2004 Report of the Belgian Ophthalmological Societies

The New Optics of the Human Eye

in the footsteps of the old masters from the
Low Countries, 1550 - 1950

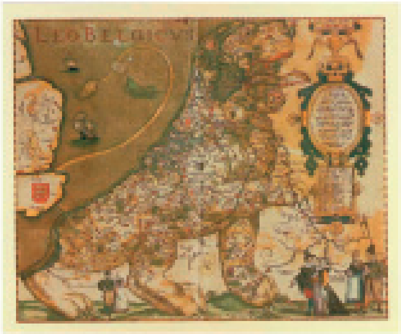

Andreas Vesalius
(1514-1564)


Simon Stevin
(1548-1620)


Hans Lippershey
(1570-1619)


Zacharias Janssen
(1580-1638)

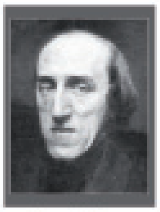

Willebrord Snell
(1581-1626)

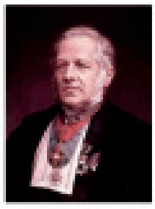


LEO BELGICUS


Christiaan Huygens
(1629-1695)


Antoni van Leeuwenhoek
(1632-1723)


Joseph Plateau
(1801-1883)


Christoph Buys Ballot
(1817-1890)


Frans Donders
(1818-1889)


Herman Snellen
(1834-1908)

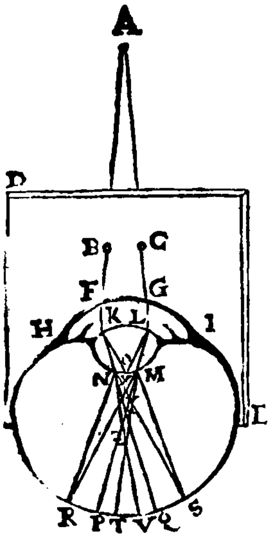

Frits Zernike
(1888-1966)

Saturday, November 27, 2004
Brussels, Belgium

Department of Ophthalmology
University of Antwerp
Belgium
Marie-José B. Tassignon

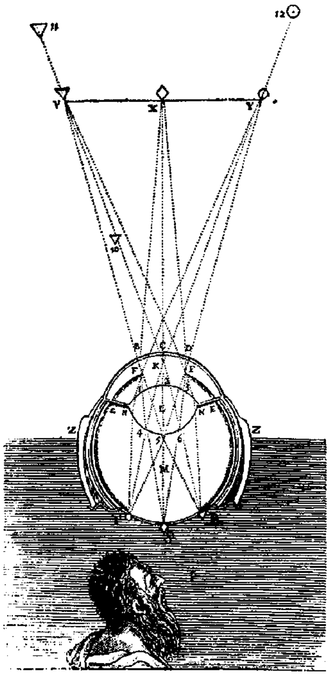
The Schepens Retina Associates
Foundation - Harvard
Boston MA
Frans J. Van de Velde

Illustrative Vignette 1



From Scheiner, C. - Oculus, hoc est fundamentum opticum ..., Agricola, Innsbruck, 1619. Scheiner's principle - parallel rays entering the eye should end up on the same retinal location when emmetropia is present - is the basis for refractometers and laser ray tracing techniques.

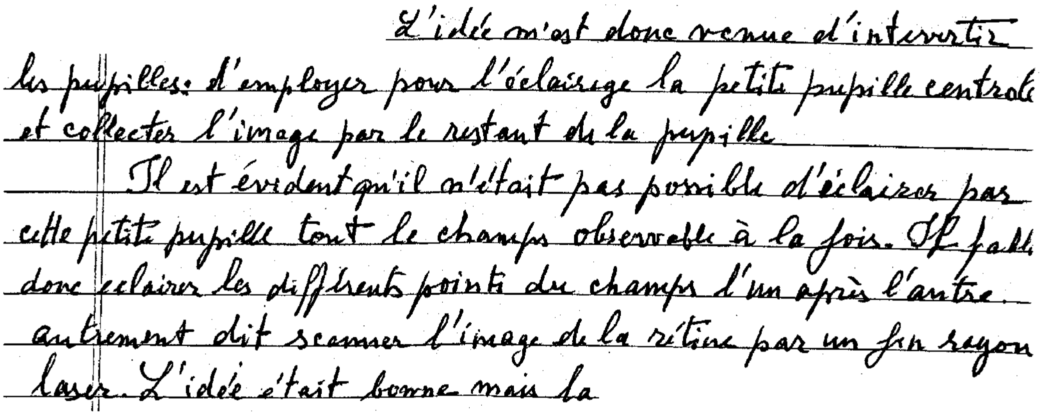
Illustrative Vignette 2



Scheiner's famous experiment of around 1610 (After a woodprint from a later work by Descartes). At this time Scheiner established that the retina was the seat of perception. The inverted image, a pseudo-problem, remained puzzling to Michelangelo.

A DEDICATION TO OLEG POMERANTZEFF, DIPL.ENG. (1910 - 1993)

Oleg Pomerantzeff was born in St. Petersbourg, Russia in 1910. His father died in 1917 and the family fled by boat from Batumi to Constantinople in 1921. Through Czechoslovakia - where he developed but recovered from rheumatoid arthritis - he reached Belgium. He was taken care of by the Institut St. Georges de Namur (sponsored by "La Libre Belgique") and finalized his high school training as a brilliant student at the Collège Nôtre-Dame de la Paix in Namur. At the school, he became the lifelong friend of Dr. Charles L. Schepens. He received a grant to study civil engineering at the University of Louvain in Belgium. As a civil mining engineer he worked in Yugoslavia and was active in the resistance during World War II. After having been imprisoned by the gestapo, he could make it to the southern part of France where he continued working for the underground movement. Some time after the war he left France for Brazil. In 1962, upon invitation of Dr. Charles Schepens, he joined the Retina Foundation in Boston, now called the Schepens Eye Research Institute, an affiliate of Harvard Medical School. This move coincided with the birth and early development of the laser. Oleg Pomerantzeff Dipl. Eng. immediately took a vivid interest in this new light source. He became a prolific inventor of diagnostic and therapeutic optical instruments. With Dr. Schepens, he further developed the small pupil binocular indirect ophthalmoscope. He was the first to use extensive computer ray tracing to obtain a considerably more accurate description of the complex optics of the eye. As mentor and collaborator he worked with many colleagues at the biophysics department of the Institute. He will be foremost remembered as an inventor of the first Scanning Laser Ophthalmoscope. He successfully formulated for the first time the three ingredients of the electronic ophthalmoscope: time-resolved imaging using a scanning laser with a small central illuminating pupil and much larger surrounding collecting exit pupil. This original design was enhanced with high-speed acousto-optic laser modulation by G. Hughes D.Sc. and co-inventor R. Webb Ph.D., enabling projection of graphics directly on the retina. Oleg Pomerantzeff, Dipl. Eng. died in Toulouse, France in 1993 as a result of the long term complication of his rheumatoid arthritis.



L'idée m'est donc venue d'intervertir
les pupilles: d'employer pour l'éclairage la petite pupille centrale
et collecter l'image par le restant de la pupille
Il est évident qu'il n'était pas possible d'éclairer par
cette petite pupille tout le champs observable à la fois. Il fall
donc éclairer les différents points du champs l'un après l'autre.
autrement dit scanner l'image de la rétine par un fin rayon
laser. L'idée était bonne mais la

Autobiographic handwriting (July 1990) of O. Pomerantzeff reciting the three principles for an electronic ophthalmoscope, invented early 1977.

Frans J. Van de Velde M.D.

PREFACE

During my tenure at the European Society for Cataract and Refractive Surgery (ESCRS), I have come to realize how often we take the physical underpinnings of our instrumentation for granted: this is the black box approach, more by necessity than by choice. The reason for this is a lack in proper course material at the undergraduate, graduate and post-graduate medical education level. We are indebted to the European Science Foundation for their grant support to start an ongoing diversified program in Biomedical Optics at our University. This report is one of the first steps in the endeavor. Understandably, biomedical optics is only one specialty field within the wide spectrum of vision science, however it is an important one for clinicians and researchers alike. And, admittedly, the material is often difficult to understand without proper knowledge of the mathematical and physical principles; but we hope that this topical volume will serve as an anchor for those who wish to explore in greater depth.
Much inspiration for our approach comes from the Schepens Retina Associates Foundation at Harvard. We would like to acknowledge our co-sponsor for their intellectual and material support.

Marie-José B. Tassignon, MD, PhD
Antwerp, November 2, 2004

Chair, Department of Ophthalmology, University of Antwerp, Belgium
President of the Belgisch Oftalmologisch Gezelschap
President European Society for Cataract and Refractive Surgery (ESCRS)

I am grateful to the Belgian Ophthalmological Societies for giving me a chance to look back over a period of nearly 60 years. In 1945 I had the first opportunity to speak about the binocular indirect ophthalmoscope at the Society's annual meeting. It is equally very satisfying to see a significant number of our Institute's alumni and current or former faculty members contribute to this report on the New Optics of the Human Eye. Since its founding in 1950, the Schepens Eye Research Institute and later the Schepens Retina Associates Foundation have been a place for MD, OD, PhD, and Dipl. Eng. degree holders to interact and as a result make significant progress in vision science. Biomedical optics and ophthalmic clinical engineering are continuing to make great advances, in particular because of the tremendous impact of photonics in just about every domain of biological science. This report is a testimony of this trend in diagnostic ophthalmic imaging and minimally-invasive laser therapies for retinal disease. Last but not least, it is a pleasure to see this symposium dedicated to my life-long friend Oleg Pomerantzeff, Dipl. Eng., a true pioneer in the field of ophthalmic optical engineering.

Charles L. Schepens, MD
Boston, Mass., November 15, 2004

The Schepens Retina Associates Foundation, Boston MA, USA
Emeritus Clinical Professor of Ophthalmology - Harvard University
Founder and President Emeritus of the Schepens Eye Research Institute

EDITORIAL

During the Renaissance, political and economical circumstances happened to be right for the Patria Belgica - a.k.a. the Netherlands or the Low Countries - to become a particularly fertile ground for researchers in optical physics (continuing to this day). Those well-known people are portrayed on the front page of this report. I strongly encourage the readers to ''google'' all their names and spend some time to find out more about their exciting life stories and fundamental contributions to optics and vision science. Andreas Vesalius from Brussels pioneered modern anatomy and Simon Stevin from Brugge put the use of the decimal system with Arabic numerals on a firm footing. Both men broke the ground for the science of physiological optics, for which the year 1619 of Christopher Scheiner's publication (see illustration and legend) can be regarded as a starting point.

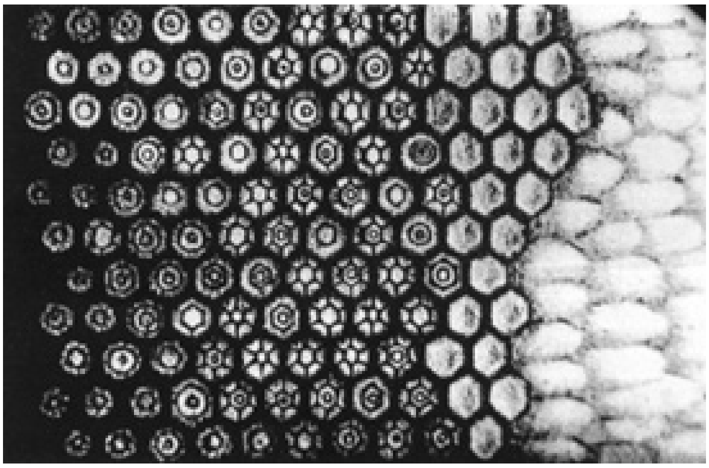
Knowledge in optics and its application to vision science then increased rapidly over time with two facts worth mentioning. Some well-known physicists were also capable physicians contributing to eye optics, notably Thomas Young and Hermann von Helmholtz. And secondly, a remarkable interaction was continuing between the sciences of astronomy, optical physics and visual optics. Some of the persons who contributed to this fruitful exchange either directly or indirectly are Christopher Scheiner himself, Isaac Newton, George Bidell Airy (the Astronomer Royal who was the first person to correct his own astigmatism and publish this feat), then Christian Doppler, James Clerk Maxwell and Albert Michelson. At present, Zernike polynomial analysis, Hartmann-Schack technology and stellar interferometry are some of the modern astronomical techniques used by the authors of this report.

I conveniently end the ''classical period'' of ophthalmic optics around 1950-1960 for some reasons. By that time our Frits Zernike had received his Nobel prize in physics, the last award issued for work in traditional optics. Secondly, by the 50s, Allvar Gullstrand (Nobel laureate of 1911), Hans Goldmann, Charles Schepens and others had put their definitive marks on classical in-vivo imaging equipment of the different eye structures. Thirdly, the advent of the computer, laser and post-WWII progress in electrical engineering during the 50s and early 60s made our modern non-invasive diagnostic equipment possible. We want to report here on the basic science aspects of some related applications of modern wave optics that are clinically very relevant. The last decade has witnessed again further development concurrent with advances in photonics. This topical volume of the Bulletin of the Belgian Societies of Ophthalmology will therefore also serve as a snapshot of what has been accomplished in ophthalmic optics around the turn of our century.

Frans J. Van de Velde, MD
Boston, Mass., November 15, 2004

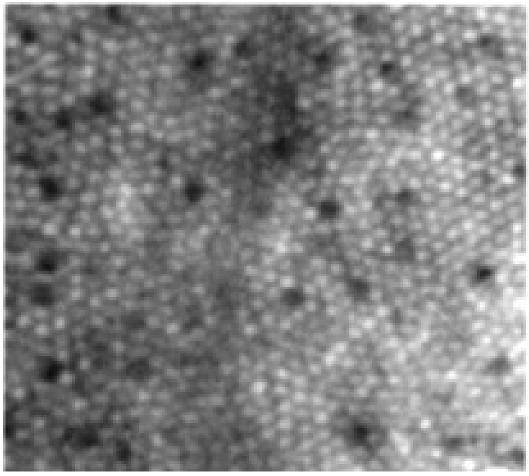
The Schepens Retina Associates Foundation, Boston MA, USA
The Schepens Eye Research Institute - Harvard University
The Department of Surgery - BIDMC - Harvard Medical School
The Department of Ophthalmology - University of Antwerp

Illustrative Vignette 3



Drawing of the frog's outer segments of photoreceptors, viewed end-on. This remarkable picture was obtained already in 1843 by Hannover (Hannover, A. - Vid. Sel. Naturv. Og Math. Sk. X, 1843). Notice the remarkable resemblance of the pattern with the image of present day laser mode guides (misinterpreted in 1848 as internal structures). See also Enoch, J. - Optical properties of the retinal receptors. JOSA, Vol. 53, pp. 71-81, 1963.

Illustrative Vignette 4



From Roorda, A., Williams, D.R. - The arrangement of the three cone classes in the living human eye. Nature, Vol. 397, pp. 520-522, 1999. This illustration shows the perifoveal photoreceptor mosaic and the sparse array of S cones, obtained in vivo using adaptive optics techniques. The mosaic puts an upper limit on the acuity resolution that can be obtained for any given pupil diameter (Sampling theorem of Shannon, Nyquist criterion). Such thinking was already present in the works of Bergman in 1857. (Bergmann, C. - Anatomisches und Physiologisches über die Netzhaut des Auges. Zeitschrift fur rationelle Medecin, Vol. 2, pp. 83-108, 1857)

IN MEMORIAM CHARLES L. SCHEPENS M.D.
BELGIUM, MARCH 13, 1912
MASSACHUSETTS, MARCH 28, 2006

Dr. Charles L. Schepens. An early model of the indirect binocular ophthalmoscope, invented by Dr. Schepens, was made part of the permanent collection of the Smithsonian Institution in Washington, D.C.

Dr. Charles L. Schepens, known as the father of modern retinal surgery, died on March 28, 2006, at the age of 94. He was a Clinical Professor of Ophthalmology, Emeritus, Harvard Medical School, where his patients and trainees established the Charles L. Schepens Professorship in Ophthalmology in 2001. His medical and scientific legacy will continue through the work of the Schepens Eye Research Institute and the Schepens Retina Associates Foundation in Boston, and live on in the hearts of thousands of grateful patients worldwide who would be blind today without his genius and skill.

A native of Belgium who emigrated to the United States in 1947, Dr. Schepens, from his youth, dedicated his entire life to the service of others. On March 21, 2006, he received the insignia of Knight of the Legion of Honor from the French Consul General in Boston. This award, established by Napoleon as the most prestigious French government medal, recognized both his lifelong contribution to advancements in the diagnosis and treatment of retinal diseases and his patriotic service to the resistance in World War II.

Dr. Schepens established the Retina Foundation in 1950 which evolved under his direction into two organizations that are currently called the Schepens Eye Research Institute and the Schepens Retina Associates Foundation. The Schepens Eye Research Institute is the largest independent eye research facility in the nation and is Harvard affiliated. The Schepens Retina Associates Foundation, where he has devoted his time for the last eight years, is dedicated to clinical eye research, teaching, and patient care. Dr. Schepens had a unique ability to communicate with his colleagues, trainees, and patients which inspired great confidence and loyalty. He is the founder of the Retina Society and Schepens International Society.

In a medical career that spanned 70 years, Dr. Schepens created numerous surgical innovations which have saved and will continue to save the sight of millions of adults and children suffering from retinal disorders. His scleral buckling procedure increased the chance of successfully reattaching a detached retina from approximately 40 percent to 90 percent.

One innovation, the binocular indirect ophthalmoscope, the instrument that first gained him international, renown, is now used the world over and is on permanent display in the Smithsonian Institute. His long life of accomplishment and innovation was enhanced and supported by the artistic talent of his wife who pioneered anatomically correct paintings of the fundus of the eye as first seen with the binocular indirect ophthalmoscope.

Over the years, Dr. Schepens and his team of scientists advanced laser surgery, and pioneered equipment such as the Laser Doppler Flowmeter and Scanning Laser Ophthalmoscope. Dr. Schepens trained several generations of retinal specialists, now practicing throughout the world. He has published over 390 scientific papers and four books on retinal diseases.

Over the years, Dr. Schepens has received countless awards. In 1999, he was voted one of ”The 10 Most Influential Ophthalmologists of the Twentieth Century” by the American Society of

Cataract and Refractive Surgery. In 2003, the American Academy of Ophthalmology named him one of only three laureates. The Laureate Recognition Award is the Academy's highest honor and is awarded to those individuals who have made the most significant contributions to the science of ophthalmology.

Dr. Schepens leaves his wife, Marie (Vander Eecken) and is the father of Claire Delori, Luc and his wife, Hester Garfield, Bernadette and her husband Thomas S. K. Butler, Catherine and her husband Andres Rojas. He is the grandfather of Henriette, Caroline, Augustin, Charles, Marc, Alexandra, Alicia, Clarence and has 5 great grandchildren.

Dr. Charles L. Schepens with Dr. Susana Marcos and 32 day old daughter Silvia, at the meeting

MAJOR HONORS AND AWARDS

- Croix de Guerre, France
- Order of Merit of the Italian Republic, Honorific Commendatore
- Order of the Rising Sun, Japan
- Legion of Honor Award by the Government of France
- Commandeur de l'Ordre de Leopold, Belgium
- Golden Door Award, Boston, MA, USA
- American Academy of Ophthalmology, Jackson Memorial Lecture
- An early model of the indirect binocular ophthalmoscope, invented by Dr. Schepens, was made part of the permanent collection of the Smithsonian Institution in Washington, D.C.
- Mildred Weisenfeld Award for Excellence in Ophthalmology
- Award by the American Society of Cataract and Refractive Surgery – One of the Ten Most Influential Ophthalmologists of the Twentieth Century
- Corresponding Member and Honorary Foreign Member of the Royal Academy of Medicine, Belgium
- Laureate Award, American Academy of Ophthalmology

Respectfully submitted on behalf of the Schepens Retina Associates Foundation,
J. W. McMeel, M.D., President *Frans J. Van de Velde M.D.*

REPRINTS OF THE PAPERS OF
CHARLES L. SCHEPENS M.D.
READ BEFORE THE
BELGIAN OPHTHALMOLOGICAL SOCIETY
CONCERNING THE OPHTHALMOSCOPE
1945 - 1996

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(1) SCHEPENS C.L. - Un nouvel ophtalmoscope binoculaire pour l'examen du décollement de la rétine.
Bull Soc belge Ophtalmol 1945; 82: 9-13

(2) SCHEPENS C.L. - The development of ophthalmoscopy.
Bull Soc belge Ophtalmol 1997; 262: 21-24

Extrait du *Bulletin de la Société Belge d'Ophtalmologie*, n° 82, 1945.

M. C. L. SCHEPENS : **Un nouvel ophtalmoscope binoculaire pour l'examen du décollement de la rétine. (Avec projection d'un film sonore.)**

La présente publication est le résultat des premières recherches que nous avons exécutées pendant la guerre, à l'hôpital Moorfields (Londres). Nous remercions le Professeur I. Mann, les Docteurs F. Juler, M. Whiting, P.G. Doyne et F. Law, pour leurs conseils et leur patiente assistance. Grâce à eux, nous avons pu acquérir en peu de temps une expérience considérable dans l'examen des décollements rétiniens.

L'appareil démontré dans le film est un ophtalmoscope à image renversée. Il a été construit entièrement par l'auteur, avec des moyens de fortune, dans les circonstances difficiles de la guerre. Il se compose de deux parties essentielles : le système éclairant et le système d'observation.

Le système éclairant repose sur un pied, pourvu d'une large base quadrangulaire, à la fois stable et mobile. Le sommet du pied est muni d'un dispositif spécial à l'extrémité duquel se monte le système éclairant lui-même. Celui-ci comprend une lampe de bas voltage, munie d'un condensateur optique très puissant. Un miroir réfléchit le faisceau lumineux. Un filtre anérythre amovible permet l'observation en lumière privée de rayons rouges. Ce procédé donne quelquefois une meilleure vue de la rétine décollée. Sous le miroir se trouve une fenêtre, à travers laquelle s'observe l'image ophtalmoscopique. Pour faire de l'ophtalmoscopie monoculaire, on regarde, à l'œil nu, à travers cette fenêtre.

Nous recommandons plutôt la méthode binoculaire au moyen d'un système d'observation un peu particulier. Il est fait d'un métal ultra-léger et se fixe sur la tête du médecin. A sa partie antérieure, se trouve un jeu de lentilles, dont l'usage permet à l'observateur de s'approcher davantage de l'image ophtalmoscopique, ce qui en augmente les dimensions apparentes et la luminosité. Le carter du casque abrite quatre prismes à réflexion totale. Un petit levier fait pivoter l'un des prismes, ce qui permet de modifier le degré de convergence.

Le système d'observation se glisse aisément devant des verres correcteurs. Il est conseillé de corriger la presbytie lors de son usage.

Pour faire de l'ophtalmoscopie binoculaire avec cet appareil ,on règle d'abord le levier de convergence pour une distance d'environ vingt-cinq centimètres. La suite du procédé est identique à celle qu'on utilise pour l'ophtalmoscopie monoculaire. La main gauche tient devant l'œil du malade une lentille ophtalmoscopique ordinaire. La main droite saisit le système éclairant et l'oriente dans la direction désirée. La maniabilité de l'instrument est très grande. Le principal avantage qui en résulte, c'est de permettre de dessiner le fond de l'œil d'une façon continue et sans cesser d'observer la région dessinée. Ce procédé est rapide et précis. Il demande peu de mémoire visuelle. Dans la méthode de Weve au contraire, l'observateur est forcé de déposer son opthalmoscope chaque fois qu'il veut s'emparer d'un crayon, procédé plus lent, plus imprécis, et qui exige beaucoup de mémoire visuelle.

Le meilleur moyen de démontrer les autres avantages que présente l'usage de cet ophtalmoscope est de le comparer à la méthode de Weve. Jusqu'à présent, cette dernière était sans contredit la meilleure qui fut pour l'examen des décollements rétiniens.

La lampe de Weve, munie d'une ampoule Nitra de 500 Watts, fournit un faisceau divergent dont une petite partie seulement est captée par le miroir ophtalmoscopique. L'intensité du faisceau de lumière qui entre dans la lentille ophtalmoscopique est d'environ 900 Lux. Avec notre appareil par contre, elle est de 2.000 Lux.

La divergence du faisceau lumineux de Weve présente deux grands inconvénients. D'abord cela éblouit fortement l'œil gauche. Ensuite, il en résulte des reflets gênants, qui forcent le médecin à se débarrasser de sa blouse blanche. Dans le nouvel appareil, le faisceau lumineux est fortement concentré et il n'y a pas de lumière perdue. Par conséquent, l'œil gauche n'est jamais ébloui et les reflets provenant de l'éclairement d'objets avoisinants sont inexistants.

L'intensité lumineuse utilisée est telle, qu'il n'est pas du tout nécessaire de faire l'obscurité pour procéder à l'examen du fond de l'œil.

Les 500 Watts de la lampe de Weve dégagent une forte chaleur, qui souvent incommode à la fois le médecin et le malade.

Les 24 Watts de la nouvelle lampe n'occasionnent que fort peu de chauffage, ce qui nous a permis de faire un appareil très compact.

Lorsqu'on pratique l'examen d'un malade couché, la méthode de Weve exige la présence d'un aide qui tienne la lampe et l'oriente dans la direction voulue. Le poids de la lampe, allié à la chaleur dégagée, rendent souvent le rôle de cet aide pénible. Le nouvel appareil évite cet inconvénient.

Nous pensons que ce nouvel ophtalmoscope constitue un heureux appoint comme instrument de diagnostic en cas de décollement rétinien. C'est un bon outil pour « la chasse à la déchirure ». Grâce à celu-ci, on peut scruter avec un minimum de fatigue tout le dôme rétinien, millimètre carré par millimètre carré. Il permet de vaincre plus aisément les divers obstacles qui gênent la bonne observation d'un décollement. En premier lieu sa puissance lumineuse permet de mieux voir lorsque les milieux transparents sont troubles. En deuxième lieu cette puissance lumineuse facilite l'examen de la périphérie. Dans cette région en effet, les milieux transparents sont presque toujours moins clairs. Le faisceau lumineux y entre très obliquement et en sort de même, d'où des pertes de lumière considérables. En troisième lieu nous l'avons trouvé utile en cas d'hésitation entre un diagnostic de décollement par tumeur et de décollement idiopathique. S'il s'agit d'une tumeur débutante, nous nous fions davantage à l'ophtalmoscopie avec le nouvel appareil qu'au résultat de la transillumination. On oublie quelquefois en effet, qu'en présence d'un néoplasme naissant, la transillumination est très souvent douteuse ou négative.

Enfin le dernier avantage du nouvel ophtalmoscope, c'est qu'il permet l'observation binoculaire de tout le fond de l'œil y compris l'extrême périphérie. La perception exacte des différents plans dans lesquels se trouvent les structures observées, est d'une importance capitale dans le décollement rétinien. On sait que le parallaxe ne fournit pas toujours des indications précises à cet égard, surtout lorsqu'il s'agit de la périphérie. L'examen binoculaire de la région comprise entre l'équateur et l'ora, à l'aide d'un appareil très maniable, n'est pas dépourvu d'intérêt. Notons que cet examen est plus aisé en position couchée qu'en position assise.

Les appareils mentionnés ci-dessus ne constituent qu'un premier modèle. Divers perfectionnements, visant notamment à accroître encore leur maniabilité et leur puissance d'éclairage, sont à l'étude. Les résultats de ces nouvelles recherches seront publiés ultérieurement dans le *Britsh Journal of Ophtalmology*.

Still video image taken from Dr. Schepens' 1945 cine film illustrating the lamp of Weve held by the assistant nurse, and simple concave mirror ophthalmoscope (courtesy Frans J. Van de Velde M.D.)

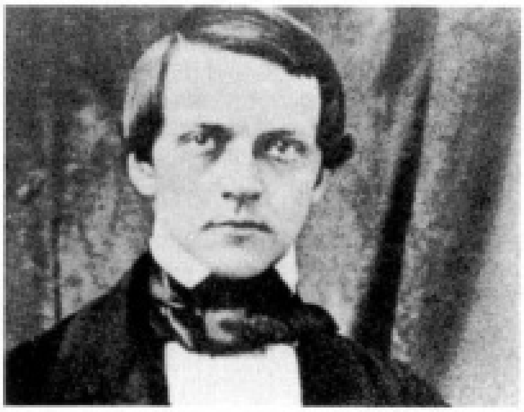
The new indirect binocular ophthalmoscope with efficient light source (courtesy Frans J. Van de Velde M.D.)

THE DEVELOPMENT OF OPHTHALMOSCOPY

Charles L. SCHEPENS, M.D.

The history of ophthalmoscopy probably started in 1704. Méry (1) was the first to see the retina in a living animal, thanks to the fact that a drowning cat's pupils did dilate. This observation was made possible because the water surface was neutralizing the cat's corneal refraction. However, Méry did not realize that what the saw was in fact the animal's retina. The phenomenon was explained five years later, by de la Hire (2). The next step was made by several European investigators who, in the first half of the nineteeth century, developed the technique to study the red reflex of the fundus, without seeing the retina in focus.

In the fall of 1851, Herman von Helmholtz (Fig. 1), a thirty year old medical doctor and physiologist, published the optical principle of ophthalmoscopy (3). He built a direct ophthalmoscope that used 3 or 4 layers of thin glass to reflect the light through the patient's pupil (Fig. 2). He could see the fundus by looking through the layers of thin glass. It only took Helmholtz a few weeks to construct a working instrument. At the time, several ophthalmologists did not think much of the invention. One famous surgeon told him that he had no use for the new instrument, because he felt it was dangerous to admit naked light in a patient's eye. Another thought that the instrument might be useful for ophthalmologists whose vision was defective. He had excellent vision and had no need for it. However the ophthalmoscope was received with enthusiasm by many and, within 3 weeks, Helmholtz's machine maker received orders for 18 instruments (4). The popularity of ophthalmoscopy grew from year to year. In 1852, Ruete (5) described the indirect ophthalmoscope and in 1861, Giraud-Teulon (6) constructed a binocular indirect ophthalmoscope. During the 29 years that followed its in-



Hermann von Helmholtz (1821-1899) four years before his invention of direct ophthalmoscope.

Helmholtz's direct ophthalmoscope (1851). Candle light was reflected into patient's eye by multiple layers of thin glass. Observer saw fundus by looking through layers of glass. Observer's vision was corrected by inserting lenses into instrument.

Bull. Soc. belge Ophtalmol., **262**, 21-24, 1997.

Fig 3. Allvar Gullstrand (1862-1930), inventor of reflexless indirect ophthalmoscopy and slit lamp.

Fig 4. Binocular indirect headband ophthalmoscope built in Brussels.

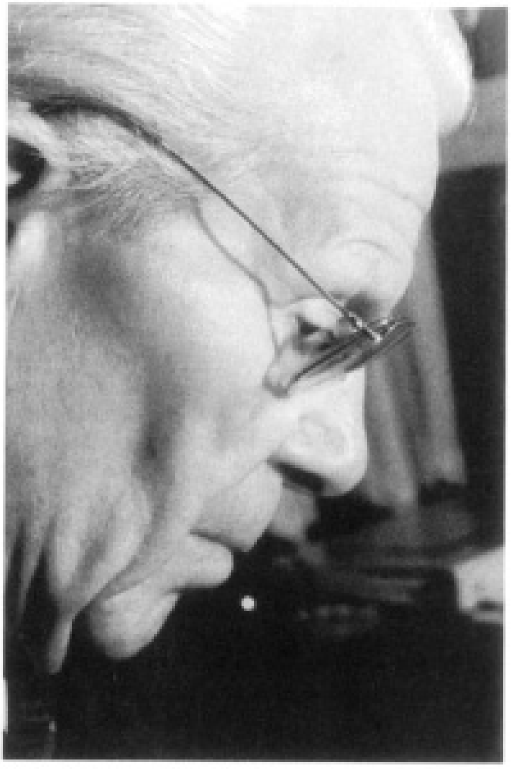


Fig 5. Oleg Pomerantzeff (1910-1993), inventor of scanning laser ophthalmoscope.

vention (1851-1880), no less than 78 models of the instrument were described.

Up to that time, the light used for the ophthalmoscopy was either candle light or an oil lamp. In 1886 Juler, an English ophthalmologist, described the first electric ophthalmoscope (7). It is in 1911 that Gullstrand (Fig. 3) described the technique to perform reflexless ophthalmoscopy (8). The following year he also described the slit lamp, which made it possible to perform slit lamp microscopy of the retina (9).

The binocular indirect ophthalmoscope of Giraud-Teulon was never used much. An instrument that was easier to use and had a more powerful light source was constructed by the author, thanks to the support of a Moorfields Hospital Scholarship (1943-1944). This was when London was being bombed regularly. All optical parts and copper or aluminum supplies were strictly reserved for the war effort. How-

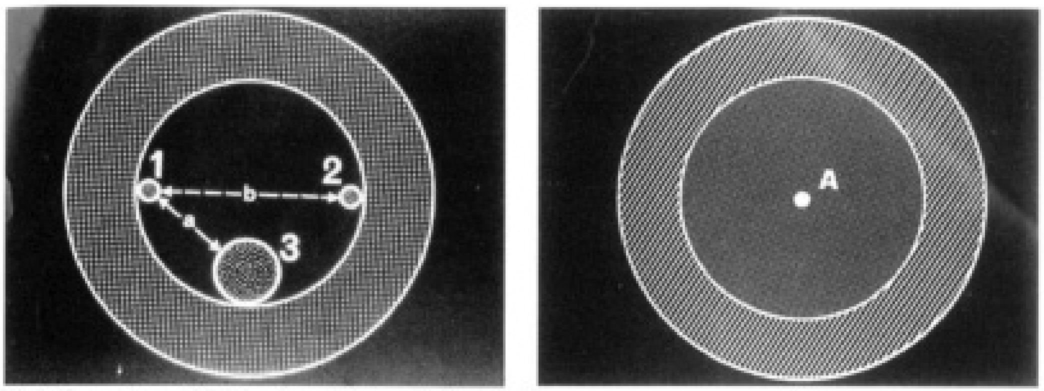


Fig 6. Comparison of Gullstrand's and Pomerantzeff's principle.
Left, small images of observer's pupils (1 and 2) need to be imaged in patient's pupil. Distance (b) determines degree of stereopsis.
Light beam (3) must be separated from images of observer's pupils by distance (a).
Right, incoming laser beam is scanned in patient's fundus and occupies very small area of patient's pupil (A). Ophthalmoscopic image is made by collecting nearly all light passing through patient's pupil.

ever I was able to obtain the necessary parts in the rubble of the bombed out hospital. The instrument was perfected in Brussels after the war (Fig. 4). It was demonstrated to the Belgian Society of Ophthalmology in 1945 (10) and was described at the American Academy of Ophthalmology and Otolaryngology in 1947 (11).

The second half of this century witnessed an amazing development in the field of ophthalmoscopy. Oleg Pomerantzeff (1910-1983) was the inventor and the mover (Fig. 5). He graduated in 1935 as a mining engineer, manufacturing engineer and construction engineer from the Louvain University. He was over 50 years old when he became a specialist in optics. In spite of his late start he optimized the binocular indirect ophthalmoscope into a very versatile instrument (12). He also developed a reflexless camera with a field of 63 degrees measured at the eye's nodal point. With a contact lens one could see 90 degrees measured at the nodal point, without reflections (13). Then he developed a fundus camera that could encompass 148 degrees measured at the nodal point (203 degrees measured at the center of the globe) (14). His crowning achievement was the discovery of a new principle of ophthalmoscopy. Up to 1968, all indirect ophthalmoscopes were built according to Gullstrand's principle. Two things were required to see the fundus. First the observer's pupils had to be imaged in the patient's pupil. These images are about 0.5 mm. in diameter. Second, a clear separation must exist, in the patient's pupil, between the illuminating beam and the images of the observer's pupils. Of the light reflected from the patient's fundus, the only light that reaches the observer's retinas is that which passes through the tiny images of his pupils, located in the patient's pupils (Fig. 6, left).

Fig 7. Scanning laser ophthalmoscope being used by its constructor, Rob Web.

In Pomerantzeff's principle (Fig 6, right) the beam that illuminates the fundus only occupies a very small area of the patient's pupil. This beam is scanned 30 to 50 times a second over the area of fundus to be observed. Nearly all the light that is reflected from the patient's

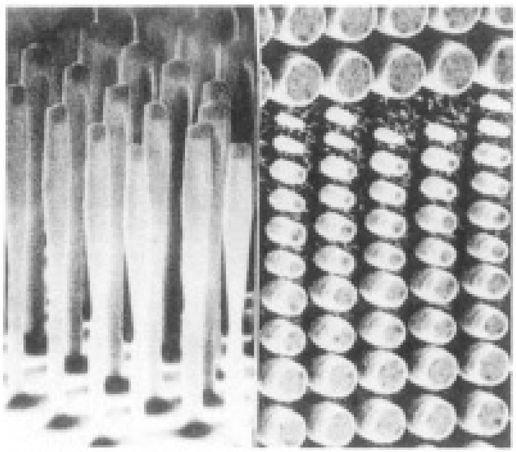


Fig 8. Array of microlasers (few microns in size) will serve to develop "pocket size" scanning laser ophthalmoscope. They can be constructed as small as one micron in diameter.
Left, microlasers viewed in profile. Right, microlasers viewed from top.

fundus and exits through his pupil is used to form the fundus image on a television screen. This discovery (15) permitted the development of the scanning laser ophthalmoscope (Fig. 7). No image of the fundus is formed except on the television screen. Since much more light is reflected from the fundus than with Gullstrand's technique, it is not necessary to dilate the patient's pupil.

The scanning laser ophthalmoscope is much more than an ophthalmoscope. It permits to record an immediate movie of the fundus and to replay it at will. The fundus of a patient can easily be demonstrated to a group of observers. It allows to do a movie of fluorescein or of indocyanine angiography. It lends itself to perform accurate and quantitative microperimetry of the macular area. Finally, one can measure accurately the visual acuity from any selected extrafoveal location.

In the near future very accurate laser *treatment* will be possible with the scanning laser ophthalmoscope. Within a few years it will be possible to miniaturize the scanning laser ophthalmoscope into an instrument that fits in one's pocket. For this purpose, an array of microscopic laser sources, a few microns in size, will be used (Fig. 8).

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THE NEW OPTICS OF THE HUMAN EYE

Program of Saturday, November 27, 2004

08.25 - 08.30 **Marie-José Tassignon, MD, PhD,** Chair Department of Ophthalmology, University of Antwerp, Belgium. Prologue

Scanning Laser Ophthalmoscopy, Therapy, and Polarimetry

08.30 - 08.45 **Frans J. Van de Velde, MD,** Department of Ophthalmology, University of Antwerp, Belgium and the Schepens Retina Associates Foundation - Harvard, Boston MA
The relaxed confocal Scanning Laser Ophthalmoscope, development and applications

08.45 - 09.05 **Ralf Brinkmann, PhD,** Medizinisches Laserzentrum Lübeck, Germany
Short pulse selective retinal photocoagulation - concept of relaxation time, anatomical effects and non-invasive retinal temperature measurements

09.05 - 09.20 **Xiang Run Huang, PhD,** Bascom Palmer Eye Institute, Miami, FL
Birefringence of the nerve fiber layer with scanning laser polarimetry, origins, significance

09.20 - 09.35 **Qienyuan Zhou, PhD,** Laser Diagnostic Technologies, San Diego, CA
Scanning Laser Polarimetry, corneal birefringence and a method for controlling this parameter

Optical Coherence Tomography and Combined Doppler, OCT-SLO

09.35 - 09.55 **Johannes de Boer, PhD,** Wellman Laboratories, Harvard University, Boston, MA
Spectral domain OCT

09.55 - 10.10 **Johannes de Boer, PhD,** Wellman Laboratories, Harvard University, Boston, MA
Polarization - sensitive OCT of the Retina

10.10 - 10.25 **Adrian Podoleanu, PhD,** University of Kent Canterbury, United Kingdom
Combining SLO and OCT technology

10.25 - 10.40 **Christoph Hitzenberger, PhD,** Department of Medical Physics, University of Vienna, Vienna, Austria
Birefringence properties of the cornea measured with OCT

Doppler Metrology

10.40 - 11.00 **Gilbert Feke, PhD,** Schepens Retina Associates Foundation, Harvard, Boston, MA
Laser Doppler instrumentation for the measurement of blood flow: theory and practice

11.00 - 11.15 **Charles Riva, DSc,** Institut de Recherche en Ophtalmologie, Sion, Switzerland
Measuring the choroidal blood flow in the foveal region

Wavefront Metrology and Photoreceptor Optics

11.15 - 11.35 **Susana Marcos, PhD,** Instituto de Óptica CSIC, Madrid, Spain
Aberrometry: basic science and clinical applications, part I

11.35 - 11.45 **Susana Marcos, PhD,** Instituto de Óptica CSIC, Madrid, Spain
Aberrometry: basic science and clinical applications, part II

11.45 - 12.00 **Jean-Marie Gorrand, PhD,** Faculté de Médecine et de Pharmacie, Clermont-Ferrand, France
Origin and Measurement of the Stiles-Crawford effects, distribution of orientation in a population

12.00 - 12.15 **Austin Roorda, PhD,** College of Optometry, University of Houston, Houston, TX
Adaptive optics, Hartmann-Shack technology and the photoreceptor mosaic

12.15 - 12.20 **Charles L. Schepens, MD,** the Schepens Retina Associates Foundation of Harvard University, Boston MA. Epilogue

ACKNOWLEDGEMENTS

This meeting is organized by the Department of Ophthalmology, University of Antwerp, Belgium, and the Schepens Retina Associates Foundation, Boston, MA under the auspices of the Belgian Ophthalmological Society. Co-conveners of the meeting are Prof. Dr. Marie-José Tassignon and Dr. Frans J. Van de Velde. The fourteen papers in this volume of the Bull Soc belge Ophtalmol ''2004 Report of the Belgian Ophthalmological Society - The New Optics of the Human Eye'' constitute the proceedings of the meeting. The ''Leo Belgicus'' image is courtesy of the Plantijn-Moretus Museum, Frits Zernike's image is courtesy of the Nobel Foundation.

The mission of the Schepens Retina Associates Foundation for Clinical Research is to improve the vision of patients affected with diseases of the eye, particularly those of the retina and vitreous. They will carry out their mission by reaching three goals. The first is clinical eye research carried out with a view to discover new methods and techniques to prevent, diagnose, and treat eye diseases and malformations. The second goal is to treat patients suffering from eye diseases, particularly those of the retina and vitreous. The third goal is to teach methods and techiques newly developed to ophthalmologists and vision care specialists all over the world. These activities are conducted in conjunction with Harvard Medical School, the Schepens Eye Research Institute, the Massachusetts Eye and Ear Infirmery, and the Department of Surgery of the Beth Israel Deaconess Medical Center at Harvard Medical School. *www.schepensretina.org*

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