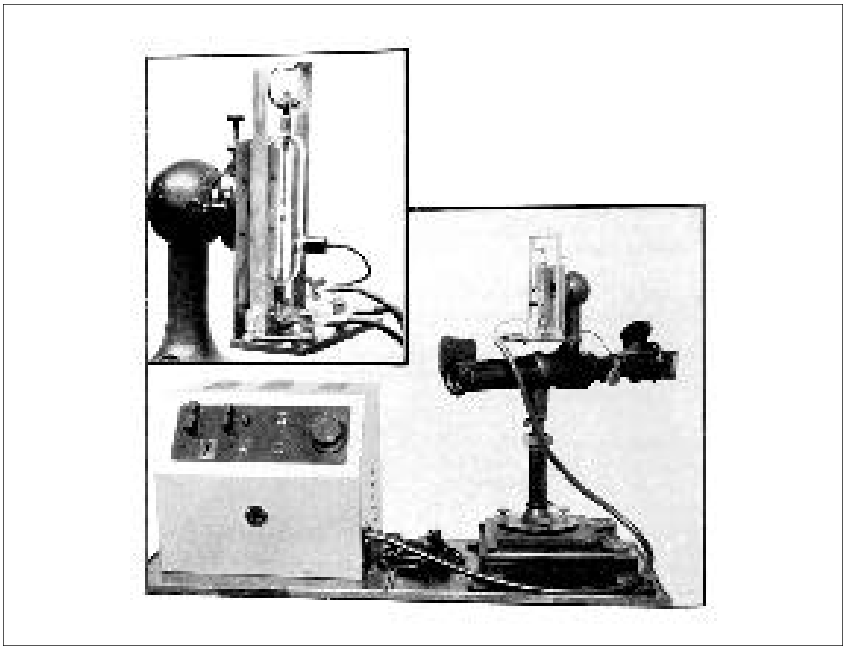


FIGURE 1-9
Hansell and Beeson adapted an electronic flash tube to a Zeiss fundus camera. (Reproduced from PHansell, EJG Beeson. Retinal photography in color. ***Br J Ophthal*** 1953;37:65.)

a "lightning illumination process" were produced by Cohn and DuBois-Reymond in 1888.[29] In 1946, Edgerton developed the electronic flash tube, and in 1949 Rizzutti introduced its use to ophthalmology.[30, 31] Electronic flash was adapted to the fundus camera in 1953 in both Britain and the United States (Figure 1-9)[28, 32]:

> *The application of a new compact xenon arc lamp (FA5) to retinal photography in colour is described. The circuit required for pulse operation of the lamp is given and some modifications of the Zeiss-Nordenson retinal camera are mentioned.…By these means standard and comparable records of the fundus oculi may be obtained on Kodachrome colour film at exposures of ½₅ sec.*[28]

> *By using again the ring of light just within the pupil to illuminate the retina, and photographing directly through the center of the pupil, one can obtain pictures which are reflex-free. Because the flash exposure of the tube is of the order of 0.0001 second, the problems of blinking and of the movements of the eye being photographed are eliminated. The use of the flash-tube technique also is less fatiguing and annoying to the patient.*[32]

By the early 1950s, fluorescein dye had been observed flowing through the retina, filters had been used to enhance the visualization of the retina filled with dye, and flash-adapted fundus cameras were a reality. A flurry of activity in the late 1950s preceded Alvis and Novotny's important paper.

Fluorescein Angiography

In early 1959, Chao and Flocks described a method for measuring the "retinal circulation time" in cats.[33] Using a stopwatch, ophthalmoscopy, and tryptan blue, they found that the circulation time of the cat retina was approximately 2 seconds. Their discussion concluded with this observation: