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SIBYLLE K. SCHOLTZ, GERD U. AUFFARTH

1911 — An Ophthalmologist Won the Nobel Price: Allvar Gullstrand, Surgeon, Mathematician and Creative Inventor

1911 — Okulista zdobył nagrodę Nobla: Allvar Gullstrand chirurg, matematyk i wynalazca

International Vision Correction Research Centre (IVCRC), Dept. of Ophthalmology University of Heidelberg

Summary
Allvar Gullstrand (1862–1930) provided outstanding contribution to theoretical optics as well as carried out fundamental research on the mathematical and physical properties of the human eye. Furthermore he invented several important devices used in ophthalmology, e.g. the slit lamp. Gullstrand's research offered detailed scientific facts of the eye as well as he invented several diagnostic devices for ophthalmology which further developments are still the standard diagnostic tools in ophthalmology today. The information which is provided by the "Gullstrand eye" and "Gullstrand Formula" is still regarded as Gold Standard.

This article is to honour Gullstrand's life and contribution to ophthalmology and science due to the 100th anniversary of receiving the Nobel Prize in 2011.

Keywords: history, Allvar Gullstrand, Nobel Price, 1911

Streszczenie
Allvar Gullstrand (1862–1930) wniósł niezwykły wkład w rozwój teoretycznej optyki, jak również wykonał podstawowe badania nad matematycznymi i fizycznymi właściwościami oka ludzkiego. Wynalazł m.in. lampę szczelinową. Badania Gullstranda wzbogaciły wiedzę na temat budowy oka o liczne naukowo potwierdzone dane. Naukowiec wynalazł wiele diagnostycznych urządzeń dla okulistyki, które po unowocześnieniach są nadal podstawowymi urządzeniami diagnostycznymi we współczesnej okulistyce. Informacje zawarte w „Gullstrand eye" i w „Gullstrand formula" są nadal uważane za złoty standard.

Artykuł ten powstał w celu uhonorowania życia Gullstranda i jego wkładu w rozwój okulistyki i nauki w setną rocznicę zdobycia Nagrody Nobla, przypadającą w 2011 roku.

Słowa kluczowe: historia, Allvar Gullstrand, Nagroda Nobla, 1911

Introduction

Allvar Gullstrand (1862–1930) was neither a specialist in geometrical optics, nor was he mathematician. He provided extreme valuable contribution to theoretical optics as well as carried out fundamental research on the mathematical and physical properties of the human eye. Gullstrand's research offered detailed scientific facts of the human eye which set the scientific basis for ophthalmology. Gullstrand determined the optical laws of imaging in the eye for the first time. The information provided by the "Gullstrand eye" and "Gullstrand Formula" is still regarded as Gold Standard today. Gullstrand is also noted for his research on astigmatism. Furthermore he invented several important devices used in ophthalmology. What's more, he developed corrective lenses for use after cataract surgery. Gullstrand applied

Fig. 1. Prof. Allvar Gullstrand, Carl Zeiss Archiv, Jena, Germany

the methods of physical mathematics to optical images and to the refraction of light in the eye. For his work, he received numerous awards, most important the Nobel Prize in Physiology or Medicine in 1911[1].

Material and Methods

The outcome of this article is based on an intensive literature research of current and historic literature on the topic in discussion via PubMed, Google Scholar and Google as well as intensive discussions and close contact to Mrs. Eva Ahlsten, Museum for History of Medicine, Uppsala (Sweden)[2] and Mr. Prof. Lennart Berggren, Uppsala (Sweden), who had personal contact to Allvar Gullstrand.

Results

Allvar Gullstrand was born on 5 of June 1862 in Landskrona, Sweden, to Dr. Pehr Alfred Gullstrand, physician, and his wife Sofia Mathilda. In 1880 he graduated from schools in Landskrona and Jönköping (Sweden). He studied medicine in Uppsala (Sweden), Vienna (Austria) as well as Stockholm and obtained his PhD in 1890. In 1891 he was appointed Lecturer in Ophthalmology at Stockholm University and from 1894 to 1913 first Professor of Ophthalmology at Uppsala University. From 1914 to 1927 he held a personal Professorship in Physical and Physiological Optics at Uppsala University. In personal appearance he was tall and slender, almost an aristocrat in manners. His stiffness and formality of his bearing passed upon intimate personal contact. In 1927 he was appointed Professor Emeritus. Three years later, on 28 of July 1930 Gullstrand died in Stockholm of a brain hemorrhage. This year will always be remembered with great sorrow by ophthalmologists: it was the year of the death of three important ophthalmologists with international reputation: Theodor Axenfeld, Ernst Fuchs and Allvar Gullstrand[3].

Allvar Gullstrand's life was for ophthalmology. It is told that Gullstrand was tireless as a worker and an excellent and lucid teacher. He sacrificed himself completely to his research. The following theoretical achievements can only be representative for his numerous accomplishments. Even if Gullstrand was an ophthalmologist his main interest in optic and the eye was pure science: Mathematics and Physics, he was entirely self-taught in the fields covering his most important work (geometric and physiological optics)[4]. The basis of the science he developed in the following years was already laid in 1890 in his doctorate thesis: *Bidrag till astigmatismens teori* (Contribution to the theory of astigmatism)[5].

Gullstrand's formula. The Gullstrand formula, a well-known formula in optics, is still the Gold Stan-

[1] A. Gullstrand: *Einiges über optische Bilder*, „Naturwissenschaften", 1926, Vol. 14, Number 28, p. 653–664; M. Herzberger: *Allvar Gullstrand*, Lecture at Fifth Conference of the International Commission for Optics in Stockholm, August 1959; M.L. Berliner: *Biomicroscopy of the Eye. Slit-Lamp Microscopy of the Living Eye*, Vol 1, Harmish Hamilton Medical Books, London; H.T. Butler: *Observations on the practical value of the slit lamp*, "The British Medical Journal", May 31, 1924; Allvar Gullstrand, [in:] *Nobel Lectures, Physiology or Medicine 1901–1921*, Amsterdam 1967; B. Ehinger: *Highlights of Swedish Ophthalmology in the 20th Century*, Acta Ophthal., Vol. 86, Iss. 8, p. 821–829; J. Ravin: *Gullstrand, Einstein, and the Nobel Prize*, Arch. Ophthal., 1999, 117, p. 670–672; C. Snyder: *Allvar Gullstrand, Nobel Laureate*, Arch. Ophthal., 1962; http://nobelprize.org/nobel_prizes/medicine/laureates/1911/gullstrand-lecture.html; E. Blaauw: *Allvar Gullstrand*, Arch. Ophthal. 1931, 5(2), p. 294–295; J.W. Nordenson: *Allvar Gullstrand*, Docum.Ophthal., 1962, Vol. 16, Nr 1, p. 283–337.

[2] www.medicinhistoriskamuseet.uu.se.

[3] *Ibidem*; M. Herzberger: *Allvar Gullstrand...*; E. Blaauw: *Allvar Gullstrand...*; .W. Nordenson: *Allvar Gullstrand...*; *Nobel Lectures, Physiology or Medicine 1901–1921*, Amsterdam 1967.

[4] E. Blaauw: *Allvar Gullstrand...*; J.W. Nordenson: *Allvar Gullstrand...*; *Nobel Lectures...*

[5] *Ibidem*; M. Herzberger: *Allvar Gullstrand...*; B. Ehinger: *Highlights...*; L. Gårding: *Mathematics and mathematicians: mathematics in Sweden before 1950*, American Mathematical Society, 1997.

$$D_{ges} = D_1 + D_2 - \frac{d}{n} \times D_1 \times D_2$$

Fig. 2. Gullstrand's formula. D_{ges}: complete refractive power of the eye (58,64 dpt); D1: first optical system (cornea) (43, 05 dpt); D2: second optical system (crystalline lens) (19,11 dpt); d: distance between optical media in meter (e.g. lens thickness); n: refractive index of media between the systems (e.g. aqueous humour n=1,336, air n=1)

dard when calculating the total refractive power of optical systems[6].

Gullstrand's eye. With his data on anatomy and physical properties of the human eye Gullstrand set a scientific schematic model of the human eye for the first time. The information provided by the "Gullstrand eye" is still regarded as Gold Standard today and can still be found in all training books for ophthalmology[7].

Gullstrand's theory of physiological optics. Gullstrand applied the methods of physical mathematics to optical images and to the refraction of light in the eye; he was recognized for making the most significant contribution to our understanding of the eye as a refractive organ. Gullstrand investigated also in the mechanism of accommodation; by his research he observed the intracapsular motion of the lens substance during accommodation. Based on his doctoral thesis on astigmatism and on Helmholtz's theories Gullstrand developed his theory of physiological optics. The complete proof of this theory is found in the following three works: *Allgemeine Theorie der monochromatischen Aberrationen und ihre nächsten Ergebnisse für die Ophthalmologie* (General theory of monochromatic aberrations and their immediate significance for ophthalmology) (1900), which received awards from the Swedish Royal Academy of Sciences and the Swedish Medical Association, *Die reelle optische Abbildung* (The true optical image) (1906), and *Die optische Abbildung in heterogenen Medien und die Dioptrik der Kristallinse des Menschen* (The optical image in heterogeneous media and the dioptrics of the human crystalline lens) (1908), which was awarded the Centenary Gold Medal of the Swedish Medical Association. Gullstrand was chosen to edit the third edition of the first part of Helmholtz´ *Handbuch der physiologischen Optik* (Handbook of physiological optics) (1909), which was called by Albrecht von Graefe the "Bible of the scientific ophthalmologist"[8].

Fig. 3. Allvar Gullstrand's diagnostic chair, now at the Museum for History of medicine, Uppsala (Sweden), www.medicinhistoriskamuseet.uu.se

[6] M. Herzberger: *Allvar Gullstrand...*; J. Ravin: *Gullstrand...*; E. Blaauw: *Allvar Gullstrand...*; J.W. Nordenson: *Allvar Gullstrand...*; B. Lachenmayr, D. Friedburg, E. Hartmann, A. Buser: *Auge — Brille — Refraktion*, Stuttgart 2005; J. Reiner: *Grundlagen der ophthalmologischen Optik*, Norderstedt 2002; Carl Zeiss Archiv, Jena, Germany.

[7] M. Herzberger: *Allvar Gullstrand...*; J. Ravin: *Gullstrand...*; E. Blaauw: *Allvar Gullstrand...*; J.W. Nordenson: *Allvar Gullstrand...*; H. Gernet, A. Franceschetti: *Ist das schematische Auge Gullstrand´s ein normales Auge?* Docum. Ophthal., 1966, Vol. 20, Nr 1, p. 519–529; A. Gullstrand: *Sammelband mit 5 Schriften 1906–24*, Stockholm 1906; P. Kroll, M. Küchle, H.J. Küchle: *Augenärztliche Untersuchungsmethoden*, Stuttgart 2007; www.szut.de/szut/sixcms/media.php/41/Formelsammlung%20OPT.pdf.

[8] A. Gullstrand: *Einiges...*; A. Gullstrand: *Zur Kenntnis der Kreispunkte*, "Acta Mathematica", 1904, Vol. 29, Nr 1, p. 59–100; L. Gårding: *Mathematics...*; E. Blaauw: *Allvar Gullstrand...*; A. Gullstrand: *Über die Bedeutung der Dioptrie*, "Graefe´s Archive of Clinical and Experimental Ophthalmology", 1899, Vol. 49, Nr 1, p. 46–70; A. Gullstrand: *Die Constitution des im Auge gebrochenen Strahlenbündels*, "Graefe´s Archive of Clinical and Experimental Ophthalmology", 1901, Vol. 53, Nr 2, p. 185–240; A. Gullstrand: *Allgemeine Theorie Der Monochromatischen Aberrationen: Und Ihre Nachsten Ergebnisse Fur Die Opthalmologie* (1900), Whitefish 2010; B. Lachenmayr, D. Friedburg, E. Hartmann, A. Buser: *Auge — Brille — Refraktion...*

FIG. 4. Examination using nitra slit lamp according to Gullstrand, Carl Zeiss Archiv, Jena, Germany

Beside of all theoretical achievements Gullstrand also invented several instruments which, as mile stones in ophthalmic diagnosis, were and still are highly valuable to ophthalmologists. As Gullstrand contributed numerous achievements to ophthalmology only a selection is shown below to demonstrate his important influence on science, valid even today.

Gullstrand's Slit Lamp. Today, Gullstrand is best known as the inventor of the slit lamp, which he discovered and used in the scientific investigation of the posterior curvature of the cornea. His methods of focal illumination, particularly by means of the slit lamp (1911), have acquired greatest importance to the practical work of all ophthalmologists. Diagnosis of alterations of the cornea, the anterior chamber or even parts of the vitreous was greatly improved by this tool, with his device Gullstrand was the first to see the finer structures of the vitreous in the living eye. For the first time it was possible to have highly improved sight into the eye by this new technique of illumination of the eye[9].

Gullstrand's Ophthalmoscope. Another milestone for diagnostic in ophthalmology was the invention of his reflex-free ophthalmoscope (1910) which is also a valuable instrument to the ophthalmological diagnostician. It offered the possibility of monocular as well as binocular view on and into the eye. In 1911 Gullstrand presented his reflex free ophthalmoscope at the Heidelberg meeting, by this device the fundus can be studied in detail, in depth and also stereoscopically. Ophthalmoscopy can be made difficult by the glare of reflexes formed from the cornea and other layers of the eye, which act like mirrors, reflecting light back at the examiner. Bright sources of illumination and small pupils are contributory factors. The solution Gullstrand found was to separate the systems of illumination and observation.

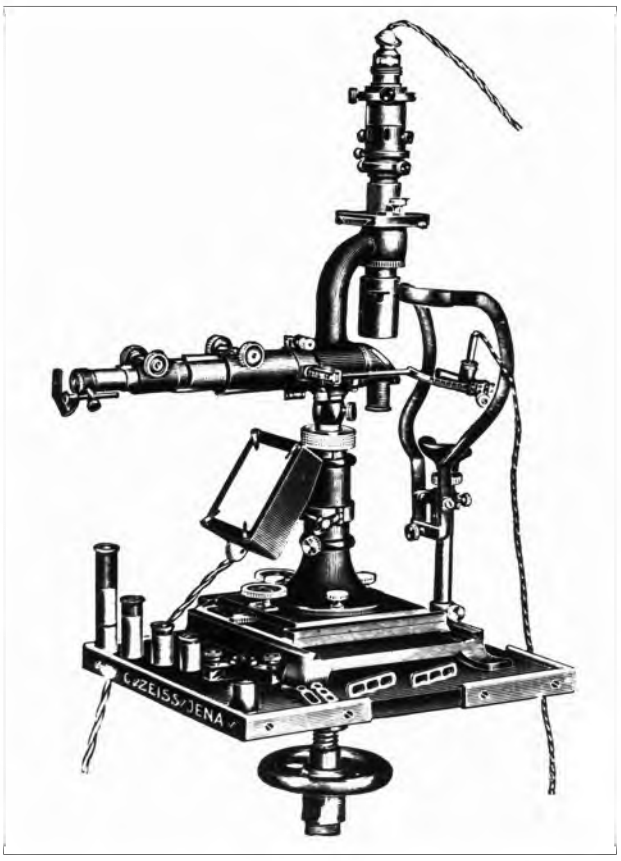

FIG. 5. Drawing of Gullstrand's ophthalmoscope, Carl Zeiss Archiv, Jena, Germany

The slit lamp together with the corneal microscope has probably been the greatest gift which the ophthalmologic world has received. It became the basis of the instrument that is still used in every ophthalmologist's office today. Before the development of this exceptionally useful device, examination of the anterior segment of the eye could be done with a corneal microscope. However, the lighting systems available were far inferior to Gullstrand's slit lamp. Gullstrand first demonstrated his slit lamp in 1911, the same year he received the Nobel Prize for his contributions to optics. It incorporated 2 important advances, far more intense light and sharp focus of the beam[10].

[9] M. Herzberger: *Allvar Gullstrand...*; M.L. Berliner: *Biomicroscopy...*; H.T. Butler: *Observations...*; J. Ravin: *Gullstrand...*; L. Koppe: *Linische Beobachtungen mit der Nernstspaltlampe und dem Hornhautmikroskop*, "Graefe's Archive of Clinical and Experimental Ophthalmology", Vol. 97, Nr 2–3, p. 198–270; *Nobel Lectures...*

[10] *Ibidem.*

FIG. 6. Gullstrand's Katral glasses, Carl Zeiss Archiv, Jena, Germany

Gullstrand's glasses. These glasses, which still carry the name of this great ophthalmologist, are point by point projecting glasses ("Katral Glasses"), which were used for aphacic eyes after cataract surgery. These glasses reduced a set of aberrations. As Gullstrand was an excellent mathematician and having good contacts to Zeiss it was able for him to construct the curvatures in lenses which he had calculated. He originated the punctual lens, the Katral lens and aspherical lenses for illumination[11].

Honoured during his life time — Gullstrand's awards. Fortune favoured Gullstrand as he received the deserved acknowledgement already during his lifetime. As he received numerous awards, only a selection can be shown in this article. His work *Allgemeine Theorie der monochromatischen Aberrationen und ihre nächsten Ergebnisse für die Ophthalmologie* (General theory of monochromatic aberrations and their immediate significance for ophthalmology) (1900) received awards from the Swedish Royal Academy of Sciences and the Swedish Medical Association. *Die reelle optische Abbildung* (The true optical image) (1906) and *Die optische Abbildung in heterogenen Medien und die Dioptrik der Kristallinse des Menschen* (The optical image in heterogeneous media and the dioptrics of the human crystalline lens) (1908) were awarded by the Centenary Gold Medal of the Swedish Medical Association. Of his other works the following received awards as well: *Objektive Differentialdiagnostik und photographische Abbildung von Augenmuskellähmungen* (The objective differential diagnosis and photographic illustration of disabilities of the eye muscles) (1892), *Photographisch-ophthalmometrische und klinische Untersuchungen über die Hornhautrefraktion* (Photographic-ophthalmometric and clinical investigations of corneal refractions) (1896) were awarded by the Swedish Medical Association. *Die Farbe der Macula centralis retinae* (The pigments of the central macula of the retina) (1905) received the Björkén Prize of the Uppsala Faculty of Medicine.

Gullstrand was honorary Doctor of Philosophy of the Universities of Uppsala, Jena and Dublin, he was elected Member of the Royal Swedish Academy of Science in 1905, member of the Academy's Price Committee for Physics and member of a number of Swedish and foreign scientific societies (e.g. Heidelberg Ophthalmological Society). He was also member of the Nobel Physics Committee of the Swedish Academy of Sciences (1911–1929), and its Chairman (1922–1929). Additionally to the already mentioned awards Gullstrand was awarded the Graefe Medal of the Deutsche Ophthalmologische Gesellschaft in 1927 (which is only awarded every ten years). This medal was given in 1886 for the first time to Helmholtz, later to Theodor Leber, Ewald Hering and Carl von Hess[12].

For his work on dioptrics of the eye he received the Nobel Prize in Physiology or Medicine in 1911, which was most probably his mayor award. The title of his Nobel lecture on 11 of December 1911 was: *How I Found the Mechanism of Intracapsular Accommodation.* He then was professor for ophthalmology in Uppsala and 49 years old. Gullstrand is the only individual who both received and also declined a Nobel Prize. In 1910 and in 1911, Gullstrand was nominated for the Nobel Prize in physics. In 1911, the Nobel Committee for Physics suggested that he receive the prize. At the same time, the Nobel Committee for Physiology or Medicine was considering him for their prize; Gullstrand declined the Nobel Prize in physics in favour of the Nobel Prize in physiology or medicine[13].

[11] M. Herzberger: *Allvar Gullstrand...*; B. Ehinger: *Highlights...*; J. Ravin: *Gullstrand...*; E. Blaauw: *Allvar Gullstrand...*; J.W. Nordenson: *Allvar Gullstrand...*; Carl Zeiss Archiv...

[12] A. Gullstrand: *Einiges...*; M. Herzberger: *Allvar Gullstrand...*; B. Ehinger: *Highlights...*; J. Ravin: *Gullstrand...*; C. Snyder: *Allvar Gullstrand...*; A. Gullstrand: *Zur Kenntnis...*; A. Benedict Cosimi: *Surgeons and the Nobel Prize*, Arch. Surg., 2006, 141, p. 340–348; L. Gårding: *Mathematics...*; http://nobelprize.org/nobel_prizes/medicine/laureates/1911/gullstrand-lecture.html; E. Blaauw: *Allvar Gullstrand...*; J.W. Nordenson: *Allvar Gullstrand...*; A. Gullstrand: *Die Farbe der Macula centralis retinae*, "Graefe's Archive of Clinical and Experimental Ophthalmology", 1905, Vol. 62, Nr 1, p. 1–72; A. Gullstrand: *Zur Maculafrage*, "Graefe's Archive of Clinical and Experimental Ophthalmology", 1907, Vol. 66, Nr 1, p. 141–188; A. Gullstrand: *Zusatz zu der Abhandlung über die Farbe der Macula Centralis Retinae*, "Graefe's Archive of Clinical and Experimental Ophthalmology", 1905, Vol. 62, Nr 2, p. 378; www.dog.org/?cat=106; *Nobel Lectures...*

[13] Allvar Gullstrand, [in:] *Nobel Lectures...*; C. Snyder: *Allvar Gullstrand...*; A. Benedict Cosimi: *Surgeons and the Nobel Prize...*; http://nobelprize.org/nobel_prizes/medicine/laureates/1911/

Discussion

Gullstrand's research offered detailed scientific facts of the eye, his empiric research on refraction of light in the human eye laid the basis for the theory of imaging in the eye. This gave a scientific basis to ophthalmology and optometry. Furthermore he invented several diagnostic devices for ophthalmology which further developments are still the standard diagnostic tools in ophthalmology today. The information which is provided by the "Gullstrand eye" and "Gullstrand Formula" is still regarded as Gold Standard. His achievements not only led to improved glasses, they also led to completely new diagnostic devices in ophthalmology beginning 20th century. Therefore Gullstrand can be regarded as one of the founding fathers of modern ophthalmology. For his work, he received the Nobel Prize in Physiology or Medicine in 1911 as well as numerous other awards. All his inventions and ideas will keep Gullstrand's name side by side with von Helmholtz's. Few scientists ever lived to see that their invention became part of the daily business of ophthalmologists; Gullstrand was gifted as he did.

Those who want to know more about Allvar Gullstrand can do this by visiting the Museum for History of Medicine in the city, where Gullstrand accomplished his most important achievements, in Uppsala (visiting address: Akademiska sjukhuset, ing 70, 1tr, 75017 Uppsala, Sweden, www.medicinhistoriskamuseet.uu.se). Allvar Gullstrand will ever be remembered by scientists with deep appreciation for his extraordinary talents and great contributions to ophthalmology and science.

gullstrand-lecture.html; G. Smith, D.A. Atchinson: *The Eye and Visual Optical Instruments*, Cambridge 1997; E.T. Crawford: *The Beginnings of the Nobel Institution: The Science Prizes, 1901–1915*, Cambridge 1987; K. Tsubota, B. Wachler, D.T. Azar: *Hyperopia and Presbyopia (Refractive Surgery)*, London 2003; *Nobel Lectures…*