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Historical Article

# Allvar Gullstrand (1862–1930) – the Gentleman with the Lamp

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**ABSTRACT.**
**This is a biography of Allvar Gullstrand (1862–1930) on the occasion of the centennial of his 1911 Nobel Prize in physiology or medicine. We reviewed pertinent literature and we did archival studies at the Uppsala University Library and the Regional State Archives at Lund as well as the Nobel Archives at the Royal Swedish Academy of Sciences in Stockholm. Allvar Gullstrand was a brilliant scientist with an exceptional personality.**
**He gave mathematical descriptions of the dioptric system of the human eye with unprecedented accuracy, and he invented and designed ophthalmological instruments of far-reaching importance. The two most valuable ones are the slit lamp and the reflexless ophthalmoscope. Both are in everyday use by any ophthalmologist in the world. Allvar Gullstrand is so far the only ophthalmologist who has been given a Nobel Prize for work in ophthalmology, and he deserved it well.**

**Key words:** Allvar Gullstrand – biography – centennial – history of medicine – Nobel Prize

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## Introduction

Allvar Gullstrand (1862–1930) is the only ophthalmologist who has been awarded the Nobel Prize for work in ophthalmology. The other ophthalmologists who received Nobel Prize Awards were Fritz Pregl in 1923 '*for his invention of the method of microanalysis of organic substances*' and Walter Hess in 1949 '*for his discovery of the functional organization of the interbrain as a coordinator of the activities of the internal organs*'. These achievements were not related to ophthalmology or vision. On the other hand, two Nobel Awards have been given for studies in vision and ophthalmology, namely to Ragnar Granit, Haldan Keffer Hartline and George Wald in 1967 '*for their discoveries concerning the primary physiological and chemical visual processes in the eye*' and David H. Hubel and Torsten N. Wiesel in 1981 '*for their discoveries concerning information processing in the visual system*', but these scientists were not ophthalmologists.

Although Gullstrand's contributions to optics are sometimes compared with those of Newton, Huygens and Helmholtz, they have not been well known and understood by most ophthalmologists in the last century. Most of them were written and published in Swedish and German, which limited their international recognition, but their very terse and complex style based on deep mathematical knowledge was certainly just as important. However, one of Gullstrand's most important original texts has been translated into English (Southall 1924).

## The Individual

Allvar Gullstrand (Fig. 1) was born on 5 June 1862 in Landskrona, a small town on the Öresund strait in southern Sweden. He was the eldest son of a respected physician, Pehr Alfred Gullstrand, Principal Municipal Medical Officer, and his wife Sofia Mathilda, born Korsell. He obtained his primary education in Landskrona, and once said that at this time, he found roaming around as a prankster in the town port much preferable to going to school. Partly because the family was dissatisfied with the school teachers in Landskrona, they moved to Jönköping on the great lake Vättern in the centre of south Sweden. Indeed, a brilliant mathematics teacher in this town managed to please the demanding Allvar Gullstrand with university-level mathematics. He taught him infinitesimal calculus and other advanced mathematical procedures (Nordenson 1930, 1962; Berg 1952; Snyder 1962).

In 1880, Allvar Gullstrand entered the faculty of medicine at the University of Uppsala. Initially, he considered studying engineering, but his physician father persuaded him to study medicine by hiring him as a medical assistant for the summer. In 1885, he married Signe Christine Breitholtz (born 4 February 1862, dead 17 September 1946), with whom he had a daughter (Esther Gisela,

**Fig. 1.** Allvar Gullstrand as a young man. Image source: Berg 1965.


**Fig. 2.** Gullstrand's Nobel Prize diploma. Image source: the University Library at Uppsala.

born on 2 March 1886). Regrettably, the girl died from diphtheria on 11 December 1888, < 3 years old.

In 1885, Gullstrand decided to leave for Vienna to learn ophthalmoscopy, otoscopy and laryngoscopy better than was in those days possible at Swedish faculties. After 1 year in Vienna, he returned to continue his medical studies in Stockholm, where he graduated in 1888.

To specialize in ophthalmology, Gullstrand entered the ophthalmology clinic of the Seraphim Hospital in Stockholm as an assistant to Johan Widmark. In 1890, he received his MD/PhD based on his thesis '*Bidrag till astigmatismens teori*'[1] (Fig. 3). It was received with great enthusiasm and was given the highest grade possible. In 1891, Gullstrand became lecturer of ophthalmology at the Karolinska Institutet in Stockholm. At the same time he also served as junior administrator ('amanuens') on the Swedish National Board of Health and Welfare ('Medicinalstyrelsen'), worked in a public outpatient department and set up a private practice. Notwithstanding, he simultaneously pursued science, proving his exceptional abilities and capacity for hard and productive work, maintained throughout his life. He once remarked that an academic teacher and scientist who is not trembling from exhaustion at the end of a semester has not done his duty (Berg 1952). Indeed, Gullstrand did his duty and endured this ordeal well. He began his working day at about 8 o'clock in the morning and continued until well after midnight, weekdays as well as weekends and holidays. In 1894, he was appointed to the first chair and professor of ophthalmology at Uppsala University without having had to apply for the position, a great honour. He moved to Uppsala where he organized an ophthalmological medical service and teaching, previously not available there (Nordenson 1930, 1962; Snyder 1962).

In 1911, Allvar Gullstrand was awarded the Nobel Prize for physiology or medicine for his work on the dioptric apparatus of the eye (Fig. 2). During 1911–1929, he was a member of the Nobel Physics Committee of the Swedish Academy of Sciences, and in 1922–1929 he was its chairman.

To relieve Allvar Gullstrand from routine hospital work and elementary clinical teaching and allow him to devote his time entirely to research, the Academic Senate of the Uppsala University requested that a personal chair in physical and physiological optics should be created for him. In 1914, this was granted by the Swedish Parliament as a Personal Professorship in Physical and Physiological Optics at Uppsala University, an exceptional gesture of appreciation.

Over the years, Gullstrand was rewarded with numerous honours, among which only some will be mentioned here. In 1892 and in 1896, he received awards from the Swedish Medical Association for his works *Objektive Differentialdiagnostik und photographische Abbildung von Augenmuskellähmungen*[2] (Gullstrand 1892) and *Photographisch-ophthalmometrische und klinische Untersuchungen über die Hornhautrefraction*[3] (Gullstrand 1896). In 1905, he received the Björkén Prize of the Uppsala faculty of medicine, and in 1909 the gold centennial medal of the Swedish Medical Society. He was honorary doctor of philosophy of the Universities in Uppsala, Jena and Dublin. He was asked to accept positions as vice chancellor of the University of Uppsala, as president of the Swedish Government Board of Health and as Surgeon General of the Swedish Army. However, he refused them all because of his engagement in science. For the same reason, he also turned down an offer to move to the Karolinska Institutet in Stockholm. That chair then went to another Swedish professor of ophthalmology, and it is said that Gullstrand noted that this meant a lesser loss to science than if he had moved from Uppsala (Berg 1952, p. 247) – he regarded himself superior to all his peers. From 1888,

[1] A contribution to the theory of astigmatism.

[2] The objective differential diagnosis and photographic illustration of disabilities of the eye muscles.

[3] Photographic-ophthalmometric and clinical investigations of corneal refraction.

he was an active member of the Swedish Medical Society, which in 1912 appointed him honorary member. For his sixtieth birthday, the Society coined a Gullstrand medal in his honour and created a Gullstrand fund to promote ophthalmic research. The Royal Society at Uppsala elected him a member in 1904, and in 1913–1914 he was its president. In 1905, Gullstrand was elected member of the Swedish Academy of Sciences, where he first entered its medical section, but later moved to its physics section. In 1925–1926, he was the president of the Academy.

Gullstrand proposed a Nordic Ophthalmology Congress at the 9th International Ophthalmological Congress in Utrecht in 1899 (the proposal had previously been presented some years earlier by the Finnish ophthalmologist Nordman). This idea came true in 1900, when the congress eventually took place in Stockholm, organized by Gullstrand. He was also one of the three founders of the Swedish Ophthalmological Society in 1908, and was for many years the leading personality at its meetings. He was also a member of several international societies, regularly attending the meetings of the German Ophthalmological Society in Heidelberg. He entered the Society in 1897 and became a member of the Society's Board of Directors in 1912. In 1927, he received their Graefe Medal, awarded only every tenth year.

In 1922, Gullstrand attended the American Society of Ophthalmology Congress in Washington. At the end of it, the congress president De Schweinitz stated that the most important contribution to the congress was Gullstrand's demonstration of his diaphragm lamp (now known as the slit lamp). He added that from that time medicine had not only the Lady with the Lamp (Florence Nightingale), but also a male counterpart – the Gentleman with the Lamp (Allvar Gullstrand).

In 1927, at the age of 65, Allvar Gullstrand retired. He then moved to Stockholm, where he continued his scientific work, mainly on the optical system laws of the fourth and fifth order. He died in Stockholm on 28 July 1930 after a cerebral haemorrhage and was buried in the Northern Cemetery of Stockholm.

## The Scientist

When Allvar Gullstrand entered medical school, he already had university-level knowledge in advanced mathematics and was at ease with infinitesimal calculus. At that time, physiology was very much concerned with measuring various parameters of the human body. Gullstrand quickly came to suspect that Sturm's description of the light ray bundle passing through the lens system of the eye was based on too simplifying assumptions. Sturm had included only low-order terms in the complex equations describing the light bundle. He reached the conclusion that in most eyes it is a conoid with two distinct focal lines, perpendicular to each other. Gullstrand suspected that including higher order terms might give other results. He was a successful medical student, and when he therefore was offered possibilities for advanced studies, he chose to examine the theory of how light is refracted in the eye, including higher orders of terms than Sturm had done. This resulted in his MD/PhD thesis in 1890 (Fig. 3), where he first gave a new and more precise definition of focal lines. He then showed how light ray bundles are refracted in the complex reality (like in the eye) rather than in infinitesimally thin theoretical lens systems. He further showed that Sturm's opinion of the form of the astigmatic pencil as a conoid with two focal lines was correct only for a very special case, but in no way for most cases in the real physical world. Sturm's conoid is useful in explaining what astigmatism is, and it has therefore survived in basic medical teaching. However, it is misleading and useless as a description of what a pencil of light is like when passing through the optics of an astigmatic eye.

Gullstrand's thesis was very well received, and for the remainder of his active life, he worked with optical problems of similar kinds. The equations formulated in his thesis later (in 1913) formed the basis for a new microscope lens design with reduced coma error by Dr H. Boegehold at the Carl Zeiss Company in Germany.

The work was remarkable also from a more social point of view: Gullstrand did not have any tutor during his thesis work. He relied entirely on the mathematics he had been taught at college and the principles he himself developed. More efficient mathematical methods were developed in Gullstrand's time, but he stayed with the ones he was familiar with. It has been said that he might have reached even further than he did, had he used the new methods (Oseen 1935).

Gullstrand's goal after his successful thesis was to present a complete theory for the refraction of the eye. As the shape of the strongest refracting part of the eye, the cornea, was unknown, he designed a precise method for measuring this by photographing the corneal reflexes made by concentric rings or squares (Gullstrand 1896). The procedure was well suited for Gullstrand's scientific endeavours, but it was cumbersome and could not be used in clinical practice until a century later when computerized processing and image analysis had become feasible.

Already in 1891, Gullstrand presented a treatise on how to simultaneously

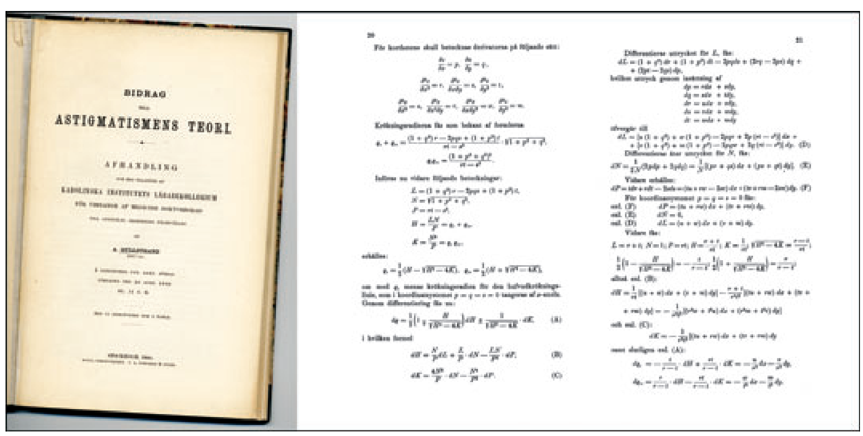
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**Fig. 3.** Gullstrand's thesis in 1890, title page and two pages with mathematical formulae.

determine the refraction of the eye and its visual acuity, forming a sound theoretical pillar for the method previously found empirically by Cornelis Donders. Gullstrand's theoretical considerations did not support the use of a chart with radiating spokes for determining astigmatism, like in Javal's method, making Donder's preferable. Gullstrand's results only slowly won international acceptance because they were first published in Swedish (Gullstrand 1891), and internationally only in his great handbook chapters several years later (Gullstrand 1909, 1911). The original treatise was finally also published in German on the occasion of Gullstrand's 60th birthday (Gullstrand 1922).

In 1900, Gullstrand presented his continued work on astigmatism, taking into account even higher orders of equation terms than he or anyone else had done before. The number of characteristic constants required to describe a bundle of monochromatic light emerging from a point light source was found to be ten. This was six more than what he described in his 1890 thesis (Gullstrand 1900). This paper is very hard to read and comprehend, and only few are likely to have done so. According to Oseen, this is probably because of the monumental wealth of facts that the work contains and that Gullstrand choose to present his results as statements, only hinting at how he had proven them, rather than giving a detailed and lengthy proof presentation (Oseen 1935, p. 16–17). Oseen had also discovered mistakes, but did not specify them, making it likely that they were only minor and without consequences. Gullstrand noted himself that the mathematical method he used was not quite sufficient for his task and that this caused him problems. This was the case also for some of his contemporaries, who noted that 'Gullstrand is so shrewd that nobody can understand him' (Oseen 1935, p. 15).

In Gullstrand's days, theoretical opticians had just begun to work with diopters rather than focal distances when stating the power of a lens, simplifying their equations considerably. However, when the refractive indices were unequal on the two sides of a lens system, like in the eye, they had to switch back to focal distances, with many difficult complications ensuing.

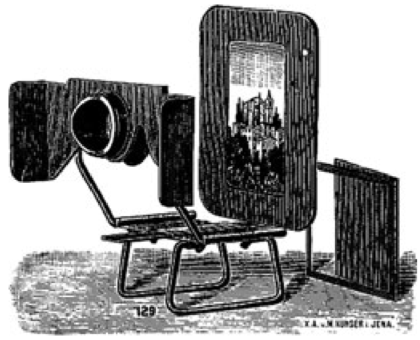

**Fig. 4.** The Verant loupe from Carl Zeiss. Image source: Adnet 1910, p. 430.

Gullstrand elegantly showed that this can be avoided by normalizing physical focal distances to distances in air, that is, dividing the distance by the refractive index of the medium (Gullstrand 1899).

For his work with precise measurements on photographs of the eye, Gullstrand needed a loupe with special characteristics. In 1901, he contacted a renowned German optical company, Carl Zeiss in Jena, and specified his requirements. To Gullstrand's excitement, M. von Rohr at the company was able to build such a loupe, called the Verant loupe (Fig. 4). It became expensive and did not sell well enough for maintained production, but it formed the start of a highly successful collaboration between Allvar Gullstrand and the Carl Zeiss company.

The successful collaboration with the Carl Zeiss company (in particular with Drs M. v. Rohr and H. Boegehold) sparked further work on instrument design. The Zeiss company produced good microscopes, useful for observing the surface of the eye, but not readily its interior parts. In 1910, Gullstrand presented an idea which every ophthalmologist has ever since been familiar with: illuminating the interior of the eye with a narrow bundle of converging light or a slit of light is in most cases far superior to using a collimated bundle of light, the standard for other kinds of microscopy. A modern ophthalmologist cannot work without a good corneal microscope equipped with Gullstrand's invention, now more than a century old: slit lamp illumination (Fig. 5). At the same time, Gullstrand formulated the principles for next to reflexless ophthalmoscopy (Fig. 6) and

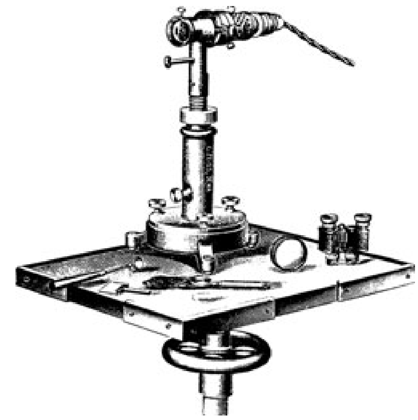

**Fig. 5.** Gullstrand's first slit lamp from 1910.

**Fig. 6.** Gullstrand's grand stationary binocular reflexless ophthalmoscope as produced by Zeiss from 1911. Image source: Pfeiffer 1989.

this generated the highly successful grand stationary ophthalmoscopes (Gullstrand 1910), designed and commercialized by the Zeiss company in 1911. This in turn formed the basis for the similarly very successful Zeiss-Nordenson fundus camera (Nordenson 1925), the golden standard for several decades.

In a monumental work from 1906, *Die reelle optische Abbildung*,[4] Gullstrand presented his 'fundamental principle for geometric optics' and based on that he deduced the solutions to a number of problems in optical imaging (Gullstrand 1906). He

[4] Real life optical imaging.

demonstrated that a point-to-point representation is normally not possible. Instead, in most cases there are two systems of lines on every surface element that can form an image, and it is usually not possible to reach beyond this. Further, the work gives a better understanding of how apertures work in optical instruments. Oseen states that with this work, the essence of optical imaging was clarified (Oseen 1935). The fundamental principle of optics was in the 1920s deduced by Herzberger and Boegehold in a more straightforward and readily accessible way, thus proving Gullstrand's original work. Continuing, Gullstrand presented laws for optical imaging in heterogeneous media (Gullstrand 1908), showing that the optical structure of the human crystalline lens can be described with six constants, amenable to empirical assessment.

When Gullstrand edited Helmholtz' classical *Handbuch der physiologischen Optik,*[5], published in 1909, he added four chapters in which he described his own achievements in accessible words (Gullstrand 1909). It was this work and his volume in Tigerstedt's physiology handbook (Gullstrand 1911) that brought wide international attention to his impressive theoretical work. Obviously, his Nobel Prize was also important for this.

When the Swedish government in 1914 made Gullstrand (Fig. 7) a research professor at Uppsala, a most unusual position at the time, he was relieved of clinical duties and got adequate resources for studies in theoretical optics. He soon published a treatise, *Das allgemeine optische Abbildungssystem,*[6] in which he formulated first order imaging laws, based on his fundamental principle for geometric optics (Gullstrand 1915). Four years later, he published a monograph on the use of aspherical surfaces in optical instruments (Gullstrand 1919). Finally, Gullstrand presented optical system laws of second and third orders (Gullstrand 1924). Oseen noted in his insightful biography that it was a task for future scientists to fully understand this last work (Oseen 1935). As it seems, this still holds true. Other mathematical methods and computerized analysis have been used to reach the same goals.

**Fig. 7.** Allvar Gullstrand in 1915. Oil painting by Erik Österman at the Swedish Medical Society in Stockholm. Image source: Svenska Läkaresällskapet.

Although Gullstrand was brilliant as a theoretical physicist, he was less successful with biomedical analyses. In several publications from 1902 to 1907, he maintained that the yellowish colour of the macula is only an illusion, because he had noted that after excision from the human eye, he was unable to see the yellowish colour with incident illumination like in ophthalmoscopy. Instead, it appeared bluish to him. It is now, a century later, clear that his laboratory facilities did not allow him to detect the yellowish pigment present in the macula.

## The Administrator

Gullstrand was influential not only as a scientist but also as an administrator. When he was appointed as professor of ophthalmology in Uppsala, his first task was to organize an ophthalmological ward and offices, because previously there were none. He subsequently supervised the design and building of a new department of ophthalmology in the town, finished in 1903, and noted proudly that nowhere was a better department to be found (Gullstrand 1904). Gullstrand handled his clinical duties with meticulous care, but when relieved of them in 1915, he clearly did not miss them.


**Fig. 8.** Allvar Gullstrand as seen by his colleague professor Carl Benedicks on the 8th of September 1926 at the Royal Swedish Academy of Sciences, where he was then president. Image source: the Royal Swedish Academy of Sciences.

As a professor of ophthalmology, Gullstrand participated in the faculty meetings and soon became dominant there, regularly having a well-supported and sound decision statement ready for every important matter. Most often, Gullstrand's colleagues had no difficulty in accepting them. Jokingly, the university vice chancellor once stated that 'brutal unanimity' reigned in the faculty of medicine, and Gullstrand often judged his colleagues by their willingness to accept his proposals. He made it clear that once he had spoken he regarded further comments as a waste of time.

The inaugural meeting of the Swedish Ophthalmological Society was held in 1908 in Allvar Gullstrand's recently finished department in Uppsala. He always participated very actively in the meetings of the Society, like in the Swedish Medical Society in Stockholm and many other international societies.

When Albert Einstein was first proposed for the Nobel Prize in 1910, the physics committee noted that more empirical evidence was required; a reasonable position at that time. Einstein was repeatedly and with increasing vigour suggested

[5] Helmholtz's treatise on physiological optics (translation: Southall 1924)

[6] The general optical imaging system.

in the following years, but the arguments against him remained the same for several years. Allvar Gullstrand, then a member of the Nobel Committee for physics (Fig. 8), forcefully argued against Einstein as a Nobel Laureate, maintaining that his theory was only a matter of unproven belief and not 'of greatest utility for mankind', a requirement in Alfred Nobel's will. After the war, with successful supporting measurements, pressure mounted on the committee to give Einstein the prize. At this time, Einstein's relativity theory was widely discussed and contested, even to the level where it entered national and international public politics, resulting in a number of disgraceful anti-Semitic arguments against it (Grandin 2000, 2007). The theory was regarded as incomplete by Gullstrand and others, in part because Einstein in vain tried to include gravity in it, and it has remained so (Elzinga 2006). Gullstrand's good friend and colleague at the physics department in Uppsala, C. W. Oseen, was also on the Nobel committee for physics and he found a way out. He had himself been convinced that Einstein should have a Nobel Prize because of Niels Bohr's successful application of Einstein's theories in his work on the structure of the atom (in particular, Einstein's laws for the photoelectric effect), solidly verified by physical measurements. In an interesting series of letters, Gullstrand voices arguments against Einstein to Oseen, who quickly responds with successful rebuttals. The letters are kept in the Nobel Archives, in the University Library at Uppsala and in the Oseen family archive at the Regional State Archives at Lund. Gullstrand finally had to admit that Einstein's laws for the photoelectric effect were worthy of the Nobel Prize. The decision for the 1921 prize had been postponed and was in 1922 awarded to Einstein 'for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect'. At the same time, Niels Bohr was awarded the physics prize for 1922. It was noted that Einstein did not receive the prize for his theories on relativity, and this is the only time a note has been published about what the prize was not awarded for.

## Gullstrand Eponyms

**Gullstrand lens:**

An approximately +14D lens with an aspherical surface and 50 mm in diameter (Fig. 9), designed by Allvar Gullstrand and produced by the Carl Zeiss company from about 1911.

**Fig. 9.** Dr Peder Jahnberg at the Museum for the History of Ophthalmology at the St Erik Eye Hospital in Stockholm demonstrates indirect ophthalmoscopy with a hand-held Gullstrand lens, a Point-o-Lite light source and a mirror ophthalmoscope from Gullstrand's days. The insert shows the lens enlarged. Image courtesy of Dr Peder Jahnberg.

**Gullstrand schematic eye:**

(1) The exact schematic eye: Based on his very precise measurements on the human eye, Gullstrand gave the exact position of the cardinal planes of the optical system of the eye (Fig. 10; Gullstrand 1909).

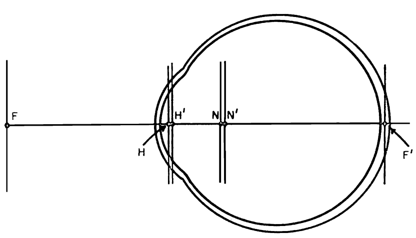


**Fig. 10.** Gullstrand's exact schematic eye with six cardinal planes: the two focal planes in front of the eye (F) and in the retina (F'), the two principal planes closely together in the middle of the anterior chamber (H and H') and the two nodal planes (N and N') just in front of the posterior pole of the lens. The original numbers can be found in Gullstrand 1909. They have subsequently been refined and adjusted for various ocular conditions.

(2) The simplified schematic eye: As the two principal planes and the two nodal planes pairwise are very close together, the eye can in many cases be regarded as having a single principal plane and a single nodal plane (Fig. 11).

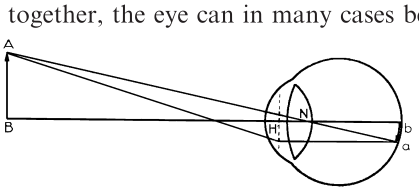


**Fig. 11.** Gullstrand's simplified schematic eye with only a single principal plane (H) and a single nodal point (N).

**Gullstrand reflexless ophthalmoscope:**

An ophthalmoscope where the illuminating light bundle passes through one part of the pupil while the reflected light rays pass through different parts (usually central and peripheral, respectively) (Gullstrand 1910). Gullstrand designed his grand reflexless ophthalmoscope (Fig. 6) according to this principle, and Carl Zeiss marketed it in 1911. It was the basis for Nordenson's fundus camera (Nordenson 1925), also marketed by Carl Zeiss.

**Gullstrand handheld ophthalmoscope:**

Although Gullstrand had high hopes for this instrument, designed according to the same principles as his stationary ophthalmoscope (Gullstrand 1910), it turned out to be difficult to use and was soon superseded by other designs (Fig. 12).

**Fig. 12.** Gullstrand's hand-held ophthalmoscope. Image courtesy of Richard Keeler and The Royal College of Ophthalmologists Collection.

**Gullstrand condition:**

Spectacle corrections were said to fulfil the Gullstrand condition when they were calculated with reference to the apparent rotation centre of the eye. This condition had been formulated before Gullstrand, and the eponym is therefore not quite appropriate.

# Acknowledgements

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Allvar Gullstrand has been the subject of several biographies, and a few in languages other than Swedish (von Rohr 1930; Berg 1952; Nordenson 1962; Snyder 1962; Nobel Institute 1967; Ravin 1999, 2001). The most insightful is that in Swedish by Gullstrand's contemporary in Uppsala, Wilhelm Oseen (Oseen 1935), a professor of mathematics and theoretical physics; Gullstrand's colleague and 17 years younger friend. He clearly admired Gullstrand's achievements and stature, but had the position and strength to point out flaws in his mathematical work and his academic judgments. J. W. Nordenson also produced a detailed biography (Nordenson 1962; in English), but being Gullstrand's devote pupil as well as a physician rather than a physicist, his evaluations of Gullstrand's achievements are less interesting than Oseen's.

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