Igor Kozak · J. Fernando Arevalo
Editors

Atlas of Wide-Field Retinal Angiography and Imaging

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To my parents, Bozena and Peter, and brother Peter for their endless support; to my friends, mentors, and colleagues, and to all our patients for inspiring us.

Igor Kozak

To my family for their patience and support, to Wilmer Eye Institute, Johns Hopkins University, and King Khaled Eye Specialist Hospital for the privilege to lead the Vitreoretinal Division to the next level, and to God for 4 wonderful and fulfilling years of my life.

J. Fernando Arevalo

Foreword

The eye may act as a window to many systemic conditions. Some retinal imaging techniques provide noninvasive methods for detecting and monitoring such pathologies, with high resolution and sensitivity to allow an ophthalmologist to make the correct diagnosis. Fortunately, clinical research and imaging developments have made notable advances in identifying retinal pathology and have been incorporated in *Atlas of Wide-Field Retinal Angiography and Imaging* to enhance the educational value of this extraordinary text. The desire to view larger areas of the retina that extend to the retinal periphery has always been there, and over the last 20 years, new imaging devices capable of obtaining ultra-wide-field images, fluorescein and indocyanine green (ICG) angiograms, as well as autofluorescence, have emerged to help us diagnose, understand, and treat retinal disease.

Beginning with improvements in photographic, ultrasonographic, and fluorescein as well as ICG angiographic technology in the 1960s, several comprehensive textbooks and atlases have been written to compile advances in imaging of retinal conditions. Even with the recent popularity of **wide-field retinal angiography and imaging**, this is one of the first books to cover the subject comprehensively. The editors, Dr. Igor Kozak and Dr. Fernando Arevalo, and the contributing authors of this text have provided by far the best documentation of **wide-field retinal angiography and imaging** for its readers. Indisputably, the co-authors are all leaders in this field with notable original and lasting contributions to one of more of the principal selected subjects covered in this text. Accordingly, each section discusses the most advanced concepts regarding **wide-field retinal angiography and imaging** of retinal disorders. In essence, a large amount of new information on **wide-field retinal angiography and imaging** has been compiled in this text in an authoritative and comprehensive format.

The topics discussed in this book include wide-field fluorescein angiography, wide-field ICG angiography, and wide-field autofluorescence on a variety of retinal conditions, including intraocular tumors and posterior uveitis. While there have been several publications which describe specific uses of **wide-field retinal angiography and imaging**, this textbook attempts to engage a select group of experts to elegantly describe and amply illustrate the variety of ocular abnormalities described in this *Atlas of Wide-Field Retinal Angiography and Imaging*. In short, Igor Kozak and Fernando Arevalo have achieved success in fulfilling a challenging goal in this concise, salient, and superbly illustrated and descriptive atlas. The editors and their expert contributors are to be congratulated for compiling an educational addition to **wide-field retinal angiography and imaging**. Essentially, this new text represents a wonderful labor by an elite group of expert clinical and scientific contributors. Their monumental efforts should be rewarded by the gratitude of clinicians and perhaps even some patients who will receive incalculable pleasure as a reader of their work.

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Preface

We were privileged to work together at King Khaled Eye Specialist Hospital (KKESH) in Riyadh, Saudi Arabia, and introduce several advancements in retinal imaging to the Middle East. The popularity of retinal imaging is based on the necessity to document and aid in the early detection and management of diseases that can affect both the retina and overall health. We as ophthalmologists need to be aware of recent advances in retinal imaging. The desire to view larger areas of the retina and the retinal periphery has been ongoing since the original fundus cameras were developed, and over the past two decades fundus cameras capable of obtaining wide field images, angiograms, and autofluorescence have emerged to help us better diagnose, understand, and treat disease.

Our experience at a very florid, high-volume Retina and Uveitis clinic at KKESH triggered a comprehensive presentation of the current clinical aspects of the *Atlas of Wide-Field Retinal Angiography and Imaging*. This book includes contributions from an internationally renowned group of experts from the United States, Spain, and Saudi Arabia. The topics discussed in this book do not pretend to be all-inclusive but include history and principles of wide-field retinal imaging, wide-field fluorescein angiography, wide-field indocyanine angiography, wide-field autofluorescence, wide-field retinal imaging of diabetic retinopathy, wide-field retinal imaging of branch retinal vein occlusions, wide-field retinal imaging of central retinal vein occlusions, wide-field retinal imaging of other retinal vascular diseases, wide-field retinal imaging of retinal dystrophies, wide-field retinal imaging of peripheral retinal degenerations, wide-field retinal imaging of pediatric retina, wide-field retinal imaging of retinal and choroidal tumors, wide-field retinal imaging of retinal and choroidal inflammatory diseases, wide-field retinal imaging of retinal and choroidal infectious diseases, and wide-field retinal imaging of other miscellaneous retinal diseases.

The impetus to edit this book has come from our students and colleagues in all fields of ophthalmology and internal medicine at KKESH and internationally. This book is intended for retina and vitreous specialists, uveitis and ocular oncology specialists, retina and vitreous fellows, uveitis and ocular oncology fellows, ophthalmology residents, comprehensive ophthalmologists, and physicians in general.

The principal objective of this atlas is to present the current information on wide-field retinal angiography and imaging from leading experts in the field. We hope their knowledge and experience will assist ophthalmologists, retina specialists, uveitis and ocular oncology specialists, and physicians in general approach a level of knowledge about wide-field retinal angiography and imaging to benefit their patients in everyday clinical practice.

Riyadh, Saudi Arabia — Igor Kozak, MD, PhD

Baltimore, MD, USA — J. Fernando Arevalo, MD, FACS

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Fundus Imaging in Wide-Field: A Brief Historical Journey

1

Ella H. Leung and Richard Rosen

Our ability to visualize has often limited our ability to conceptualize, in medicine as well as technology, science, and mathematics. Before we were able to see the retina, our perspective of ocular disease was largely confined to disorders of the anterior segment, such as strabismus, corneal disease, conjunctivitis, and cataracts. Our understanding of blindness and amaurosis was hidden behind the seemingly impenetrable pupillary curtain.

In 1704, Jean Méry (Fig. 1) first described to the French Royal Academy of Sciences in Paris the retinal vessels in a living cat by immersing the animal in water [1]. In 1709, physicist Philippe de la Hire (Fig. 2) elucidated the optics of water's neutralization of the corneal curvature (Fig. 3) [1].

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Fig. 1 Jean Méry (Reproduced from Heitz [1]; with permission)

Fig. 2 Philippe de la Hire (Reproduced from Heitz [1]; with permission)

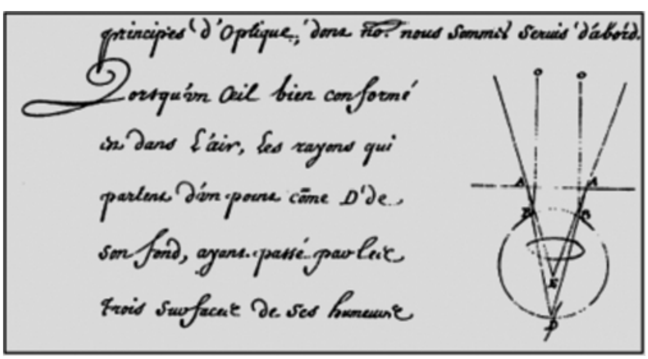

Fig. 3 The optics of water's neutralization of the corneal curvature (Reproduced from Heitz [1]; with permission)

However, it was Jan Evangista Purkinje (Fig. 4) who first described the principles of an ophthalmoscope in 1823 using the red reflex from a dog's eye (Figs. 5 and 6) [2, 3]. He had difficulty convincing clinicians to use the technique and his descriptions were lost for many years [2].

Fig. 4 Jan Evangiste Purkinje (Reproduced from Albert and Miller [2]; with permission)

Fig. 5 Jan Evangiste Purkinje's drawing of the "tree of the eye" (Reproduced from Albert and Miller [2]; with permission)

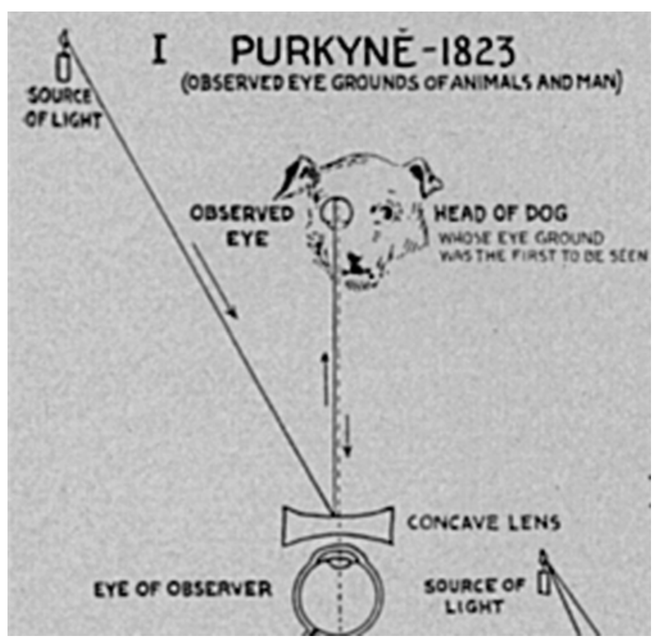

Fig. 6 Jan Evangiste Purkinje's optical description (Reproduced from Thau [3]; with permission)

Adolf Kussmaul, in 1845, recognizing the value of his predecessors' work, reproduced Méry's experiment and attempted to build his own ophthalmoscope but failed to produce a usable image [4]. In 1846, William Cumming used the light from a window to study the luminous internal reflecting membrane of the eye and made some intraocular diagnoses [5]. A year later, Charles Babbage (Fig. 7), the inventor of the computer, used a small silvered-glass to examine the retina (Fig. 8). Unfortunately, the ophthalmologist he consulted was unable to see a clear image and dismissed its potential value [6].

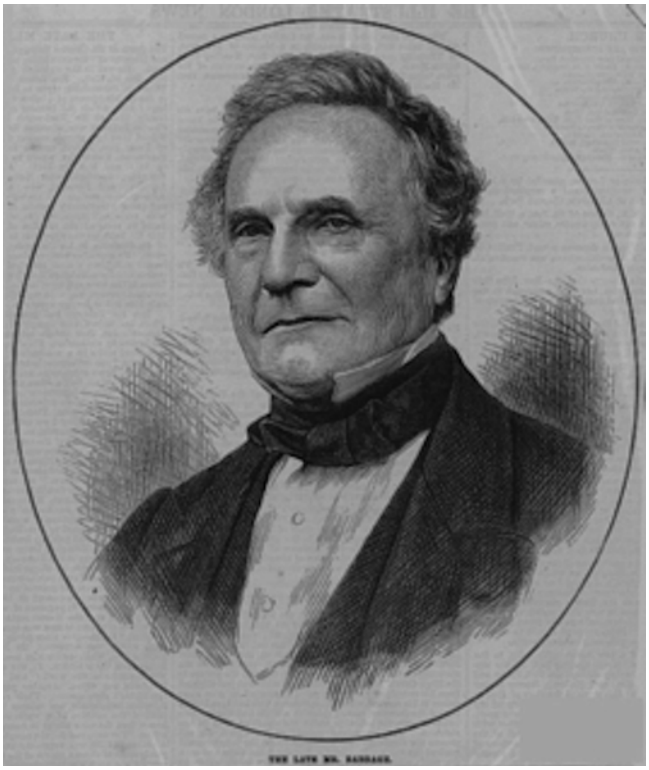

Fig. 7 Charles Babbage

Fig. 8 Babbage's ophthalmoscope (Courtesy of The College of Optometrists, London)

It was Hermann von Helmholtz (Fig. 9) in 1951 who was thus credited with producing the first direct ophthalmoscope (Figs. 10 and 11) [7]. Semi-reflecting mirrors illuminated the patient's fundus, and the reflected parallel light rays were focused on to the retina of the observer. A flurry of fundus discoveries quickly followed, including the presence of retinal tears and detachments in 1853 by Coccius, drusen and pigmentary retinopathy in 1854 by Donders, venous occlusions in 1855 by Leibreich, diabetic retinopathy in 1856 by Jaeger, arterial occlusions in 1859 by von Graeffe, and macular degenerations in 1874 by Hutchinson [8].

Fig. 9 Hermann von Helmholtz

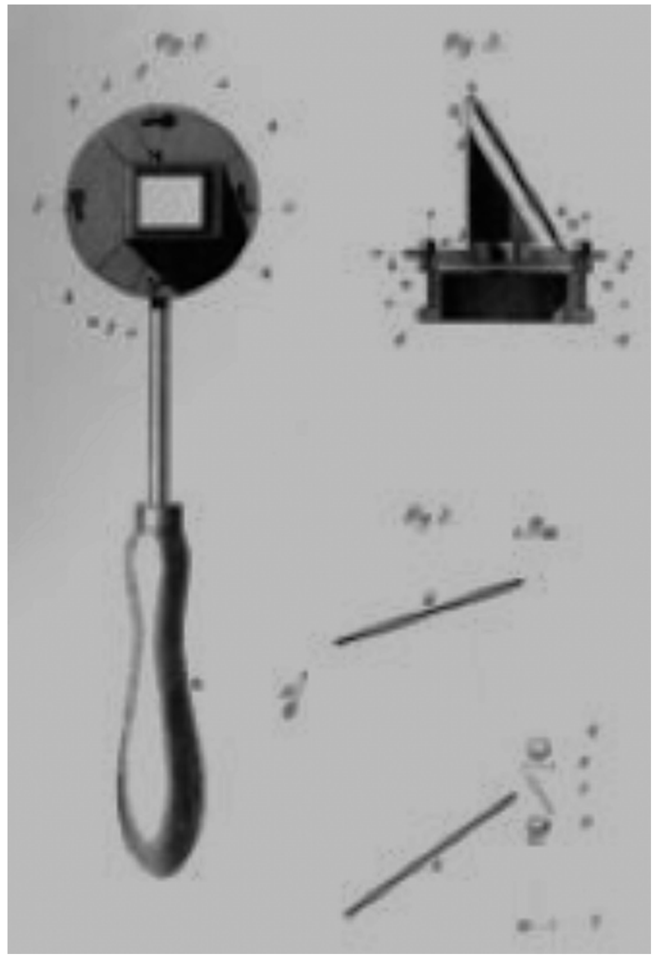

Fig. 10 Helmholtz's ophthalmoscope

Fig. 11 Helmholtz's ophthalmoscope (Web archive historical)

Theodor Ruete introduced the indirect ophthalmoscope (Fig. 12) in 1852, which gave him a much wider field of view [9]. Nearly a century later, Charles Schepens (Fig. 13) in 1945 fastened the light source to a head band, leaving the user's hands free to hold a condensing lens and a scleral depressor, making complete evaluation of the peripheral retina possible [10]. Surgical outcomes from retinal detachment repairs rapidly improved as the techniques of the binocular indirect ophthalmoscopic exams and fundus drawings gained popularity [4, 11].

Fig. 12 Ruete indirect ophthalmoscope (Web archive historical)

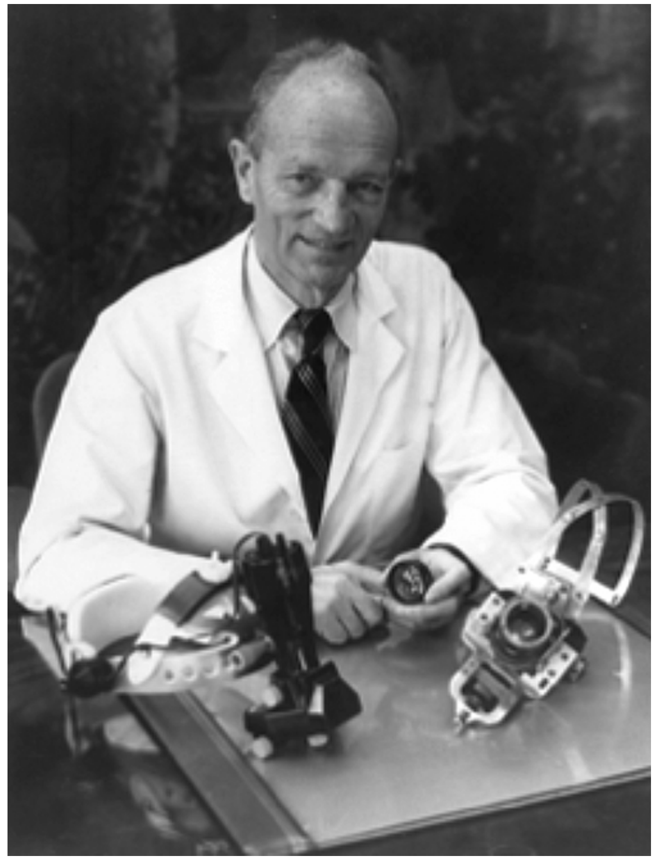

Fig. 13 Charles Scheppens with head-mounted binocular indirect ophthalmoscope (Courtesy of Schepens Eye Research Institute)

Photography was invented by Nicephore Niepce in 1823, and Louis Jacques Mande-Daguerre advanced the field with the introduction of the daguerreotype in 1839; however, the technology was still not sufficiently fast or portable enough to allow fundus photographs [12]. In 1851, Frederic Scott Archer improved the quality of images by coating glass plates with light-sensitive emulsions. While these plates had to be used wet, they were sensitive enough for Dr. Henry Noyes (Fig. 14) to photograph the first fundus of a living creature, a rabbit, in 1862. Later that year, Dr. Rosenbrugh obtained a retinal photograph of a cat. No pictorial records of these experiments remain, however, and it took another 20 years before Dr. Lucien Howe (Fig. 15) in 1885 produced the first photographic image of a human retina.

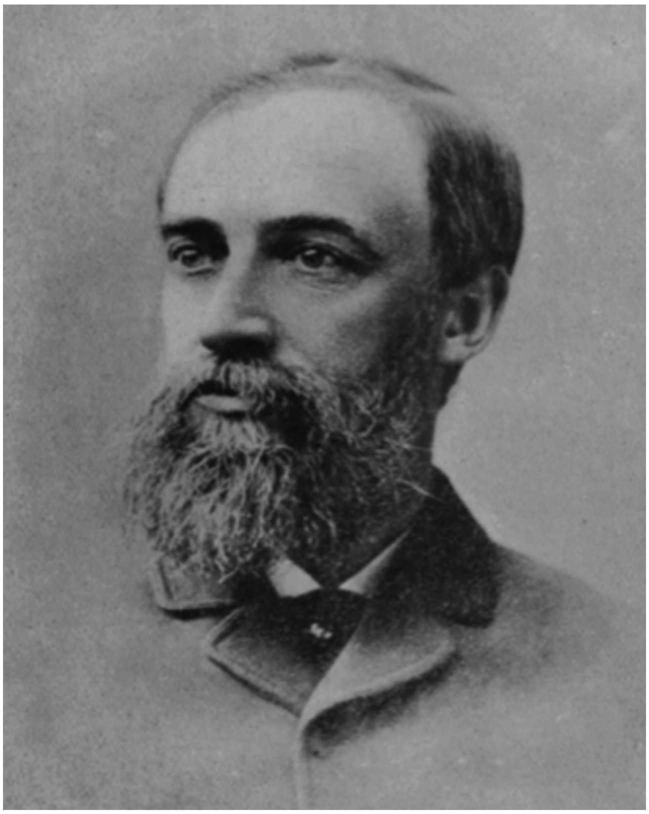

Fig. 14 Dr. Henry Noyes (From the American Ophthalmological Society; with permission)

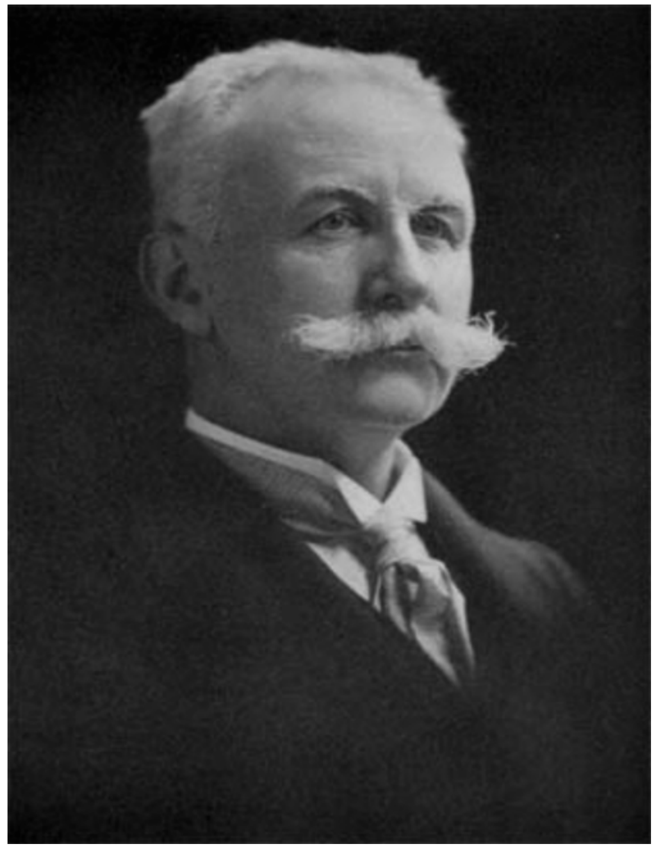

Fig. 15 Dr. Lucien Howe (Courtesy of the Museum of Vision and The American Academy of Ophthalmology)

Drs. Jackman and Webster were the first to publish an image in 1886 (Fig. 16). Although the 2.5-min exposure time and large central reflection artifact limited the detail that could be seen, the optic disc and some of the larger blood vessels could be appreciated (Fig. 17).

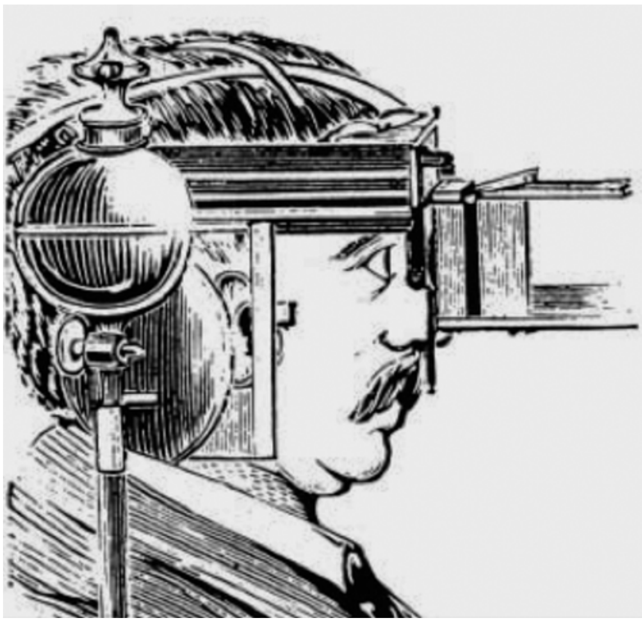

Fig. 16 Apparatus used to create the first published human fundus photograph. The light source was an albocarbon burner, and a 2.5-min exposure was required (Reproduced from Mark [13]; with permission)

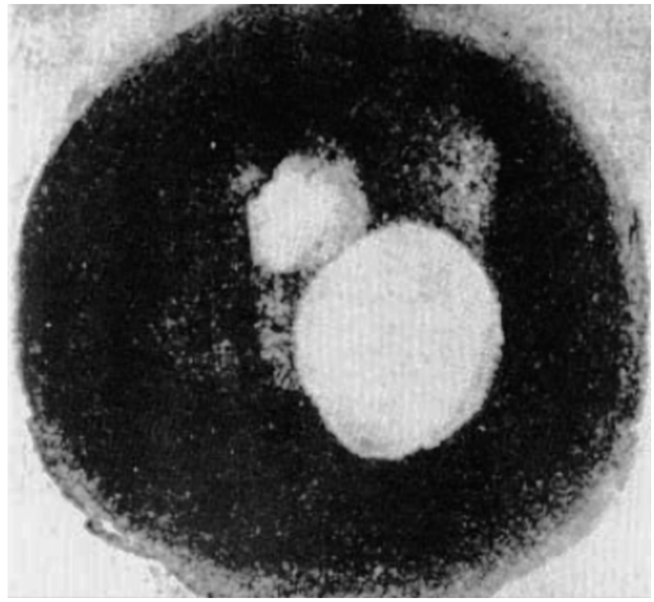

Fig. 17 First published fundus photo features a large light reflection artifact which all but obscures the blood vessels and optic nerve details (Reproduced from Mark [13]; with permission)

In 1891, Gerloff published a low-magnification retinal photograph (Fig. 18), which was much clearer than previous efforts [13, 14].

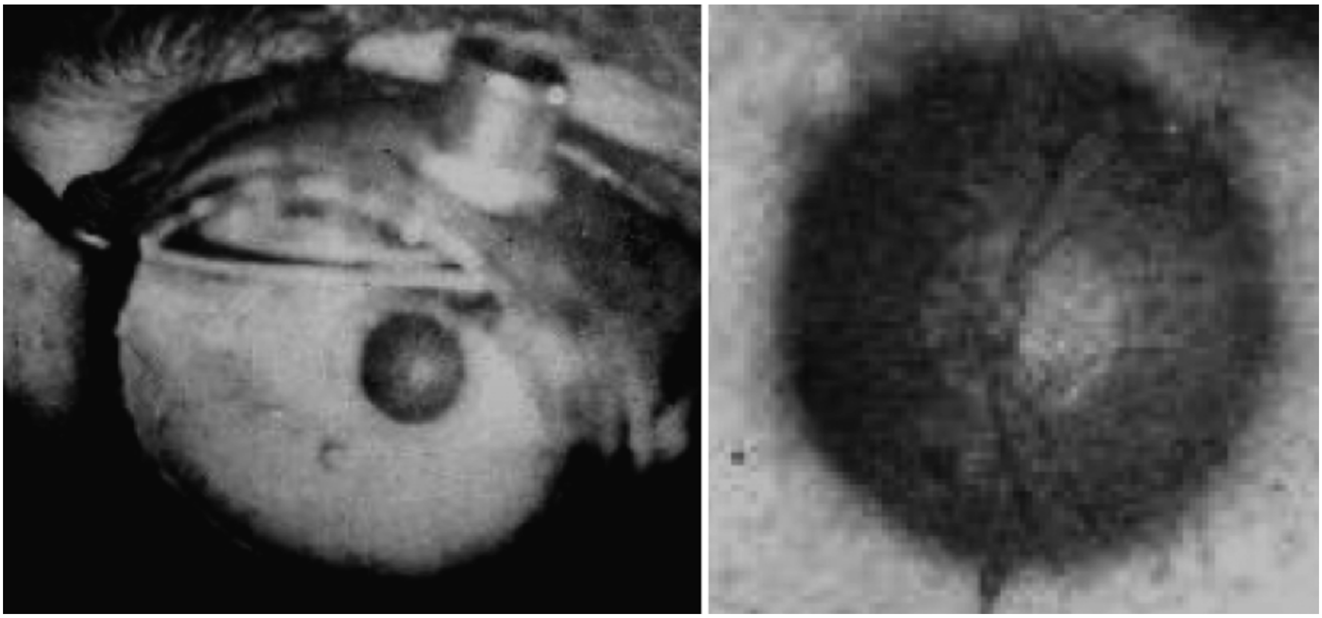

Fig. 18 Gerloff's fundus photograph (Reproduced from Gerloff [14]. Public domain)

Dr. Walter Thorner in 1899 developed an ophthalmoscope in conjunction with manufacturers F. Schmidt and Haensch in Berlin, which partially solved the reflex problem [15]. Thorner's ophthalmoscope later was attached to a camera, producing photographs with the artifact decentered inferiorly (Fig. 19).

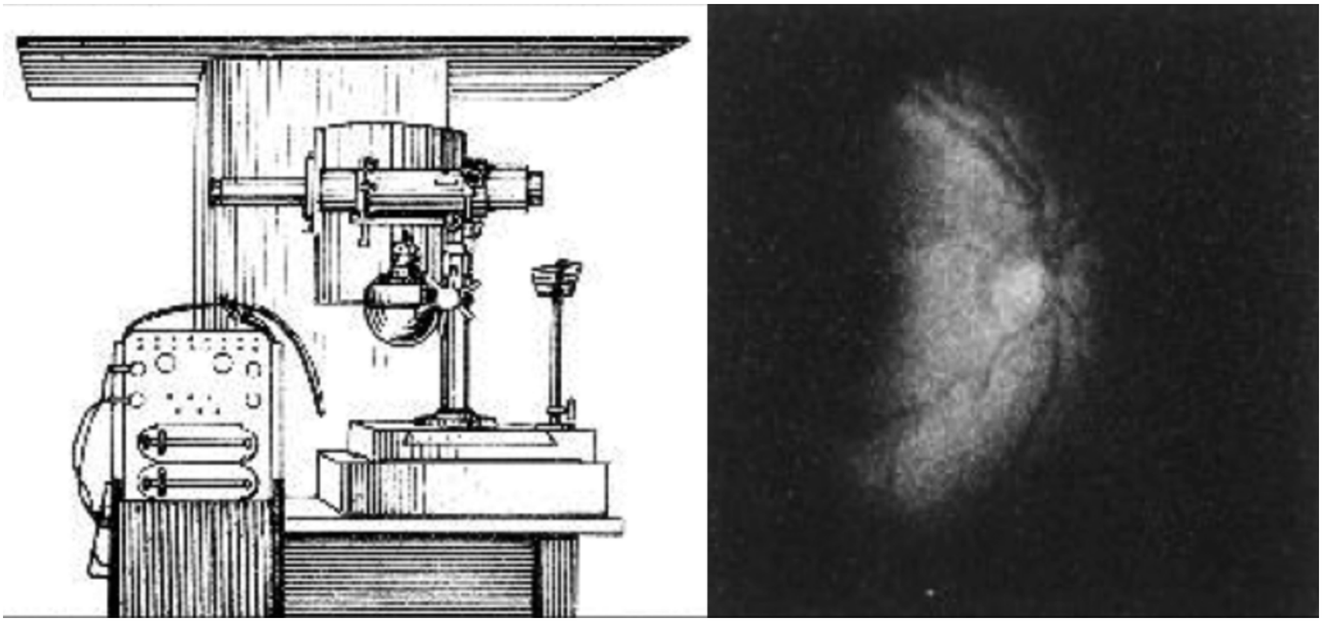

Fig. 19 Thorner's camera (*left*); Thorner's fundus images with good detail but uneven illumination (*right*) (Reproduced from Thorner [15]. Public domain)