Chapter IX

The Era of Orthoscopes

INTRODUCTION

François-Pourfour du Petit had demonstrated in 1723 the neutralization of corneal refractive power of human and animal cadavers eyes by contact with a liquid maintained by a water-container. Meanwhile *Thomas Young* had utilized, in 1800, a new optical structure made of glass inserted into the anterior part of a water containing microscope eyepiece placed before his eye in order to transfer to a living person the concept of corneal neutralization and to replace the lost refractive power. It is therefore not surprising that, in 19th century, physiologists and anatomists were to repeat these experiments and to complete them with the aim of developing a more rational approach to ocular physiology and anatomy.

Several authors dealing with corneal power neutralization devices based on the principle of ocular contact with a liquid thus mark the middle and the second half of the 19th century (1851-1891):

- ***Czermak*** who thought of and utilized a water-container for scientific use that he designated '***orthoscope***'.

- ***Hasner, Arlt, Coccius*** and ***Zander***, who adapted and utilized *Czermak's* orthoscop for the clinical examination of the eye.

- ***Helmholtz*** with his applications of the orthoscope and his citation of it, including an illustration in his treatise on physiological optics.

- ***Woinow***, who applied the orthoscope's capability to neutralize corneal refractive power to some experimental research on accommodation,

- ***Fick, Gerloff*** and ***Zehender***, who utilized the power of contact with water to eliminate corneal refractive power by water contact for fundus photography.

I plan to analyze successively the above contributions to the relevant literature for which the chronology is presented in *table 9-1*. Then, I will discuss and comment on these, with particular emphasis on those contributions to the evolution of scientific knowledge of anatomy, physiology and optics resulting from this new method of corneal refractive power neutralization with elimination of corneal reflections.

Finally, I will position the studies on the orthoscope in the chronology of the procedures for neutralization of corneal dioptric power and assess how much appreciation contact lens historians have of these aspects.

Table 9 -1

Chronology of studies and publications on the orthoscope in the second half of the 19th century.

YEAR	AUTHOR	STUDIES ON	CHARACTERISTICS
1851	Czermak	Anatomy and physiology of anterior segment	Original 'Orthoscope'
1851	Hasner	Diagnostic application for anterior segment	Glass eyecup as closed orthoscope
1853	Arlt cited by Czermak	Clinical diagnosis	Closed orthoscope with 'gutta percha' walls
1852	Coccius	Ophthalmoscopy	Application on the cornea of a drop of water covered by a glass slide
1853	Coccius	Ophthalmoscopy	Glass eyecup, eventually cut off and sealed flat glass plate
1853	Van Tright	Ophthalmoscopy	Survey
1853	Cramer	Orthoscopes	Orthoscopes
1859	Zander	Ophthalmoscopy	Survey
1864	Helmholtz	Anatomy of the iris plane	Czermak's original orthoscope
1869	Woinow	Accommodation	Czermak's 'gutta percha' orthoscope
1891 (1892)	Fick	Photography of rabbit fundus	'Contactbrille' (glass plate on water filled cylinder)
1891	Gerloff	Photography of human fundus	'Wasserkammer'
(1897)	Zehender	Fundus photography (survey)	Orthoscope

1 - Source Documents

(Table 9 – 1)

1.1 - Czermak's Orthoscope (1851)

(Figures 9 – 1 & 9 – 2)

Vierteljahrschrift
für die
praktische Heilkunde,
herausgegeben
von der
medicinischen Facultät in Prag.

Red.: Dr. J. Halla und Dr. J. v. Hasner.

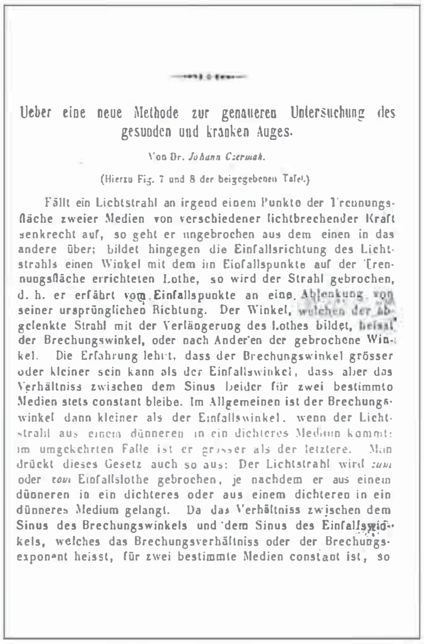
Achter Jahrgang 1851.
. Vierter Band
oder
zweiunddreissigster Band der ganzen Folge.

PRAG.
Verlag von Karl André.

Figure 9 - 1

Vierteljahresschrift für praktische Heilkunde, 8 (32), 1851 in which Czermak and Hasner has published the works on orthoscopes.

In 1851, under the title ***"Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auge"*** *(On a new method for more precise study of the healthy and the sick eye), Johann Nepomuk Czermak*, Professor at the University Institute of Physiology in Prague, published a lengthy article in *Vierteljahrschrift für praktische Heilkunde*, in which he included his presentation of a device for neutralizating corneal refractive power and eliminating light reflected from the cornea. This device, which *Czermak* designated as **the orthoscope,** permitted the examination of the anterior areas of the living eye in a living person and in their true proportions.



Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auges.

Von Dr. *Johann Czermak.*

(Hierzu Fig. 7 und 8 der beigegebenen Tafel.)

Fällt ein Lichtstrahl an irgend einem Punkte der Trennungsfläche zweier Medien von verschiedener lichtbrechender Kraft senkrecht auf, so geht er ungebrochen aus dem einen in das andere über; bildet hingegen die Einfallsrichtung des Lichtstrahls einen Winkel mit dem im Einfallspunkte auf der Trennungsfläche errichteten Lothe, so wird der Strahl gebrochen, d. h. er erfährt vom Einfallspunkte an eine Ablenkung von seiner ursprünglichen Richtung. Der Winkel, welchen der abgelenkte Strahl mit der Verlängerung des Lothes bildet, heisst der Brechungswinkel, oder nach Anderen der gebrochene Winkel. Die Erfahrung lehrt, dass der Brechungswinkel grösser oder kleiner sein kann als der Einfallswinkel, dass aber das Verhältniss zwischen dem Sinus beider für zwei bestimmte Medien stets constant bleibe. Im Allgemeinen ist der Brechungswinkel dann kleiner als der Einfallswinkel, wenn der Lichtstrahl aus einem dünneren in ein dichteres Medium kommt; im umgekehrten Falle ist er grösser als der letztere. Man drückt dieses Gesetz auch so aus: Der Lichtstrahl wird *zum* oder *vom* Einfallslothe gebrochen, je nachdem er aus einem dünneren in ein dichteres oder aus einem dichteren in ein dünneres Medium gelangt. Da das Verhältniss zwischen dem Sinus des Brechungswinkels und dem Sinus des Einfallswinkels, welches das Brechungsverhältniss oder der Brechungsexponent heisst, für zwei bestimmte Medien constant ist, so

Figure 9 - 2

Johann Nepomuk Czermak: "Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auges" (On a new method for more precise study of the healthy and the sick eye), Vierteljahresschrift für praktische Heilkunde, 8 (32), 1851, 154-165.

In this article, Czermak includes his presentation of the orthoscope for neutralizating corneal refractive power and eliminating light reflected from the cornea. and examination of the anterior areas of the living eye in a living person and in their true proportions.

1.1.1 - Review of the Laws of Refraction

The publication starts by defining refraction, the angle of incidence and the angle of reflection. *Czermak* illustrates the laws of refraction by the example of a coin placed at the bottom of a vase, not visible to an observer placed at the side and which becomes apparent in proportion to the elevation of the water level, without the observer changing position. In 1728, *François-Pourfour du Petit* had previously utilized the same example in his explanation of the optical illusion of the apparent forwards vaulting of the iris.

1.1.2 - Why is the Iris seen as Vaulted and the anterior Chamber Flatter than it really is?

For these same reasons, the various structures of the anterior chamber undergo an apparent modification of their true position, because the rays of light that they reflect are refracted and deviated by the spherical surface of the cornea as these pass from within the eye to air. It follows that the iris appears displaced forwards in the anterior chamber of the eye, which itself also appears shallower. The optical illusion is thus produced as that of the coin at the bottom of the vase filled with water:

"The inner parts of the eye, in so far as they are visible from outside, are subject to a change in their appearance and an apparent displacement from their normal position, because the rays reflected from them emerge from the ocular media that are of higher refractive index into air and are refracted at the spheroidal surface of separation between them."

« Die inneren Theile des Auges, so weit dieselben von Aussen her sichtbar sind, erfahren eine Gestaltveränderung und eine scheinbare Verschiebung aus ihrer natürlichen Lage, weil die von ihnen reflectirten Strahlen aus den stärker lichtbrechenden Medien des Auges in die Luft gelangen und an den sphäroïdischen Trennungsflächen gebrochen werden. » (1)

There is the added special point of note that the surface of separation between the humors of the eye and air is spheroidal and that the phenomenon is therefore more pronounced at the center of the cornea than at the periphery. This explains the illusion of an iris not only displaced in a forward direction, but also vaulted and more protuberant in its central part.

"The consequence of this is that the anterior chamber loses its depth and cannot be seen from its lateral aspects; the iris apparently arches forwards, and occupies practically all of the space bordered by the cornea".

« Die Folge hiervon ist, dass die vordere Augenkammer ihre Tiefe verliert, und keine Profilansicht gestattet; die Iris wölbt sich scheinbar vor, und füllt mit ihrem Bilde nahezu den ganzen von der Cornea begrenzten Raum aus. » (2)

1.1.3 - The Principle of Neutralization of Corneal dioptric Power by Water

In order to observe the structures of the anterior segment of the eye in their true anatomical relationship, it would be necessary to eliminate the refraction of light rays as they pass from air towards the cornea and aqueous humor. It is, in fact, the difference of refractive indices between the two media that causes the optical illusion. By surrounding the eye with a milieu of the same refractive index as both cornea and aqueous and thus eliminating this refraction, one would create favorable conditions for observation of the true and objective relationships of the anterior chamber structures:

"The greatest deviation that is experienced by all the light rays as they leave the eye, occurs at the outer surface of the cornea, because this structure constitutes the border between the eye and the outside world and it thus refracts light much more strongly than air."

1. Czermak 1851, p. 156 - 157.
2. Czermak 1851, p. 157.

„Die grösste Ablenkung, welche alle das Auge verlassenden Lichtstrahlen erfahren, findet an der äusseren Oberflächen der Cornea statt, weil diese das Auge gegen die Aussenwelt begrenzt, und das Licht weit stärker als die Luft zu brechen vermag. » (3)

Water possesses the ideal refractive index of 1.33 and the fluidity necessary for good contact with the eye. The indices of refraction of cornea and aqueous are so close that refraction of light rays as they pass between these two media is negligible (4).

1.1.4 - Construction of the Orthoscope
(Figures 9 – 3 & 9 – 4)

Czermak had conceived an apparatus suitable for scientific purpose that would maintain a sufficient quantity of water anterior to the eyes for the duration of the observations. It consists essentially of a kind of small box with four walls, each of which is hermetically sealed. The anterior and exterior walls are made of glass, while the inferior and internal walls are made of blackened tinplate, in order that the contour of the eye is seen more readily detached from it. The posterior border of the inferior and nasal walls are cut off to be able to be applied precisely to the cheek beneath the orbital margin and between the medial canthus and the base of the nose, respectively. The lateral border is applied against the temple. For each eye, there is a corresponding symmetrical device specific to each lateral orbital contour:

"My device is a kind of small box consisting of four walls stuck together at right angles and with sealed junctions so as to be waterproof. The anterior and external walls are made of pure glass, while the inferior and medial walls are formed from tinplate. I had these two walls made from glass, but preferred non-transparent and blackened surfaces, so that the eye stands out more against this darkened background. The free posterior borders of the inferior and medial walls are cut in such a way so that they can be applied very precisely to the cheek underneath the orbital border and between each medial canthus and the base of the nose. The posterior portion of the external glass wall comes to lie flat on the temple. Each eye has its own separate device, because the facial contour for the right side must be curved in the direction opposite to that on the left."

« *Mein Apparat ist eine Art Kästchen, und wird aus vier rechtwinklig zusammenstossenden Wänden gebildet, welche wasserdicht auf einander gefügt sind. Die vordere und die äussere Wand sind aus reinem Glase, die untere und die innere aus Blech. Es liessen sich auch diese beiden Wände*

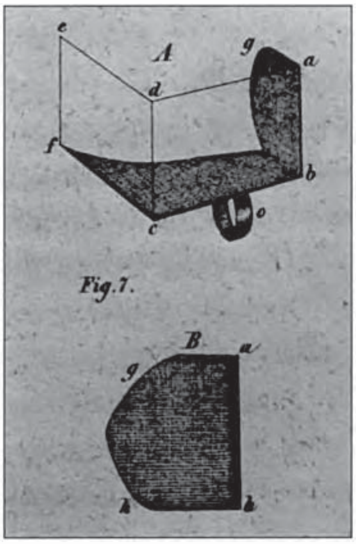


Figure 9 - 3

Johann Nepomuk Czermak: "Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auges" Plate, Figure 7.
Schematic representation of the orthoscope, its internal (medial) surface (figure A and B). The container is formed from two walls of "tin plate", the inferior fcb and nasal gab, of which the side is cut according to the facial profile. The anterior wall abcd and the external cdef are made of plate glass. A ring, fixed to the inferior wall, allows the container to be pressed to the skin surface. Bread balls assure water-tightness.
(Czermak, Vierteljahresschrift für praktische Heilkunde, 8 (32), plate, 1851)

3. *Czermak 1851, p. 158.*
4. *The index of refraction of the cornea is 1.376, that of the tears and of aqueous humor is 1.336.*

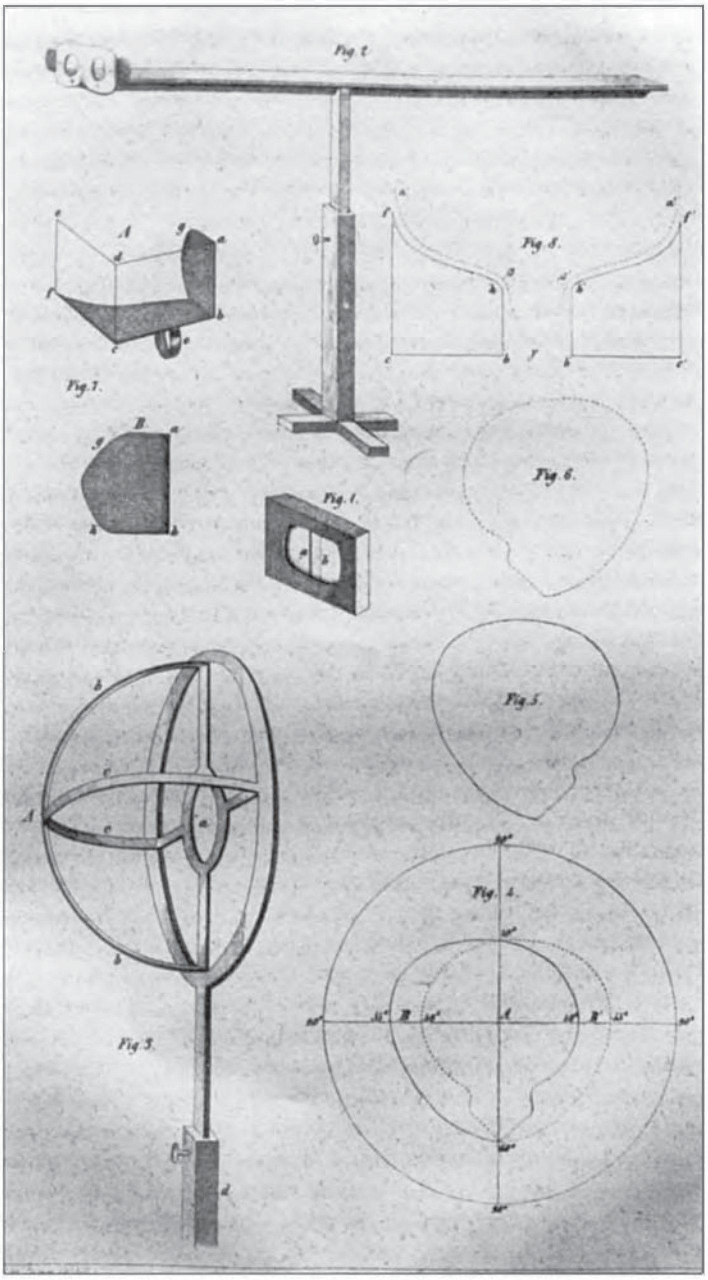


Figure 9 - 4

Johann Nepomuk Czermak: Plate to "Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auges". (Czermak, Vierteljahrschrift für praktische Heilkunde, 8 (32), plate, 1851) *aus Glas herstellen, allein ich zog es vor, undurchsichtige und geschwärzte Flächen daselbst anzuwenden, weil sich das Auge aus dieser dunklen Umgebung besser hervorhebt. Die freien hinteren Ränder der unteren und der inneren Wand sind so ausgeschnitten, dass sie unterhalb des Augenhöhlenrandes an die Wange und zwischen dem inneren Augenwinkel und der Nasenwurzel genau angedrückt werden können. Der hintere Theil der äusseren gläsernen Wand kommt flach auf die Schläfe zu liegen. Für jedes der beiden Augen gehört natürlich ein eigener Apparat, weil der Gesichtsausschnitt für die rechte Seite in entgegengesetzter Richtung gekrümmt sein muss, als jener für die linke. »* (5)

The device, held by a little ring fixed onto its inferior surface, is firmly applied to the face. The eye is thus enclosed in the little box, which is open above. The height of the walls allows it to be filled with water up to the superior orbital rim.

1.1.5 - The Applications of the Device
(Figure 9 – 5)

In order to prevent the water running out, should the contour of the device not accurately fit the facial conformation, *Czermak* recommended the insertion of cotton balls and strips between the face and the free border of the water container. One can understand that it must have been very difficult to achieve a watertight fit at the medial canthus and at the temple:

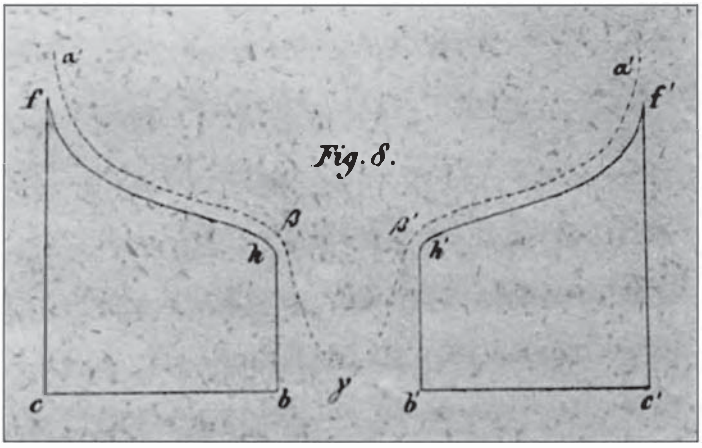


Figure 9 - 5

Johann Nepomuk Czermak: "Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auges" Plate, Figure 8.
Schematic horizontal sections of orthoscopes for the right and left sides of the face. The portion delineated a ß ß 'a ' corresponds with the section of the face underneath the inferior orbital rim. The portion ß ß' corresponds with the nose. (Czermak Vierteljahresschrift für praktische Heilkunde, 8 (32), plate, 1851)

"In order to stop the water from leaking out as much as possible when the device does not exactly fit the contour of the face, I place large or small cotton-balls or rolls as needed along the line where it is in contact with the face and press on them firmly. Hitherto, I have always fixed the device as described and attempted to retain the water. It is, however, self-evident that, for use in routine clinical ophthalmology, various practical modifications of the instrument and its method of application must be considered, e.g. an India rubber trimming for the facial contour, and so on."

« Um das Ausfliessen des Wassers, welches dann statt findet, wenn der Ausschnitt des Apparates für die Gesichtsbildung nicht genau passt, möglichst zu verhindern, lege ich längs der Linie, wo das Gesicht berührt wird nach Bedarf kleinere oder grössere Ballen oder Würstchen von Baumwolle unter und drücke dann fest auf. Bisher habe ich den Apparat stets auf die beschriebene Weise angelegt und das Wasser zu fixieren gesucht. Es versteht sich aber von selbst, dass namentlich für die praktische Augenheilkunde verschiedene zweckdienliche Modificationen des Apparates und der Anlegung zu erdenken sind, z.B. ein Kautschuk-Besatz für den Gesichtsausschnitt etc." (6)

5. Czermak 1851, p. 159.
6. Czermak 1851, p. 160.

In a note published after the article had been accepted and that was published at the end of the same article, *Czermak* indicated that he had obtained better results with well-kneaded bread balls than with cotton, which he had used initially. He had also tried some cotton impregnated with wax, but with less success. He considered that a rubber roll fixed to the free border of the instrument would work best and he regretted not having found a craftsman to make this for him.

"After this and that of Dr. von Hasner's paper had already been delivered to the printer, I succeeded in preventing the water from running out in a more reliable manner than that of the placement of cotton underneath. Instead of cotton, I now take kneaded 'mica panis' (breadcrumbs, see note 7) *that sit very nicely on the face and with gentle, but firm, pressure press the border of the device into them. Assuming that the bread is well kneaded in advance and that there are no breaks or slits in the crumbs and that one also pressed the wall of the device deeply into them by using the necessary pressure, not a drop of water escapes. I have also tried a little cotton bolster, which I have waterproofed with wax. It sticks onto the face extremely well. The border of the device cannot however sink in sufficiently deeply and has therefore to be adhered to the waxed cotton bolster to make a watertight junction and to achieve its goal satisfactorily. The best and most convenient way will be if you can attach a specially molded rubber trimming applied to the facial contour. I have already referred to it above and might have put this idea into effect long ago, had I obtained the services of a suitable craftsman."*

„Nachdem bereits diese und Dr.v. Hasner's Abhandlung dem Druck übergeben war, ist es mir gelungen, das Abfliessen des Wassers auf eine sichere Weise als durch Unterlagen von Baumwolle zu verhindern. Ich nehme statt Baumwolle geknetete Mica panis, welche sich an das Gesicht sehr genau anlegt, und den Rand des Apparates bei gelindem und anhaltendem Druck tief in sich aufnimmt. Hat man das Brot vorher gut durchgeknetet, so dass es keine Risse und Spalten hat, ferner den Rand tief eingedrückt und einen gehörigen continuirlichen Druck angewendet, so fliesst kein Tropfen ab. Ein mit Baumwolle ausgestopftes Pölsterchen von Wachsstaffet habe ich auch versucht. Am Gesichte hält es vortrefflich. Der Rand des Apparates kann jedoch nicht tief genug einsinken, und müsste, wenn diese Vorrichtung ihren Zweck ganz erfüllen soll, wasserdicht mit dem Polster verbunden werden. Am besten und bequemsten wird es sein, wenn man einen besonders gestalteten Besatz von Kaoutchouk an den Gesichtsauschnitt anbrigen lässt. Ich habe schon oben davon Erwähnung gethan, und hätte schon längst diese Idee ausgeführt, wenn ich eines Arbeiters habhaft geworden wäre. » (7)

Czermak also recommended fixing the instrument to the patient with a headband. It was then filled with water poured in via its upper open part, with the patient keeping his eyes closed and then opening them gradually as he became accustomed to the contact with the water:

"One pours the water into the device from above and keeping the eyes shut initially, so that, with gradual opening of the eyes, they become gradually accustomed to the frightening sensation of the unaccustomed medium."

« Man giest das Wasser von oben in den Apparat ein, und lässt das Auge vorläufig schliessen, damit es sich beim allmäligen Oeffnen mit dem etwas abschreckenden Eindruck des ungewöhnten Mediums nach und nach befreundet. » (8)

7. Czermak 1851, note p. 160. "Mica panis": breadcrumbs typically taken from central portion of German or French traditional bread.
8. Czermak 1851, p. 161.

1.1.6 - Examination of the Eyes through the Device
(Figure 9 – 6)

The device, once filled with water, causes the cornea to resemble a strikingly clear blue colored transparent hemisphere, when seen in side view. The iris appears set back and looks almost like a flat curtain. When the pupil is dilated, the anterior surface of the crystalline lens becomes clearly visible. The structures of the anterior segment of the eye are then seen in their normal position and their relationships can be appreciated with the greatest accuracy:

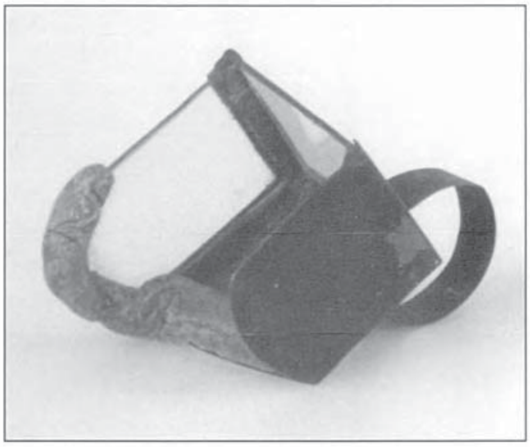


Figure 9 - 6

Czermak's Orthoscope. This "classical" model for a right eye is preserved in the Utrecht Museum. Its posterior border is provided with a strip of gray-colored substance, probably bread balls.
(The Donders and Snellen Collection in the University of Utrecht, inventory # 19.10.006, reproduced in " Eye and Instruments", Tonkelaar et al., Edition Batavian Lion, Amsterdam 1996, p.149)

"Once the eyes are opened, an unusual change is apparent to the observer; the frontal appearance is less striking than the lateral view. The iris goes posterior like a flat curtain, whereas the cornea, by contrast, arches forwards like a clear glass hemi-spherical bubble that permits lateral visualization of the anterior chamber. The crystalline lens is visible through a very widely dilated pupil and can be studied in detail. In a word, all the most important relationships that we examine in the anterior segment of the eye, present themselves in their almost natural condition, and these can therefore be studied with greater precision than before."

„Hat es sich endlich geöffnet, so erscheint es dem Beobachter ganz eingenthümlich verändert: von vorn gesehen weniger auffallend als in der Profilansicht. Die Iris tritt als ein ebener Vorhang weit zurück, die Cornea hingegen wölbt sich als eine glashelle halbkuglige Blase hervor, und gestattet eine seitliche Durchsicht durch die vordere Augenkammer. Bei sehr stark erweiterter Pupille liegt die Linse blos und kann genau untersucht werden. Mit kurzen Worten alle räumliche Verhältnisse der vorderen Theile des Auges, welche wir hauptsächlich berücksichtigen, präsentieren sich nahezu in ihrer natürlichen Beschaffenheit, und können daher mit grösserer Präcision als bis jetzt beurteilt werden." (8)

Czermak emphasizes the importance of in vivo examination of true three-dimensional topography, both for anatomic and physiologic studies and for ophthalmologic diagnosis. He himself meanwhile makes use of the device for his researches into possible displacement of the crystalline lens during accommodation:

"When I constructed my device, I intended to bring under direct observation those possible changes of position by the crystalline lens that are presumed by some to explain the power of accommodation."

« Ich selbst hatte bei der Construction meines Apparates den Zweck, die etwaige Ortsveränderungen der Linse, welche zur Erklärung des Accommodationsvermögens von Einigen vorausgesetzt werden, direct zur Anschauung zu bringen. » (8)

8. Czermak 1851, p. 161.

About the use of the instrument in ophthalmology, *Czermak* replies as follows to objections that contact with water would be unpleasant and possibly harmful to patients:

"Of course, it is true that it is not exactly pleasant to open the eye under water, yet one can accustom well to this medium, as I have experienced with several of my friends and also on myself. Besides, the water can be warmed up a little or you can add viscous materials, egg white or other similar substances."

« *Es ist allerdings wahr, dass es nicht gerade angenehm ist, das Auge unter Wasser aufzuthun, allein man kann es ganz gut an dieses Medium gewöhnen, wie ich an mehreren meiner Freunde und an mir selbst erfahren habe. Uebrigens kann das Wasser etwas erwärmt oder mit schleimigen Mittel oder mit Eiweiss u. dgl. versetzt werden.* » (8)

Czermak refers also to experience with his instrument by *Hasner* and *Arlt* at the University Eye Clinic in Prague, where patients had not been particularly inconvenienced, even if this eye bath be irritating for them. The physician should, however, consider potential medical contraindications.

1.1.7 - The Diver's Vision

Czermak also tackled the interesting question of the vision of an eye equipped with the water-device. According to evidence from divers, vision is blurred under water. Contrary to the situation in air, where the rays of light are refracted by the corneal convexity and are focused on the retina, the corneal refractive power is eliminated under the water. Light rays are then only refracted by the crystalline lens and come to focus far behind the retina, the latter only perceiving a diffusion circle:

"The crystalline lens now receives relatively divergent rays of light and could bring them together into one point only at a significant distance behind the retina. There occurs in consequence a diffusion circle on the retina, but no sharp image."

« *Die Linse empfängt jetzt relativ divergirende Lichtstrahlen, und könnte sie erst in einer bedeutenden Entfernung hinter der Retina zu einem Punkte vereinigen. Auf der Retina entsteht demnach ein Zerstreuungskreis und kein deutliches Bild.* » (9)

The diver's eye typically becomes markedly hypermetropic under water, as the optical effect of both the cornea and aqueous are practically eliminated. In order to obtain sharp images, you would have to place a convergent lens in front of the eye. The situation is comparable to that in aphakia: the patient who has been operated for cataract has lost his or her crystalline lens, while the individual under water has lost the effects of both cornea and aqueous. A corrective lens for sharp vision in water would, according to *Czermak*, have to possess a "*focus of nearly 4.6 lines*":

"The eye becomes terribly far-sighted under water, because the optical power of the cornea and the aqueous that together can be regarded as a lens of approximately 16''', 3982 focal length, is almost completely removed. Very shortsighted individuals will see generally less badly than far-sighted people under water. Should a person, however, wish to obtain clear images of objects of regard under water, he would require to put a converging lens in front of his eye, just as a patient who has had a cataract operated and for the same physical

9. Czermak 1851, p. 162.

reasons. The eye of the operated person has lost the crystalline lens, whereas that of the individual finding himself under water has lost the power of his cornea plus aqueous humor. It has been calculated that the usual radius of a biconvex glass lens with refractive index of 1.55 specified for clear vision in water must come to nearly 4.6 lines. - The question posed above must therefore be answered in the following way: clear vision under water for our eye is a physically impossibility. The retinal images of objects of regard are no less present but blurred and require imagination to fulfill the deficiencies of eyesight."

„Das Auge wird unter dem Wasser ungeheuer Weitsichtig, da die optische Wirkung der Cornea und des Humor aqueus, welche zusammen als eine Linse von etwa 16''',3982 Brennweite betrachtet werden können, beinahe ganz wegfällt. Sehr kurzsichtige Individuen werden unter Wasser im Allgemeinen weniger schlecht sehen als Weitsichtige. Wollte man unter Wasser dennoch klare Bilder von den Gegenständen erhalten, so müsse man, wie ein Staaroperierter und aus demselben physikalischen Grunde wie dieser eine Sammellinse vors Auge nehmen. Das Auge des Operierten hat die Krystallinse, jenes des unter Wasser befindlichen Individuums die Cornea sammt dem Humor aqueus verloren. Es ist berechnet worden, dass der gemeinschaftliche Halbmesser einer für das deutliche Sehen im Wasser bestimmte biconvexen Glaslinse, deren Substanz 1,55 lichtbrechende Kraft besitzt, etwa 4,6 Linien betragen müsste. - Die oben aufgeworfene Frage muss dennoch folgendermassen beantwortet werden: Eine deutliches Sehen unter Wasser ist für unser Auge physikalisch unmöglich, nichts desto weniger entstehen aber zerstreute Bilder der Gegenstände auf der Retina, welche für die ergänzende Imagination des Sinnes hinreichen, unvollkommene Gesichtswahrnehmungen zu vermitteln." (10)

These observations of the diver's vision are transferable to the eye equipped with the device, as conceived by *Czermak*. The only difference is that the objects of regard are placed in air and separated from the eye by a glass wall. The distortions induced by this pane of glass plate with parallel sides are, in any event, of no consequence:

"Everything I have just told is, generally speaking, valid for vision through my device, except that you should take into consideration that the objects seen here are not under water the same as they are in the previous scenario. The rays of light passing from air through the device towards the eye undergo a double refraction at the glass plate and the water before reaching the cornea. The rays undergo this same double refraction when they leave the device; when the observer looks into the device through one of the two glass walls, the entire eye appears to him more or less displaced out of to its natural position, without, in any event, causing any fundamental change or loss of detail, as the glass wall has parallel sides. Besides, it is equally possible to examine the eye from above, where the device is open; the rays of light are only refracted there once and this occurs at the level of the water surface."

« Alles, was eben gesagt wurde, gilt im Allgemeinen auch vom Sehen durch unseren Apparat, nur muss man mit in Rechnung bringen, dass die hier gesehenen Gegenstände nicht wie dort ebenfalls unter Wasser sind. Die aus der Luft durch den Apparat zum Auge gelangenden Lichtstrahlen erleiden durch die Glaswand und das vorgeschlagene Wasser, ehe sie die Cornea erreichen, eine zweifache Brechung. Diese zweifachen Brechung erleiden auch die aus dem Apparat herauskommenden Strahlen; wenn der Beobachter daher durch eine der beiden Glaswände in den Apparat hineinsieht, so erscheint ihm das ganze Auge mehr oder weniger aus seiner natürlichen Lage verschoben, ohne jedoch hierdurch in seinen Einzelheiten wesentlich verändert zu sein, da die Glaswand parallele Begrenzungsflächen besitzt. Uebrigens kann man auch von oben her, wo der Apparat offen ist, beobachten; die Strahlen werden da nur einmal und zwar an der Oberfläche des vorgeschlagenen Wassers gebrochen. » (11)

10. Czermak 1851, p. 163.

1.1.8 – Giving the Instrument a suitable Name

Czermak proposed to name the instrument constructed according to this principle as ***"the orthoscope"***. In order to justify this choice of name, *Czermak* noted that the principal property of the device consisted in the elimination of refraction at the surface of the cornea of an eye under examination. As the course of the rays is now rectilinear, the view obtained is undistorted. An instrument having these properties would, therefore, justify the denomination of "orthoscope" (composed of Greek roots *ORTHOS*, meaning "straight" or "rectilinear" and *SKOPEIN*, meaning "look at" or "see"):

"Finally, I allow myself to present a name for my instrument, because I hope that it will not be thrown rapidly into the 'lumber room for out-of-date objects' right away. It is difficult to summarize in the narrow space of a few words what the capabilities of the device are. After all, I believe I have found a term, which, while not correct, would, at the same time, seem to be adequate. The chosen word does not amount to much once it is sanctioned by usage. The main property of the instrument, which can always be modified, and its objective function, is, that the refraction of the reflected rays of light coming from the interior of the eye at the outer surface of the cornea is significantly reduced."

« Schliesslich erlaube ich mir noch für meinen Apparat einen Namen in Vorschlag zu bringen, weil ich hoffe, dass derselbe nicht gleich in die akologische Rumpelkammer geworfen werden wird. Es ist schwer, das was der Apparat eigentlich leistet, in den engen Raum eines Wortes zusammen zu drängen. Doch glaube ich ganz eine Bezeichnung gefunden zu haben, welche, wenn auch nicht ganz richtig, immerhin genügend sein dürfte. Im Grunde kommt es auf das gewählte Wort nicht viel an, wenn es einmal durch den Sprachgebrauch sanctionniert ist. Die Haupteingenschaft des Apparats, er mag wie immer modificirt werden, oder das, was er objectiv bewirkt, ist, dass er die Brechung der aus dem Auge reflectirten Lichtstralen an der Oberfläche der Cornea bedeutend verringert. » (11)

"Thus, when the instrument is used, the rays of light hold their rectilinear direction to a considerable extent and produce images which correspond fully to objective conditions. If we are willing also to ignore the remaining small inaccuracies, we would then need to ascribe a function to the apparatus, namely one of causing the rays of light to exit from the eye in an unbroken straight direction, presenting accurate spacious viewings from its interior parts. An instrument with these characteristics could then be named an ***Orthoscope*** *(from æŁ ç straight, rectilinear and Œ ø examine, seen). I know that, on using this term, I am overestimating the capabilities of my apparatus, but I hope that the name, with a little good will, may be plausible."*

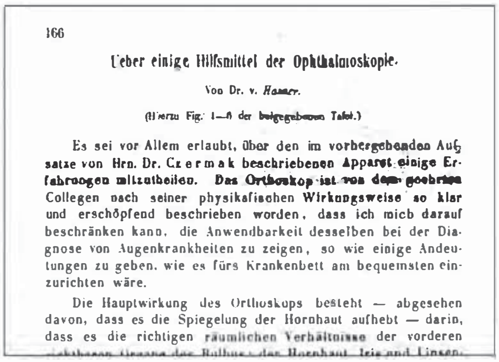
„Die Lichtstralen behalten also bei Anwendung des Apparates ihre geradlinige Richtung ziemlich bei, und erzeugen dann Bilder, welche den objectiven Verhältnissen fast vollkommen genau entsprechen. Wollen wir auch von der noch übrig bleibenden geringen Ungenauigkeiten absehen, so würden wir den Apparat die Wirkung zuschreiben müssen, die Lichtstrahlen in ungebrochener gerader Richtung aus dem Auge heraus zu leiten, und richtige räumliche Anschauungen von den inneren Theilen des Auges hervorzubringen. Ein Instrument von diesen Eigenschaften könnte dann ein ***Orthoskop*** *(von æŁ ç gerade, recht und Œ ø betrachten, sehen) benannt werden. Ich verkenne nicht, dass durch diese Bezeichnung etwas zu viel von meinem Apparate ausgesagt wird, allein bei einigem gutem Willen lässt sie sich schon plausibel machen." (12)*

11. Czermak 1851, p. 164.
12. Czermak 1851, p. 164-165. The orthoscope of Czermak conceptually transposes to the living human eye the water-box (la cuve à eau) that Francois-Pourfour du Petit had used in 1728 for his studies on enucleated human cadaver and animal eyes.

1.2 – Hasner's Adaptation for clinical Use (1851)

(Figure 9 -7)

In a article, "***Ueber einige Hilfsmittel der Ophthalmoskopie***" (*Concerning some aids to ophthalmoscopy*), which appeared in the same issue of the *Vierteljahrschrift für praktische Heilkunde* immediately following *Czermak's* article, *Joseph von Hasner*, Professor of Ophthalmology at the University Eye Clinic in Prague, described an adaptation for clinical use of *Czermak's* orthoscope and its application in ophthalmology. *Hasner* highlights the interest of *Czermak's* invention as follows: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Ueber einige Hilfsmittel der Ophthalmoskopie.

Von Dr. v. Hasner.

(Hierzu Fig. 1—6 der beigegebenen Tafel.)

Es sei vor Allem erlaubt, über den im vorhergehenden Aufsatze von Hrn. Dr. Czermak beschriebenen Apparat einige Erfahrungen mitzutheilen. Das Orthoskop ist von dem geehrten Collegen nach seiner physikalischen Wirkungsweise so klar und erschöpfend beschrieben worden, dass ich mich darauf beschränken kann, die Anwendbarkeit desselben bei der Diagnose von Augenkrankheiten zu zeigen, so wie einige Andeutungen zu geben, wie es fürs Krankenbett am bequemsten einzurichten wäre.

Die Hauptwirkung des Orthoskops besteht — abgesehen davon, dass es die Spiegelung der Hornhaut aufhebt — darin, dass es die richtigen räumlichen Verhältnisse der vorderen

Figure 9 - 7

Joseph von Hasner: "Ueber einige Hilfsmittel der Ophthalmoskopie". (Hasner, Vierteljahresschrift für praktische Heilkunde, 8 (32), 1851, p.166)

"The function of the orthoscope - aside from its removal of the corneal mirror effect - consists essentially of permitting an examiner to view the correct relationships of the anterior elements of the ocular globe, i.e. cornea, iris and lens capsule, by eliminating the apparent elevation of iris and lens towards the cornea. In a word, it provides us with an undistorted lateral view of both anterior and posterior chambers, and this certainly results in its applicability for diagnostic purpose."

« Die Hauptwirkung des Orthoskops besteht - abgesehen davon, dass es die Spiegelung der Hornhaut aufhebt - darin, dass es die richtigen räumlichen Verhältnisse der vorderen sichtbaren Organe des Bulbus: der Hornhaut, Iris und Linsenkapsel zur Anschauung bringt, indem es die scheinbare Hebung der Iris und Linse gegen die Hornhaut hin aufhebt. Es gewährt uns mit einem Worte eine vollkommen richtige Profilansicht der Augenkammern, und seine Anwendbarkeit zu diagnostischen Zwecken ergibt sich daraus wohl von selbst." (13)

1.2.1 - Applications for medical Diagnosis

Hasner lists several ocular conditions in which the orthoscope would facilitate diagnosis:

- in the presence of irido-corneal synechiae, the orthoscope would permit superior detection and information than examination with the naked eye or loupe (14) of the position and extent of adhesions and of the volume of the rest of the anterior chamber, all of which are important factors for the choice of optical iridectomy,
- the orthoscope would permit appreciation of the anterior chamber in the case of the forwards vaulted iris with iridocapsular synechiae or of the iris pushed back due to aphakia, phthisis of the crystalline lens or vitreous loss,
- orthoscopic examination from the lateral aspect would provide the available means of detecting the position and size of iris exudates, retro-corneal or capsular deposits, and pyramidal cataract,
- the localization of a corneal opacity and the condition of surrounding structures would be more accurate with the orthoscope.

13. Hasner 1851, p. 166.
14. Biomicroscopes and slit-lamps had not yet been invented at this epoch. Lighting was from candlelight and examination was by means of a magnifying loupe.

Hasner accepts, however, that the orthoscope is only one diagnostic means amongst others, even if it allows three-dimensional examination of the anterior segment of the eye, and that its use must be completed by the naked eye or loupe examination with focal illumination:

"The orthoscope permits merely an accurate visualization of the three-dimensional relationships and, as far as the examination of the structure of the organ is concerned, cannot replace either the use of the loupe or naked eye."

« Das Orthoskop gewährt lediglich eine richtige Anschauung räumlicher Verhältnisse, und kann bei der Untersuchung der Organe auf ihre Structur den Gebrauch der Luppe und selbst jenen des freien Auges nicht ersetzen. » (15)

1.2.2 - The Water Contact with the Eye under Examination and Leakages

The defensive reactions that occur at the time of contact of water on the eye represent a manifest inconvenience, especially when they cause attacks of blepharospasm. *Hasner* recommends that clinicians should follow *Czermak's* recommendations to use warm water and to avoid examination of those patients who are suffering from inflammatory diseases:

"Moreover, the contact of the water with the ocular surface produces an uncomfortable feeling of pressure and cold, and leads to involuntary spasmodic closure of the eye in many individuals that cannot be relieved, especially in photophobic patients and those suffering from inflammatory eye diseases. The device is not suitable for use in these patients. With others, the sensation is transitory and disappears as soon as the water has reached a higher temperature. It is therefore recommended to fill the instrument with water warmed up to 23-36 degrees Réaumur."

„Die Berührung der Oberfläche des Auges mit dem Wasser erzeugt ferner ein lästiges Gefühl von Druck und Kälte, und führt bei manchen Individuen zur unwillkürlichen krampfhaften Verschliessung des Auges, welche durch nichts zu beheben ist, namentlich bei lichtscheuen Kranken und solchen, welche an Entzündungen des Auges jeder Art leiden. Bei diesen ist der erwähnte Apparat daher auch gar nicht anwendbar. Bei anderen ist die Empfindlichkeit blos momentan, und verliert sich, sobald das Wasser eine höhere Temperatur angenommen hat. Es ist deshalb räthlich, zur Füllung des Apparates stets Wasser von 23°-26° R. zu nehmen." (15)

There is in addition the problem of sealing the sides of *Czermak's* orthoscope and of water overflowing through the open upper side of the water-container, with resultant wetting of the patient's face and clothes:

"Quite apart that the apparatus cannot always be pressed sufficiently onto the face so as to be watertight, and for that reason the cheeks and the clothes of the patient are soaked. Also, the upper side of the device is open and its inside wall hardly reaches the height of the upper orbital margin. For this reason, water which reaches up to the orbital margin overflows with the slightest head movement."

« Abgesehen davon, dass der Apparat nicht immer ganz wasserdicht an das Gesicht gedrückt werden kann, und daher die Wangen und Kleider des Kranken befeuchtet werden, so ist er auch oben offen, und da seine

15. Hasner 1851, p. 167. The nasal side is the hardest to stop up. Furthermore, the orbital rim limits the height of the walls.

innere Wand kaum die Höhe des oberen Orbitalrandes hat, so fliesst bei der geringsten Neigung des Kopfes das bis an den Rand reichende Wasser über. » (15)

1.2.3 – Hasner's "Wasserwanne"

For these reasons, *Hasner* conceived and constructed a "*Wasserwanne*" ***(water-bath)*** made of glass forwards curved, probably cut from a blown glass ball, "*that was pressed in its entire circumference against the eye so that the water cannot run away in any patient's position*" (16). The device that he described has a diameter slightly larger than that of the ocular globe and is applied to the soft tissues inside the orbital margin. The glass shell had to be deep enough so as not to interfere with the eyelid motility and thus combine the advantages of the orthoscope with those of a good hermetic seal. *Hasner* expressed confidence that future improvements of the orthoscope and of the ***eye-bath*** (*Augenwanne*, which is another term that he utilized in addition to *Wasserwanne*) would allow the construction of a practical instrument for the diagnosis of ocular diseases.

Hasner also envisaged the use of a cube of cut glass, open only in a posterior direction, the posterior borders of which would correspond with the orbital contour at the ocular periphery and the superior wall would possess an aperture with a cork stopper, through which one could pour water:

"*If you wished to have an device with flat walls, you could make it from a cube of cut glass, the posterior wall of which should be open and all four posterior borders of which are cut according to the contour of the eye, while, in the upper wall, a narrow opening with a stopper would be provided through which water might be poured.*"

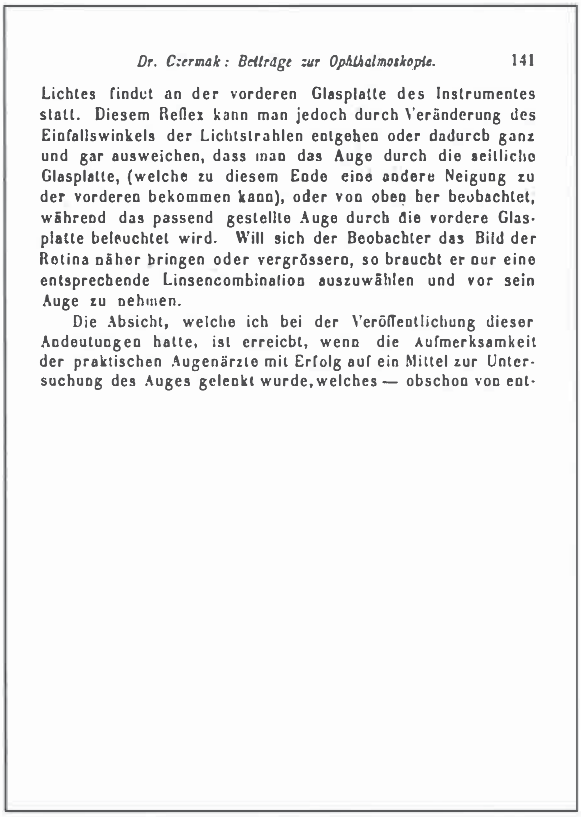
„*Wollte man durchaus einen Apparat mit geraden Oberflächen, so könnte wohl ein Cubus aus Glas geschliffen werden, dessen hintere Wand offen, und dessen hintere vier Ränder der Umgebung des Auges entsprechend zugeschliffen sind, während an der oberen Wand durch eine enge, mit einem Stöpsel zu versehende Oeffnung Wasser einzugiessen wäre.* » (17)

Hasner concludes that the inconveniences of orthoscopes thus modified would be minimal, compared with the benefits that they would bring to diagnosis in ophthalmology. There is no doubt that the possible modifications would make them into indispensable ophthalmological instruments, as they would remove corneal refractive and reflective obstacles, thus facilitating examination of the structures of the anterior segment of the eye.

16. Hasner 1851, p. 167: "Dies veranlasste mich, den Versuch mit gläsernen Augenwannen (mit krummen Oberflächen) anzustellen, welche im ganzen Umfange an das Auge gedrückt werden, so dass das Wasser in kleiner Stellung des Kranken abfliessen kann."
"This persuaded me to set up the experiment with glass eyebaths (with curved surfaces) that were pressed in their entire circumference against the eye so that the water cannot run away in any patient position."
17. Hasner 1851, p. 168.

1.3 – Arlt's Gutta-percha Orthoscope (1853)

(Figure 9 – 8)



Dr. Czermak: Beiträge zur Ophthalmoskopie. 141

Lichtes findet an der vorderen Glasplatte des Instrumentes statt. Diesem Reflex kann man jedoch durch Veränderung des Einfallswinkels der Lichtstrahlen entgehen oder dadurch ganz und gar ausweichen, dass man das Auge durch die seitliche Glasplatte, (welche zu diesem Ende eine andere Neigung zu der vorderen bekommen kann), oder von oben her beobachtet, während das passend gestellte Auge durch die vordere Glasplatte beleuchtet wird. Will sich der Beobachter das Bild der Retina näher bringen oder vergrössern, so braucht er nur eine entsprechende Linsencombination auszuwählen und vor sein Auge zu nehmen.

Die Absicht, welche ich bei der Veröffentlichung dieser Andeutungen hatte, ist erreicht, wenn die Aufmerksamkeit der praktischen Augenärzte mit Erfolg auf ein Mittel zur Untersuchung des Auges gelenkt wurde, welches — obschon von ent-

Figure 9 - 8

Description of Ferdinand von Arlt's gutta percha orthoscope by Czermak (1853).

In an appendix ("Nachschrift") to an article on ophthalmoscopy, Johann Nepomuk Czermak indicates that, at the Eye Clinic in Prague, Ferdinand von Arlt utilized on his advice a gutta-percha orthoscope with only one glass wall, obliquely oriented from the front on the nasal side to the back on the outside.

(J. N. Czermak, "Beiträge zur Ophthalmoskopie - Nachtrag", Vierteljahrschrift für praktische Heilkunde, 10 (38) 1853, p. 141)

In an appendix to an article on ophthalmoscopy ***"Beiträge zur Ophthalmoskopie"*** (*Contributions to ophthalmoscopy*) published in 1853 in *Vierteljahrschrift für praktische Heilkunde*, *Czermak* indicates that, at the Eye Clinic in Prague, *Ferdinand von Arlt* utilized on his advice a gutta-percha orthoscope with only one glass wall, obliquely oriented from the front on the nasal side to the back on the outside:

"Professor Arlt, who has undertaken the practical application of the orthoscope with tireless energy since my first communications, had constructed a short time ago an orthoscope that is fully applicable to medical practice. The little box consists essentially of gutta percha and has only one glass wall, which is inclined from inwards to outwards from front to back. Through a moderate pressure the device is applied very snugly on the facial contour, and thus prevent any leakage of water. The observer easily avoids the reflections from the inclined glass plate through adjustment of the incident direction of the light rays. The price of this instrument is not more than one florin."

„Herr Prof. Arlt, welcher sich seit meinen ersten Mittheilungen mit unermüdlichem Eifer um die praktische Verwertung des Orthoskops angenommen hat, liess vor Kurzem ein für ärztliche Zwecke vollkommen brauchbares Orthoskop construiren. Das Kästchen besteht aus Gutta Percha und hat nur eine gläserne Wand, welche von vorn und innen, nach hinten und aussen geneigt ist. Der Gesichtsausschnitt legt sich durch mässiges Andrücken des Apparates sehr genau an und verhindert jedes Abträufeln des Wassers. Dem Reflex von der geneigten Glasplatte entgeht der Beobachter leicht durch die passende Regulierung der Einfallsrichtung der Lichtstrahlen. Der Preis dieses Intrumentes übersteigt nicht 1 fl. » (18)

18. Czermak 1853, Nachschrift (Post Script) p. 141. Coccius recalled the description in the same year: Coccius 1853, p. 150-151: "Very recently, Dr Czermak recommended this method to physicians, and he described a small glass box made out of gutta percha and which was also used by Arlt. It is perhaps more convenient than the glass shells which we use." "In neuerster Zeit hat auch Dr Czermak Aerzten diese Methode empfohlen und in einer Nachschrift ein Glaskästchen mit Gutta-Perchafassung beschrieben, welches von Arlt angewendet wird und vielleicht praktischer ist, als das von uns gebrauchte Glasschaelchen."

Gutta-percha is elastic and insulating gum obtained from the solidification of the latex of certain trees growing in Malaysia. When placed in warm water, the latex of the borders of the apparatus became soft. It is then compressed against the orbit and fixed there by virtue of the gum-like nature of the material, guaranteeing that it is watertight. After hardening of the gum and filling of the instrument with water, the light reflection from the inclined glass wall was found to be easier to eliminate than with a perpendicular glass wall. The modified orthoscope, constructed from gutta-percha as described by *Arlt* seems to have been used at the Prague Eye Clinic at the same time as the closed water-bath of *Hasner. (19)*

1.4 - Neutralization of Corneal refractive Power by Coccius (1852, 1853)

1.4.1 The contact Glass-plate

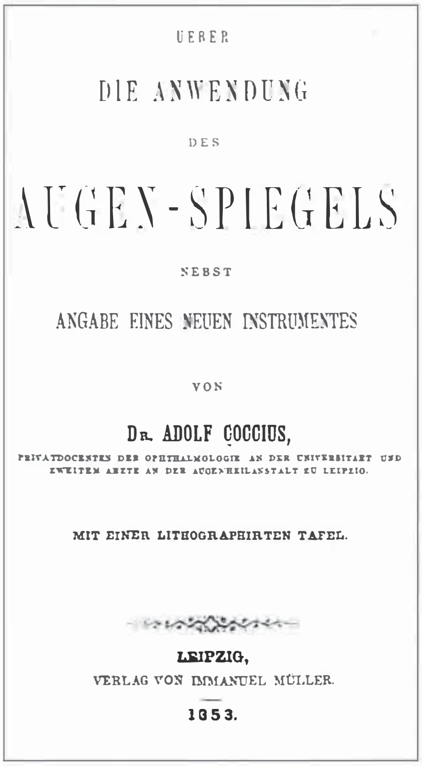
(Figure 9 – 9)

In 1852, *Adolf Coccius* described, in his treatise on corneal pathology with the title ***"Ueber die Ernährungsweise der Hornhaut"*** *(On the corneal nutrition)*, a simple corneal neutralization technique, based on *Méry's* observation as interpreted by *La Hire*:

"Indeed the gentle application on the cornea of a flat glass plate with a drop of water is sufficient to view the retina clearly (in eyes with tapetum, by white rabbits and by albinos)."

Figure 9 - 9

Adolf Coccius. "Ueber die Anwendung des Augen-Spiegels nebst Angabe eines neuen Instruments", Müller Leipzig, 1853.
In this monograph on ophthalmoscopy Coccius describes in detail his fundus examination technique. He states that a 'contact glass plate' allows ocular examination, even across an irregular or hazy cornea. This procedure would guarantee an even better examination than the ophthalmoscope on certain occasions. Coccius emphasizes at length the analogy with La Hire's procedure and the advantage of corneal power neutralization by water.


UEBER
DIE ANWENDUNG
DES
AUGEN-SPIEGELS
NEBST
ANGABE EINES NEUEN INSTRUMENTES
VON
DR. ADOLF COCCIUS,
PRIVATDOCENTEN DER OPHTHALMOLOGIE AN DER UNIVERSITAET UND ZWEITEN ARZTE AN DER AUGENHEILANSTALT ZU LEIPZIG.
MIT EINER LITHOGRAPHIRTEN TAFEL.
LEIPZIG,
VERLAG VON IMMANUEL MÜLLER.
1853.

« Schon das sanfte Anlegen einer Glasplatte mit einem Tropfen Wasser an die Hornhaut genügt (bei tapet-haltigen Augen und denen der weissen Kaninchen und Albinos), um die Netzhaut deutlich zu sehen.“ (20)

In 1853, the year following, and in a monograph on ophthalmoscopy ***"Ueber die Anwendung des Augen-Spiegels"*** *(On the application of the ophthalmoscope)* (21),

19. According to Hirschberg, there existed at the Prague University Eye Clinic a bitter rivalry between Arlt, the Chief of the Service and Hasner his assistant. Arlt never published articles in the Vierteljahresschrift für die praktische Heilkunde, although the Faculty of Medicine at Prague published this journal and Hasner was its editor.
Hirschberg VI, § 1227, p. 355: "Arlt hat sein ganzes Leben lang den Gegner Hasner nicht sehr glimflich behandelt." (Arlt throughout his whole life treated his competitor Hasner rather harshly).
20. Coccius 1852, note p. 102.
21. Coccius' treatise is dated 10th May 1853.

Coccius returns in detail to this examination technique and promotes interest in it. He states that the '*contact glass plate*' allows ocular examination, even across an irregular or hazy cornea. This procedure would guarantee an even better examination than the ophthalmoscope on certain occasions. *Coccius* emphasizes at length the analogy with *La Hire's* procedure and the advantage of corneal power neutralization by water that seems to him even more efficacious than the ophthalmoscope:

When there exists opacification of the cornea or irregularities of its surface, La Hire's method, as we have just recalled, seems to us sometimes superior to that of the ophthalmoscope. I have already emphasized the advantages of this method in another article ('Ernährung der Hornhaut' p. 39). In order to have the possibility of viewing through the clouding, flattening of the cornea by water is appropriate, because the opacification then appear less sharp and one can thus better appreciate the relative transparency of the healthy cornea in relationship to the surrounding water."

« Indem wir mit der Trübung der Hornhaut und den Unregelmässigkeiten ihrer Oberfläche beginen, finden wir die eben besprochene de la Hire'sche Methode in ihren Leistungen bei gewissen Fällen vorzüglicher, als die Anwendung des Augenspiegels. Ich habe schon anderswärts (Ernährung der Hornhaut S.39) sowie in dieser Abhandlung darauf hingewiesen, welche Vortheile jene Methode mehr als der Augenspiegel bei den Veränderungen der Hornhaut gewährt. Um nämlich Trübungen der Hornhaut im Ganzen zu überschauen, ist die Applanation der Hornhaut duch das Wasser ein treffliches Mittel: die Trübungen treten zugleich schärfer hervor, und man kann ausserdem auch die relative Durchsichtigkeit der gesunden Hornhaut im Verhältniss zu dem Wasser, welches sie umgibt, kennen lernen. " (22)

1.4.2 The orthoscopic Eyebath
(Figure 9 - 10)

Fig. 51.

Figure 9 - 10

The Coccius' Orthoscope.
Coccius proposed to manufacture an "orthoscopic eyebath" consisting essentially of a glass eyecup for eye baths, of which the lower third is cut off and replaced by a sealed glass plate.
"For this examination, you use of an adapted eye-bath device which is available from commercial glass manufacturers. This container portion is easy to manipulate and may be held by the patient himself. If you wish also to examine the eye from in front, e.g. in order to have an over-all view of an extensive corneal opacity, you must cut off the lower third of the cup and fix with a cut glass plate to replace the gap." (Coccius 1853, p. 157, and illustration in Zander 1859, p. 58, figure 51)

Next, *Coccius* recommended clinical examination of the eye through an eyebath or eyecup of a type readily available in all commercial glass shops, in order to eliminate errors of perspective due to corneal refraction that would give the illusion of a flat or shallow anterior

22. *Coccius 1853, p. 156-157.*

chamber. To examine the eye from in front, it was sufficient to cut off the lower third of the eyecup and to attach there a glass plate:

"The examination under water shows the anterior chamber in its natural state. One has an instrument suitable for this examination in the form of so-called eyebaths available in glass stores. Eyebaths are easy to handle and are held by the patient himself. If one wishes to examine the eye from in front as well, e.g. to make an overall examination of a broad corneal opacity, one should have the lower third of the cup cut off and a polished glass plate adhered to replace it."

« Die Untersuchung der vorderen Kammer unter Wasser zeigt die letztere im natürlichen Verhältniss. Man hat zu dieser Untersuchung ein entsprechendes Instrument im sogen. Augenbader der Glashandlungen. Derselbe ist leicht zu handhaben und wird vom Kranken selbst gehalten. Will man das Auge zugleich von vorn untersuchen, um z.B. eine verbreitete Trübung der Hornhaut im Ganzen zu überschauen, so lässt man das untere Drittel des Napfes abschleifen und eine geschliffene Glasplatte aufkitten." (23)

In order to eliminate the corneal reflection at the time of ophthalmoscopic examinations (24), *Coccius* used also a closed orthoscope, the border of which lay inside the orbital rim on the palpebral periphery, the front surface being a glass plate. The device was filled with warm water and was fitted to the eye of the patient as he leaned forwards. The instrument was held by a ribbon, which permited prolonged observation (25). *Coccius* used also an orthoscope with a lateral glass plate, in order to study the effect of accommodation in the pupillary plane:

"I had someone manufacture the little glass shell for examination of the iris from the lateral side, with one transparent surface aligned, in order to place under the strictest criticism the alleged forward projection of the iris in accommodation of the eye for near."

„Ich liess das Glaschälchen zu Beobachtung der Iris von der Seite, in einer Linie mit derselben, anfertigen, um die angegebene Vorwärtsdrängung der Iris bei der Accommodation des Auges für die Nähe unter die sicherste Kritik zu stellen." (26)

23. *Coccius 1852, p. 39.*
24. *Helmholtz described the ophthalmoscope the year before, in 1851 : " Beschreibung eines Augen-Spiegels zur Untersuchung der Netzhaut im lebenden Auge" (Description of an Ophthalmoscope for examination of the Retina in the living Eye) Berlin, Ed Foerstner, 1851.*
25. *Coccius refers to Méry and de La Hire, from which he quotes extensively (and in the French language) pages 100-103 of the Mémoires de l'Académie royale des sciences pour l'année 1703. Coccius describes his orthoscope in the following manner:*
Coccius 1853, p. 150:
"I provide myself, specifically, with a small glass cup, the opening of which has the form of the soft parts of the orbital aperture and of which the inferior surface is constructed with plano ground plate glass. This cup is filled with lukewarm water and laid against the closed eye of the patient, while the latter leans forwards over it."
"Ich bediene mich nämlich einer kleinen Glasschale, deren Öffnung die Form der Orbitalspalte mit den Weichteilen entspricht und deren Boden von einem plangeschliffenen Glase gebildet wird. Diese Schale wird mit lauen Wasser gefüllt und an das geschlossene Auge des kranken angelegt, während sich derselbe nach vorn überneigt."
26. *Coccius 1853, p. 151.*

1.5 - Van Tright and the School of Donders (1853)

(Figure 9 – 11)

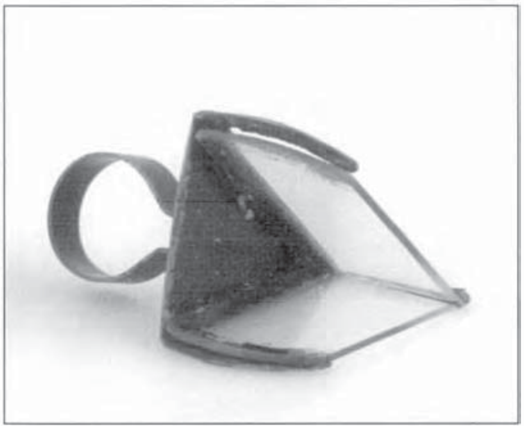


Figure 9 - 11

Triangular Orthoscope.
This triangular model is original in the sense that it does not correspond to the descriptions of Czermak, Zander or Arlt. It is preserved in the Utrecht Museum and forms a part of the Donders and Snellen collection there. It is likely that it was constructed on site for Tright's experiments (1853).
(The Donders and Snellen Collection in the Utrecht Museum, Inventory # 19.10.007, reproduced in "Eye and Instruments", Tonkelaar et al. Ed. Batavian Lion, Amsterdam, 1996, p.149)

On the 16th June 1853, in Utrecht, *Adrien Christoph Van Tright* inspired by Professor *Cornelius Donders*, presented his doctoral thesis in which he evoked the use of *Czermak's* orthoscope for the examination of the anterior chamber for the diagnosis of irido-capsular synechiae in the presence of corneal irregularity (27). He described also the procedure of neutralization of an irregular cornea by a drop of water spread out under a glass plate:

"A drop of water spread out over the (animal's) eye is covered with a glass plate on the cornea, in order that this may acquire a flat surface."

"aqua guttata in oculum, (animalis) immitenda cum lamina vitrea corneae apposita, ut illa quoque planam superficiam acquirat." (28)

According to *Hirschberg, Van Tright* would have drawn his conclusions without knowledge of the work of *Coccius*. In any event, if one takes into consideration the fact that *Coccius* had described corneal neutralization by glass plate in 1852 and that *Donders*, as *Tright*'s thesis director, had been very much implicated in the development of both the ophthalmoscope and the keratometer, this supposition appears rather unlikely.

Furthermore, the Medical Museum of Utrecht has in its collection two orthoscopes from the epoch of *Donders*. One of these is a classic, on which one can still recognize traces of kneaded breadcrumbs on its border. The second consists of two glass plates inclined together, stuck on a triangular base made of sheet metal. The maintenance of cutaneous contact of these instruments was probably not easy. This model proves, however, the research interest in the Ophthalmological Clinic and Institute of Anatomy and Physiology of *Donders* at Utrecht for corneal neutralization by a water bath.

In addition, in the same year (1853), *Antoine Cramer* of Groningen, published a monograph on *Czermak*'s orthoscope (29). Since 1848, he had done research on accommodation which he presented publicly in 1851 and of which neither *Donders* nor *Tright* could hardly have been unaware (30). Many years later, *Schauenburg's* German language translations and adaptation (1854, 1859) of the Dutch language included re-issuing of *Cramer's* publication and *Van Tright's* Latin text that reached a relatively wider audience that the originals.

27. For Van Tright's thesis, see: Tonkelaar et all., 1988.
28. Van Tright, 1853.
29. According to Hirschberg, § 850 p. 135, 1915.

1.6 – Zander's Descriptions (1859)

In 1859, *Adolph Zander* included in his book describing ophthalmoscopy and entitled "***Der Augenspiegel***" *(The ophthalmoscope)* a chapter on the examination of the eye by neutralization of corneal dioptric power under water. He summarized the main elements of the four corneal neutralization procedures that were current in his era:

1/ The "classical orthoscope" of *Czermak*.

2/ The "gutta-percha orthoscope" of *Arlt*, that was equipped with an oblique glass plate eliminates reflections and permits anterior and lateral examination of the anterior segment. This model had a reasonable price and would lend itself perfectly to clinical examinations:

"In another orthoscope described by Professor Arlt, the water-container consists of gutta percha and has only one glass wall which slopes obliquely from forward inside to backwards outside. The device fits the facial contour very precisely after application of mild pressure and prevents all leakage of water. The observer avoids the light reflex from the inclined glass plate by suitable regulation of the rays of light. This instrument is fully usable for medical purposes and its price is not more than one florin."

« Bei einem anderen von Prof. Arlt angegebenen Orthoscop besteht das Kästchen aus Gutta-Percha und hat nur eine gläserne Wand welche von vorn und innen nach hinten und aussen geneigt ist. Der Gesichtsausschnitt legt sich durch mässiges Andrücken sehr genau an und verhindert jedes Abträufeln des Wassers. Dem Reflex von der geneigten Glasplatte entgeht der Beobachter leicht durch passende Regulierung der Lichtstrahlen. Dieses Instrument dessen Preis nicht 1 fl.C.M. übersteigt, ist ein für ärztliche Zwecke vollkommen brauchbares. » (31)

3/ The *Coccius* "orthoscopic eye-bath" consisting of a eyecup, of which the bottom is cut off and replaced by a glass slide:

"The Coccius small bath consists of a little glass shell with its opening corresponding to the contour of the soft parts of orbital tissues while the bottom is formed from a plane cut glass plate. This shell is filled up with lukewarm water and is applied to the closed eye of the patient, while the latter leans forward. You can also use the so called eyecup from the glass stores with the inferior third cut off and a plane glass plate glued in."

« Das Wännchen von Coccius besteht aus einer kleinen Glasschale, deren Oeffnung der Form der Orbitalspalte mit den Weichteilen entspricht, und deren Boden von einer plangeschliffenen Glastafel gebildet wird. Diese Schale wird mit lauem Wasser gefüllt und an das geschlossene Auge des Kranken angelegt, während sich derselbe nach vorn überneigt. Man kann zu diesem Instrument auch die sogenannten Augenbader der Glashandlung benutzen, in denen man das untere Drittheil abschleifen und eine ebene Glasplatte aufkitten lässt." (32)

30. Cramer had undertaken research projects on accommodation following a competition set by the "Hollandsche maatschappij der Wetenschappen" (Netherlands Academy of Sciences), which he presented in 1851 (published in 1853). This work did not refer to the orthoscope. Nevertheless, according to Tonkelaar et al., it was on this occasion that he would have realized the significance of Czermak's orthoscope. For the publications of Cramer concerning accommodation, see Tonkelaar et al., 1990.
31. Zander 1859, p. 57.
32. Zander 1859, p. 58.

4/ The "contact glass-plate" procedure of *Coccius*, with a drop of water covered by a flat glass plate:

"Still easier, but also more laborious, is the Coccius procedure, in which a drop of water is instilled on the eye and pressed on the cornea by means of a little thin flat glass plate."

« Noch einfacher, aber auch lästiger, ist das Verfahren von Coccius, ein Tropfen Wasser auf das Auge zu bringen und ihn mittest eines dünnen Glasplättchens an die Hornhaut anzudrücken." (32)

1.7 - The Works and the Publications of Helmholtz (1867)

(Figure 9 - 12)

The publications of *Hasner*, *Arlt*, *Coccius* and *Van Tright* were forgotten. Those of *Czermak* would probably have passed unnoticed, had it not been that *Hermann Helmholtz* regenerated interest in the orthoscope in his ***"Handbuch der physiologische Optik"*** *(Handbook on physiological Optics)* successive editions of which have served as a reference for half a century to students and ophthalmologists in Europe (33).

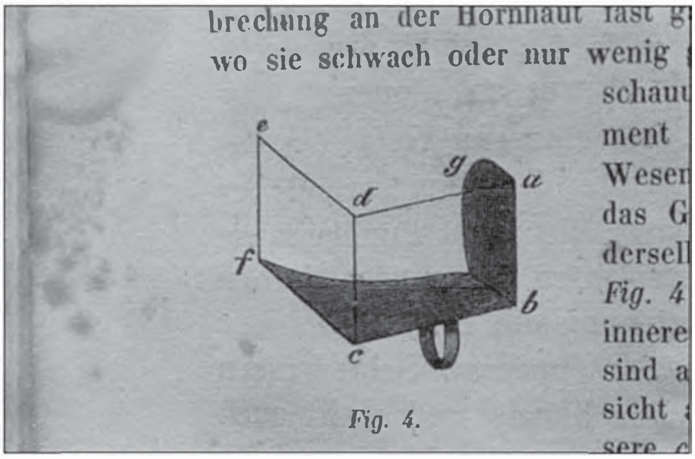


Figure 9 - 12

Czermak's Orthoscope, illustrated by Helmholtz.
The dissemination of the idea of the neutralization of corneal refractive power was accelerated by the publication in Helmholtz's treatise on physiological optics of a detailed description with illustration of Czermak's orthoscope. This notoriety in respect of Czermak's instrument eclipsed the Coccius, Hasner and Arlt orthoscopes which were intended for clinical use, although these latter instruments were more sophisticated than Czermak's.
(Helmholtz, "Handbuch der physiologischen Optik", Leopold Voss, Leipzig, first edition, 1867)

It was at the time of his description of the iris that *Helmholtz* dealt with the question of the apparent deformation of that structure due to a refractive effect from cornea and aqueous:

"In the intact eye, the iris is seen through the cornea. It appears closer to the cornea and therefore more arched forwards than it really is, because of the effect of refraction. If, on the contrary, one places a cadaver eye under water, of which the refractive power is more or less the same as that of the watery tissues, then the refractive power of the cornea almost disappears, and one sees the iris in its natural state, in which it is weakly or only a very little curved forwards. J Czermak, in his

33. Helmholtz described the orthoscope of Czermak and produced an illustration of it on page 14 of the first volume of the first edition of his "Handbuch der physiologischen Optik".

attempts to obtain a true view of the iris in the eye in vivo, has invented a instrument with the name of orthoscope, which, essentially is a little container with glass walls that is placed on the face in such a way that the eye forms the posterior wall of the instrument and then it is filled up with water."

« Am unverletzten Auge sieht man die Iris durch die Hornhaut. Durch die Wirkung der Strahlenbrechung erscheint sie der Hornhaut näher, also mehr nach vorn gewölbt, als sie es in Wirklichkeit ist. Wenn man dagegen das Auge einer Leiche unter Wasser bringt, dessen Brechungsvermögen dem der wässrigen Feuchtigkeit ziemlich gleich ist, so fällt die Strahlenbrechnung an der Hornhaut fast ganz weg, und man sieht die Iris in ihrer natürlichen Lage, wo sie schwach oder nur wenig gewölbt erscheint. Um am lebenden Auge eine richtige Anschauung von der Iris zu erhalten, hat J.Czermak ein Instrument angegeben unter dem Nahmen Orthoskop, welches im Wesentlichen eine kleine Wanne mit Glaswänden ist, die an das Gesicht so angesetzt wird, dass das Auge die Hinterwand derselben bildet, und dann voll Wasser gegossen wird. » (34)

In his treatise, *Helmholtz* reproduces *Czermak's* original illustration and gives a very detailed description of the orthoscope. He concludes that the cornea appears in the form of a transparent vaulted ball, when viewed from the side, with the iris dropping back and resembling a nearly flat curtain:

"The cornea, when viewed from the side, projects forwards as a transparent arched bubble, while the iris drops back to resemble an almost flat curtain."

« Die Hornhaut tritt von der Seite gesehen als eine durchsichtige gewölbte Blase hervor, die Iris tritt als eine fast ebener Vorhang von ihr zurück." (35)

Helmholtz later advanced other arguments regarding iris topography and that of the anterior crystalline lens surface, these being essential, in his opinion, for the theories of accommodation. In a note at the end of the chapter, *Helmholtz* gives also an historical view of iris topography:

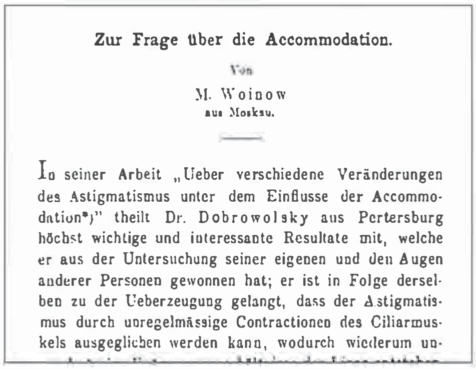
"The anatomists have many times challenged the view that the iris may lie against the lens and be arched forwards. The older anatomists accepted it until Petit, basing this on his experiments with frozen eyes, maintained the opposite and accepted the existence of a so-called posterior chamber between the iris and lens. One sometimes finds thin leaves of ice in frozen eyes between iris and crystalline lens, but not always. Nearly all the anatomists of later generations followed Petit's opinion until, in most recent times, Stellwag von Carion and Cramer declared themselves again in favor of close contact between iris and lens. By using the method described above, I personally find it possible to make the relevant observations that allow me no shadow of doubt that the last opinion is correct."

« Dass die Iris der Linse anliege und nach vorn gewölbt sei, ist von den Anatomen vielfach bestritten worden. Die älteren Anatomen nahmen es an, bis namentlich Petit, auf Grund seiner Untersuchungen an gefrorenen Augen, das Gegenteil behauptete und zwischen Iris und Linse die sogenannte hintere Augenkammer annahm. In gefrorenen Augen findet man bald dünne Eisblätter zwischen Iris und Linse, bald nicht. Der Meinung von Petit folgten fast alle späteren Anatomen, bis in der neuersten Zeit Stellwag von Carion und Cramer sich wieder für die enge Anlegung der Iris an die Linse erklärten. Ich selbst finde es möglich, in der obenbeschriebenen Weise directe Beobachtungen dafür zu liefern, welche mir keinen Zweifel übrig zu lassen scheinen." (36)

34. Helmholtz 1867, p. 14.
35. Helmholtz 1867, p. 15.
36. Helmholtz 1867, p. 19.

1.8 - The Study of Accommodation by Woinow

(Figure 9 – 13)


Zur Frage über die Accommodation.

Von

M. Woinow
aus Moskau.

In seiner Arbeit „Ueber verschiedene Veränderungen des Astigmatismus unter dem Einflusse der Accommodation*)" theilt Dr. Dobrowolsky aus Pertersburg höchst wichtige und interessante Resultate mit, welche er aus der Untersuchung seiner eigenen und den Augen anderer Personen gewonnen hat; er ist in Folge derselben zu der Ueberzeugung gelangt, dass der Astigmatismus durch unregelmässige Contractionen des Ciliarmuskels ausgeglichen werden kann, wodurch wiederum un-

Figure 9 - 13

Mikhail Mikhalovitch Woinow "Zur Frage der Akkommodation" (1869)
Woinow was using the orthoscope to neutralize the dioptric power of his own cornea in order to prove or disprove the hypothesis of possible cylindrical accommodation of the crystalline lens. He replaces the lateral walls and the bottom of Czermak's instrument with gutta-percha plaques, but left the back and upper parts open.
(Woinow M., Archiv für Ophthalmologie, 15-2, 1869, p.167)

In 1869, *Mikhail Mikhalovitch Woinow*, a famous ophthalmologist in Moscow, was using the orthoscope to neutralize the dioptric power of his own cornea in order to prove or disprove the hypothesis of possible cylindrical accommodation of the crystalline lens. In a publication "***Zur Frage der Akkommodation***" *(On the question of accommodation)*, he describes that he replaced the lateral walls and the bottom of *Czermak*'s instrument with gutta-percha plaques, but left the back and upper parts open. He seemed to be unaware of the improvements added by *Hasner*, *Arlt* and *Coccius*. In the short description of his device, *Woinow* indicated that lukewarm sodium chloride solution of 0.5% strength, was more comfortably tolerated than plain or distilled water:

"The instrument itself is built according to Czermak's principle, but I have modified it somewhat, in so far as I gave it the shape of a small box; its lateral walls and the bottom were made from gutta percha and its anterior wall from a clear glass plate, while I remove the posterior and superior walls completely. Before starting the experiment, I softened the posterior edge in hot water and then brought it into contact with the periorbital area, where, because of the adhesiveness of the material, it stuck on easily as soon as the instrument was attached, with a time interval of not exceeding 3-4 minutes. [...] At this point, I poured water into the instrument, with the eye serving as its posterior wall. I should mention here that regular and even distilled water was poorly tolerated by the eye, whereas, by contrast, half percent sodium chloride solution was very well tolerated for up to ¾ of an hour (but the water had to be lukewarm). After that, all objects appear usually as if enveloped in smoke, but this is only a passing phase, perhaps as the result of imbibition of water by the corneal epithelium; after 10 to 15 minutes this phenomenon disappears once again."

« *Das Instrument selbst, nach dem Prinzip von Czermak gebaut, hatte ich etwas verändert, indem ich ihm die Form eines Kästchens gab; die Seitenwände desselben und der Boden bestanden aus Guttapercha, die vordere Wand bildete eine klare planparallele Glasplatte, während die hintere und obere ganz fehlte. Vor Beging des Experiments erweichte ich den hinteren Rand in heissem Wasser und brachte ihn dann an die Umgebung des Auges, woselbst er in Folge der Klebrigkeit des Material auch leicht haftete, sobald das Instrument befestigt war, wozu es nicht mehr als eines Zeitraumes von 3-4 Minuten bedurfte. [...]. Jetzt wurde in das Instrument, als dessen hintere Wand das Auge diente, Wasser gegossen. Ich muss hier bemerken, dass gewöhnliches und sogar destilliertes Wasser vom Auge schlecht ertragen wurden, sehr gut dagegen bis zu 3/4 Stunden und mehr eine halbprocentige Kochsalzlösung (Das Wasser muss lauwarm sein). Danach erscheinen in der Regel alle Gegenstände wie in Rauch gehüllt, aber nur vorübergehend, vielleicht in Folge der Imbibition des Hornhautepithels; nach 10 -15 Minuten schwindet diese Erscheinung wieder.* » (37)

37. Woinow 1869, p. 169 - 170.

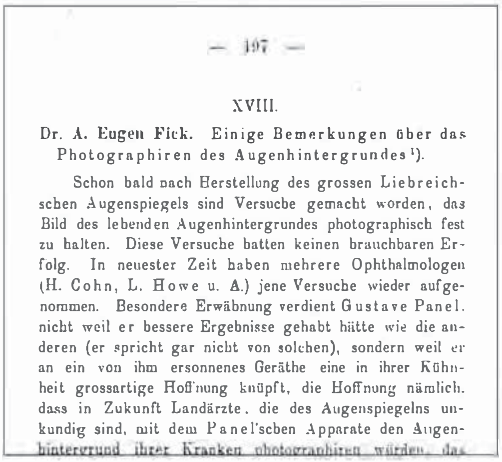
1.9 - The photographic Orthoscopes

The advances in photographic techniques at the end of the 19th century encouraged researchers to try to fix the image of internal ocular structures on a plate (38). The reproduction of an image of the fundus seemed to be out of reach for ages and attempts failed during this era because of the diminutive size of the object to be photographed and most of all because of the effects of corneal refraction and reflection, blocking the image (39). Several attempts were made to photograph the fundus, notably by *Fick* and *Gerloff* who tried to overcome these hindrances by using the principle of corneal immersion in water.

1.9.1 – Fick's photographic « Contactbrille » (1891)

(Figure 9 – 14)

Eugen Fick, lecturer at the University Eye Clinic in Zurich, presented the first paper associating the neutralization of corneal refractive power with fundus photography three years after his first description of contact lenses. *Fick* had intended to present his work in 1890 at the International Congress of Ophthalmology in Berlin. He presented his paper in the following year at the Congress of the German Society of Ophthalmology in Heidelberg under the title ***"Einige Bemerkungen über das Photographiren des Augenhintergrundes"***, *(Several Comments on Ocular Fundus Photography)*.



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XVIII.

Dr. A. Eugen Fick. Einige Bemerkungen über das Photographiren des Augenhintergrundes [1]).

Schon bald nach Herstellung des grossen Liebreich-schen Augenspiegels sind Versuche gemacht worden, das Bild des lebenden Augenhintergrundes photographisch fest zu halten. Diese Versuche hatten keinen brauchbaren Erfolg. In neuester Zeit haben mehrere Ophthalmologen (H. Cohn, L. Howe u. A.) jene Versuche wieder aufgenommen. Besondere Erwähnung verdient Gustave Panel. nicht weil er bessere Ergebnisse gehabt hätte wie die anderen (er spricht gar nicht von solchen), sondern weil er an ein von ihm ersonnenes Geräthe eine in ihrer Kühnheit grossartige Hoffnung knüpft, die Hoffnung nämlich. dass in Zukunft Landärzte. die des Augenspiegelns unkundig sind, mit dem Panel'schen Apparate den Augenhintergrund ihrer Kranken photographiren würden, das

Figure 9 - 14

Adolf Eugen Fick "Einige Bemerkungen über das Photographiren des Augenhintegrundes".
(Report of the 21st meeting of the Ophthalmologische Gesellschaft Heidelberg 1891 in Klinische Monatsblätter für Augenheilkunde, 19, 1892, Beilageheft, p. 197)

His paper recalls the usual failures to photograph the upright virtual image of the fundus because this demands close proximity between the instrument of observation and the eye. This situation is rendered even more challenging because of the mandatory interposition of an illuminating mirror. Making a record of the image was greatly hindered, first, by the diminutive size of the fundus, the enlargement the image of which required intense illumination and, secondly, by the red color of the structures that made little impression on the plates available at the time. However, the most important obstacle remained in the corneal reflection. The white spots interpreted by some people as the optic nerve head were often no more as the image of this reflection. *Fick* overcame this difficulty by covering the cornea, as happens with a contact lens, with a layer of water held there by a glass cylinder which was covered by a microscopic cover-slip:

38. For the history of the first photographs of the eye and the fundus, see Dimmer (1905) and Hirschberg 1895-1918, XV § 1025.
39. Gerloff 1891, p. 398: "Hat doch bei diesen Aufnahmen der Reflex der Lichtquelle auf der Cornea einen grossen Teil des an sich schon kleinen Bildes verdeckt." ("In these pictures, the reflection of the light source on the cornea has masked a large portion of the image that was in itself already quite small.")

"This disturbing circumstance is easy to overcome and I have wondered why this simple method has not found an application before now, namely, covering the cornea with a layer of level water. The open end of an ordinary glass test tube is cut off about 4-5 mm wide and on to the low-powered cylinder thus obtained, a round cover slip is fixed with sealing wax. You have as the result of this a contact-spectacle, which can be fastened onto the eye without difficulty and without further preparation and filled with fluid with the same refractive index as the cornea."

« Dieser störende Umstand ist leicht zu beseitigen und ich habe mich gewundert, dass dies einfache Mittel bis jetzt noch keine Verwendung gefunden hat, es heisst: Bedecken der Hornhaut mit einer eben begrenzten Wasserschicht. Das offene Ende eines gewöhnlichen Reagenzgläschen wird etwa 4 bis 5 mm breit abgesprengt und auf den so gewonnenen niedrigen Cylinder ein rundes Deckgläschen mit Siegellack aufgekittet; man hat so eine Contactbrille, die sich ohne Schwierigkeit und ohne weitere Vorrichtung an dem Auge befestigen und mit einer Flüssigkeit von dem Brechungsindex der Hornhaut füllen lässt. » (40)

By inclining this device in an adequate manner, *Fick* eliminated the corneal reflection. Moreover, the contact spectacle had the advantage of making the eye hypermetropic and thus enlarging the virtual image of the fundus. *Fick* illustrated his presentation with photographs of the fundus of an albino rabbit devoid of reflections, in which one could recognize *"the optic disc, several retinal vessels and even the choroidal vessels."* Unfortunately, these illustrations are not attached to the article.

Fick's device is not, to be sure, an orthoscope in the meaning of *Czermak*, but rather, because of its conception, a water bath covered with a plate glass placed on the eye. It is a structure intermediate between the orthoscope and the contact glass such as *Fick* had described in 1888.

1.9.2 - The photographic "Wasserkammer" of Gerloff and Meissner (1891)

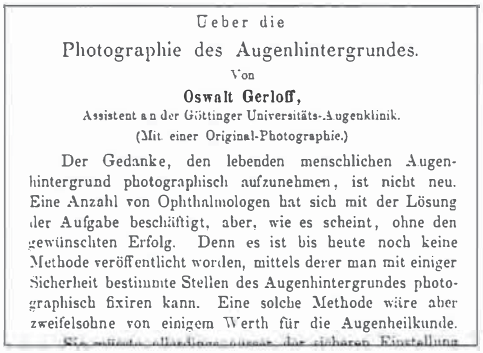
(Figures 9 – 15, 9 – 16, 9 – 17 & 9 - 18)

Oswald Gerloff, assistant at the Eye Clinic of the University of Goettingen, proposes in a paper, which appeared in 1891, ***"Ueber die Photographie des Augenhintergrundes"*** *(On photography of fundus oculi)*, resolution of the two principal difficulties of fundus photography, namely the corneal reflection and the small image size, by a *"simple and well-know method"* as follows:

"Two important difficulties, which are the disturbing corneal reflection and the diminutive size of the image have been overcome simultaneously by a simple and well-known procedure. You set a water chamber in front of the eye to be photographed, the anterior wall of which consists of a plano-parallel glass plate. This excludes the corneal reflection and it is possible, at the same time, to bring a large part of the posterior pole of the eye into view."

« Zwei Hauptschwierigkeite, der störende Reflex auf der Cornea und der geringe Umfang des Bildes sind durch ein einfaches und bekanntes Verfahren gleichzeitig überwunden worden. Setzt man nämlich vor das zu

40. Fick 1892, p. 200. See Chapter X: Adolf Eugen Fick's "Contactbrille".


Ueber die

Photographie des Augenhintergrundes.

Von

Oswalt Gerloff,

Assistent an der Göttinger Universitäts-Augenklinik.

(Mit einer Original-Photographie.)

Der Gedanke, den lebenden menschlichen Augenhintergrund photographisch aufzunehmen, ist nicht neu. Eine Anzahl von Ophthalmologen hat sich mit der Lösung der Aufgabe beschäftigt, aber, wie es scheint, ohne den gewünschten Erfolg. Denn es ist bis heute noch keine Methode veröffentlicht worden, mittels derer man mit einiger Sicherheit bestimmte Stellen des Augenhintergrundes photographisch fixiren kann. Eine solche Methode wäre aber zweifelsohne von einigem Werth für die Augenheilkunde.

Figure 9 - 15

Oswalt Gerloff, "Ueber die Photographie des Augenhintergrundes" (1891)
In this publication, Oswald Gerloff, proposes the resolution of the two principal difficulties of fundus photography, namely the corneal reflection and the small image size, by a "photographic water-chamber".
(Klinische Monatsblätter für Augenheilkunde, 29, 1891, p.397)

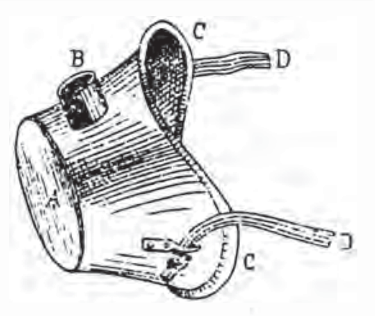


Fig. 1. A. Planparallele Glasplatte. B. Einführrohr. C. Rand mit Gummiband belegt. D. Gummi-

Figure 9 - 16

Diagram of Gerloff's "Photographic Water-chamber" (Wasserkammer)
A. Plaque of plate glass with parallel sides.
B. Tube for the introduction of liquid.
C. Edge covered with an elastic band.
D. Rubber seal.
(Oswalt Gerloff, "Ueber die Photographie des Augenhintergrundes" Klinische Monatsblätter für Augenheilkunde, 29, 1891, figure 1, p.401)

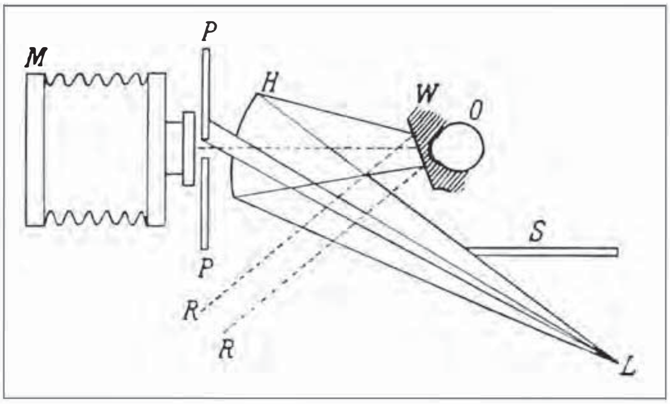


Figure 9 - 17

Diagram of Gerloff's Retinograph and "Wasserkammer" (1891)
Diagram of the structural set-up that Gerloff used to eliminate corneal reflection for fundus photography by means of ocular immersion. A flash from ignited magnesium produced a source of illumination "L", which is directed towards a concave pierced mirror "H". The light is projected towards the "water chamber" "W", the reflections from which are deviated towards "RR". A pierced screen "PP" protects the apparatus from light interference. A screen "S" protects the subject from magnesium sparks.
(Dimmer F. " Die Photographie des Augenhintergrundes " Bergmann, Wiesbaden, 1907, figure 3, p. 7)

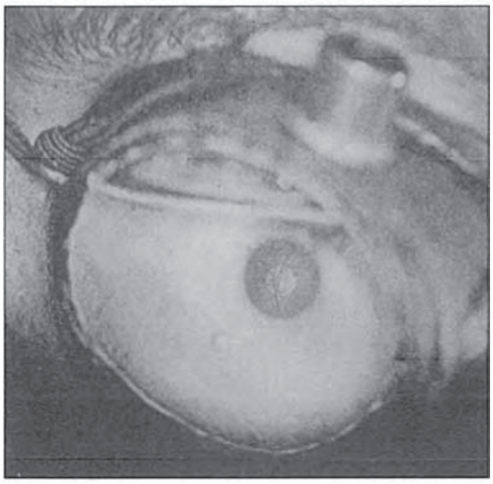


Figure 9 - 18

Fundus Photograph obtained by Gerloff across the "Wasserkammer" (1891).
This reproduction shows the system of ocular contact of the "water chamber". An assembly of rubber bands and ribbons maintains the "water-chamber", with its filling tube above, in place on the soft orbital surface. The posterior pole of the eye, with the optic nerve head and the retinal vessels, is visible across the central part of the "water chamber" window. This is the first sharp retinal photograph of a human eye to be published in the medical literature.
(Oswalt Gerloff, "Ueber die Photographie des Augenhintergrundes", Klinische Monatsblätter für Augenheilkunde, 29, 1891, color plate)

photographierende Auge eine Wasserkammer, deren vordere Wand aus einer planparallelen Glasplatte besteht, so ist der Cornealreflex beseitigt, und es ist gleichzeitig möglich, einen grösseren Theil des Augenhintergrundes zur Anschauung zu bringen. » (41)

Gerloff illustrates his text with the diagram of the "*photographic water-chamber*" and the ophthalmoscopic "*photogramme*", achieved with *Meissner's* technical assistance (42). This represents the first photograph of the human fundus published in the medical literature.

Gerloff briefly described the device he used and included a diagram. He placed it on the subject's eye after anaesthetizing it with cocaine and fixed it firmly against the orbit with a rubber band around the head before filling it with a solution of warm physiological saline:

"Then, the water-chamber was pressed against the orbit with a rubber band round the head and filled with warmed physiologic saline solution."

« *Dann wurde die Wasserkammer durch ein um den Kopf gelegtes Gummiband gegen die Orbita gedrückt und mit erwärmter physiologischer Kochsalzlösung gefüllt.*" (43)

In a note added after publication of *Gerloff's* article, its author added: *"At the last meeting of the ophthalmologists at Heidelberg, Mr. Dr. E. Fick presented photogrammes that are obtained by a technique similar to those described here."* (44)

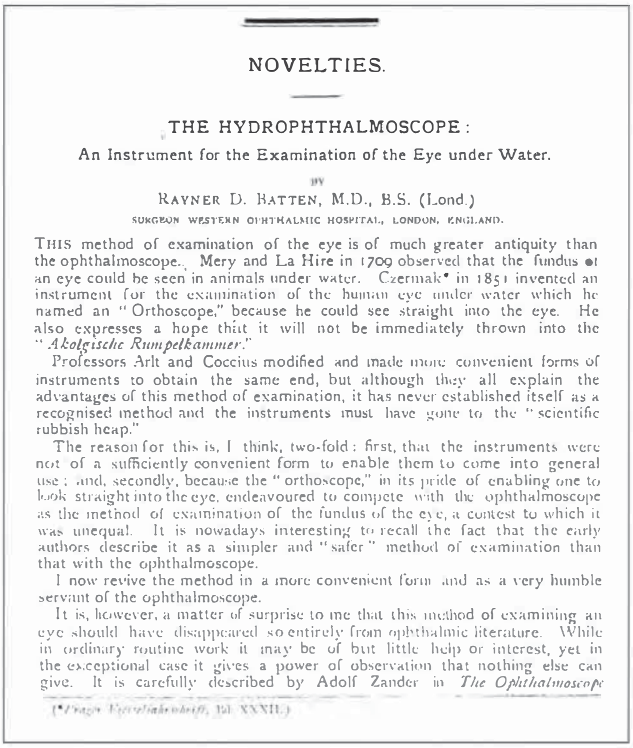
41. Gerloff 1891, p. 399.
42. Meissner will subsequently claim his contribution:
Meissner 1896, p. 275 : "Im Verein mit Dr Gerloff (Goettingen) habe ich bereits vor fünf Jahren eingehende Versuche über die Photographie des Augenhintergrundes angestellt, deren Resultate von Hrn. Dr Gerloff seiner Zeit in den Zehender'schen Monatsheften veröffentlicht wurden [...]. Die sehr üble Eigenschaft der Cornea in Folge ihrer Krümmung Lichtreflexe zu liefern, wurde durch eine vorgesetzte Wasserkammer beseitigt."
"In conjunction with Dr Gerloff (Goettingen), I have already set up experiments on photography of the posterior eye-grounds, some five years before, the results of which were published in his time in the Zehender Monatsblätter [...]. The very frustrating property of the cornea to reflect light due to its curvature was overcome by a water-chamber placed in front of it."
For details of Gerloff's photographic technique: see Dimmer 1907, p. 6-8.
43. Gerloff 1891, p. 401.
44. Gerloff 1891, p. 403: "auf der letzten Ophthalmologen-Versammlung in Heidelberg, hat Herr Dr E. Fick Photogramme vorgelegt, welche nach einer der hier beschriebenen ähnlichen Methoden angefertigt sind". The publication of Gerloff occurred after the presentation of Fick's communication, which was not however published until 1892.

1.10 - Other Users of the Orthoscope Principle

1.10.1 – At the End of the 19th Century

Several authors used *Czermak's* original orthoscope in the years that followed, together with *Gerloff's* water-chamber and the glass slide of *Coccius* for corneal neutralization or trials of fundus photography.

Thus, in 1897, *Karl Wilhelm von Zehender* claimed that he had used these methods from *"the years 1890 or 1891"*, for the elimination of corneal reflections when he was attempting fundus photography (45). This claim appears reasonable, as *Gerloff* made reference to a letter that *Zehender* had sent him on this subject (46). According to *Dimmer*, *Grebe* of Kassel also used *Gerloff's* water-chamber for fundus photography (47).


NOVELTIES.

THE HYDROPHTHALMOSCOPE:

An Instrument for the Examination of the Eye under Water.

BY

RAYNER D. BATTEN, M.D., B.S. (Lond.)

SURGEON WESTERN OPHTHALMIC HOSPITAL, LONDON, ENGLAND.

THIS method of examination of the eye is of much greater antiquity than the ophthalmoscope. Mery and La Hire in 1709 observed that the fundus of an eye could be seen in animals under water. Czermak* in 1851 invented an instrument for the examination of the human eye under water which he named an "Orthoscope," because he could see straight into the eye. He also expresses a hope that it will not be immediately thrown into the "*Akolgische Rumpelkammer*."

Professors Arlt and Coccius modified and made more convenient forms of instruments to obtain the same end, but although they all explain the advantages of this method of examination, it has never established itself as a recognised method and the instruments must have gone to the "scientific rubbish heap."

The reason for this is, I think, two-fold: first, that the instruments were not of a sufficiently convenient form to enable them to come into general use; and, secondly, because the "orthoscope," in its pride of enabling one to look straight into the eye, endeavoured to compete with the ophthalmoscope as the method of examination of the fundus of the eye, a contest to which it was unequal. It is nowadays interesting to recall the fact that the early authors describe it as a simpler and "safer" method of examination than that with the ophthalmoscope.

I now revive the method in a more convenient form and as a very humble servant of the ophthalmoscope.

It is, however, a matter of surprise to me that this method of examining an eye should have disappeared so entirely from ophthalmic literature. While in ordinary routine work it may be of but little help or interest, yet in the exceptional case it gives a power of observation that nothing else can give. It is carefully described by Adolf Zander in *The Ophthalmoscope*

(*Prager Vierteljahrsschrift, Bd. XXXII.)

Figure 9 - 19

Rayner D. Batten "The Hydrophthalmoscope: An Instrument for the Examination of the Eye under Water" (1910)

Rayner Batten, while referring to orthoscopes, described an "hydrophthalmoscope" capable of neutralizing corneal refractive power suitable for ophthalmoscopic examination of patients with high myopia and astigmatism.

(R. Batten "The Hydrophthalmoscope: An Instrument for the Examination of the Eye under Water" The Ophthalmoscope, 8, 1910, p.92)

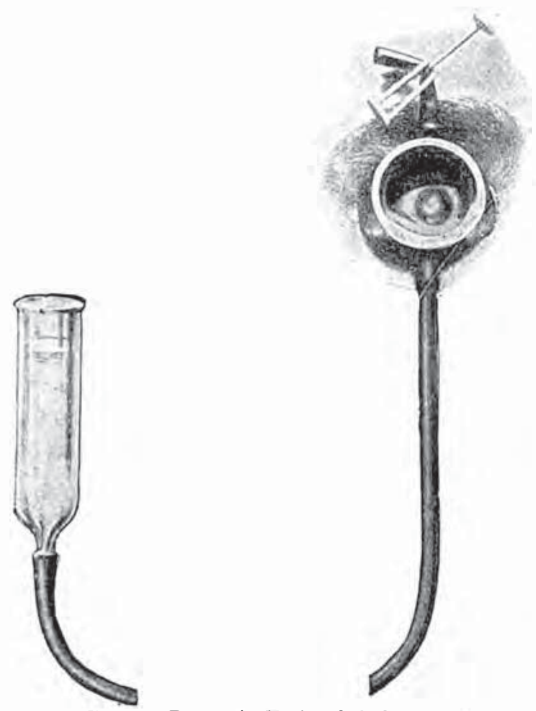
In spite of all these researchers embracing the concept of neutralization of corneal refractive power by contact with water during this epoch, not one clinician had at any time replaced the loss of corneal dioptric power resulting from the use of the orthoscope with a suitable corrective lens, particularly in the grossly distorted corneas of patients affected for example by keratoconus. *Czermak* had however indicated after 1851 the power of a spectacle lens required to compensate for lost corneal refractive power needed for vision through the orthoscope.

1.10.2 At the Beginning of the 20th Century

(Figures 9 –19 & 9 – 20)

In 1910, the London ophthalmologist *Rayner Batten*, while referring to orthoscopes, described an ***"hydrophthalmoscope"*** capable of neutralizing corneal refractive power suitable for ophthalmoscopic examination of patients with high myopia and astigmatism:

45. Zehender 1897, p. 133.
46. Gerloff 1891, p. 403: "ist mir durch Herrn Prof Zehender schriftlich mitgeteilt worden."
"Professor Zehender gave this to me in a personal letter".
47. Dimmer 1907, p. 12-13 : "Es wird die Wasserkammer nach Gerloff verwendet.")
"the water chamber as described by Gerloff was used."



Rayner Batten's Hydrophthalmoscope.

Figure 9 - 20

Rayner D. Batten "The Hydrophthalmoscope: An Instrument for the Examination of the Eye under Water" (1910)

The "hydrophthalmoscope" consists of a metal cup resembling the eye bath, with a plane glass front surface, with two short metal tubes soldered into it for the attachment of rubber tubing. To the upper tube is fitted a short piece of tubing closed with a clip. To the lower tube is attached a rubber tube, terminating in a glass reservoir. For use, the instrument is applied as to hold the upper lid. The reservoir is then raised and the clip opened, allowing the instrument to fill with water. The clip is at once closed, the reservoir is lowered when the instrument should be held in position by succion.
(R. Batten "The Hydrophthalmoscope: An Instrument for the Examination of the Eye under Water" The Ophthalmoscope, 8, 1910, 92- 94)

"The instrument is very simple. It consists of a metal eye bath with a plane glass front, with two short metal tubes soldered into it for the attachment of rubber tubing. To the upper tube is attached a short piece of tubing with a clip sufficiently strong to close it. To the lower tube is attached a rubber tube about 2 ½ ft. long, terminating in a glass reservoir, which consists of a barrel of a 2-oz. glass syringe.
In applying it to the eye, the reservoir should be half filled with warm water or lotion, and given to the patient to hold in his left hand. The cup is then filled over the eye, drawing the eyelids open. The patient is then directed to raise the reservoir above his head, while the surgeon steadies the eye-bath with one hand and holds the clip open with the other. As soon as the water appears in the upper tube the clip is closed and the patient directed to lower the reservoir. When it has been lowered about 10 or 20 in. the eye-bath will be found to be firmly in place." (48)

48. Batten 1910, p. 93-94 and 1920 p. 358-359.

2 - Discussion

2.1 - The Models

The documents relevant to the orthoscopic period cover the years 1851 to 1891. In the course of these forty years, the orthoscope was presented in two different forms: the open orthoscope and the closed,

2.1.1 - The open Orthoscope

The open form of the orthoscope was used by physiologists and anatomists, notably *Czermak*, *Helmholtz* and *Woinow*, who were satisfied with a short contact on a volunteer for the experiment with healthy eyes and the head held horizontally. It was used under experimental conditions in order to examine the ocular media (*Czermak*) and for experiments on accommodation (*Czermak, Helmholtz, Woinow*).

2.1.2 - The closed Orthoscope

The closed version was used by clinicians *Hasner*, *Arlt* and *Gerloff* on a sick eye, on a patient who was not always ready for these investigations. The closed orthoscope allows examination with different angles of incidence, an examination that is often long and repeated. One must take account of the unpredictable lighting conditions available at the time: daylight, artificial light by candle or kerosene (paraffin) table-lamp, aided by mirrors and loupes.

The dissemination of orthoscopes was probably greater than that which is reported in publications; one orthoscope is today in the Ingolstadt Museum (*Haugwitz's* collection of ancient eye instruments) and two are in the Utrecht Museum (*Donders/Snellen* collection).

The Prague School, which included such names as *Czermak*, *Arlt*, *Hasner* and *Coccius*, was engaged during that era with the description of normal and pathological structures of the cornea (49). What is astonishing, however, is that *Hasner* did not make any connection between these various pathological conditions under study and the potential neutralization of abnormal optical power by the "*water-baths*" and "*water-boxes*" which he used. On the other hand, he cannot be criticized for having placed his shell on the periphery of the eyelids and not under them. He did not have a local anesthetic, which would have been necessary had he attempted the trial of a contact shell placed directly on the eye. Topical anesthetics were not available until *Koller* first described the ocular use for cocaine in 1884 (50).

2.2 - Technical Aspects

Czermak's orthoscope was a primitive instrumental device for scientific use, but which was not suitable for routine ophthalmic examination. Fixed to the external orbital margin and

49. For the history of treatment of staphylomas of the cornea and of conical cornea (keratoconus) at this time, see Hirschberg Geschichte des Staphyloma, in Hirschberg Geschichte der Augenheilkunde, III, 8, § 544, Leipzig 1911.
50. For the history of the introduction of local anesthesia into ophthalmology in 1884, see Heitz, 2000.

equipped with a plane lens, it was not watertight and allowed only one attempt, provided that this did not last more than a minute.

The suggestions of *Hasner* and *Coccius* to replace the open container by a glass shell or a closed cube that would have been applied to the soft part of the palpebral periphery inside the orbital rim seem neither to have been known about, let alone followed for nearly forty years.

When *Gerloff* and *Woinow* each utilized and described the orthoscope, in turn, and placed it against the soft orbito-palpebral surface, they did not refer to *Hasner's* article, notwithstanding its publication in the same revue immediately following *Czermak's* article. It is probable that the detailed citation by *Helmholtz* prevented readers from consulting *Czermak's* original article and at the same time *Hasner's*, both of which appeared in the same journal.

2.3 - Physiological Aspects

2.3.1 - The Applications and the Maintenance in Position of the Liquid

The maintenance in position of the liquid depends on the bearing surface of the device and, consequently on how watertight the edge would be. Depending on the period of time, the bearing surface varied from being extra-orbital, orbito-palpebral or ocular.

A - Extraorbital bearing Surface

Czermak applied the orthoscope really outside the orbit, i.e. on the forehead, temples, cheek and orbito-nasal furrow. This produced insoluble problems while trying to achieve watertight junction between the instrument and the skin surface as noted by *Czermak* and by all those who tried to imitate him. *Czermak* tried to achieve waterproofness by using cotton, and then cotton impregnated with wax and then finally bread crumbs ("*mica panis*"):

"I take kneaded 'mica panis' instead of cotton, which fits very nicely on the face and takes the wall of the device very precisely and deeply into itself with firm and steady pressure."

"Ich nehme statt Baumwolle geknetete Mica panis, welches sich an das Gesicht sehr genau anlegt und den Rand des Apparates bei gelindem und anhaltendem Drucke sehr genau tief in sich aufnimmt." (51)

However, the ideal solution was, according to his proposal a gutta-percha cushion. Under these conditions, the orthoscope could not be used for clinical examination, because:

"Apart from the fact that it cannot always be pressed up against the face in a completely watertight fashion, for which reason the cheeks and the clothes of the patient are soaked, the device is open above , and because its inner wall hardly reaches the superior orbital rim, the water reaching the upper end of this wall readily overflows at the slightest head movement of the patient."

51. Czermak 1851.

Abgesehen davon, dass derselbe nicht immer ganz wasserdicht an das Gesicht gedrückt werden kann, und daher die Wangen und Kleider des Kranken befeuchtet werden, so ist er auch oben offen, und da seine innere Wand kaum die Höhe des oberen Orbitalrandes hat, so fliesst bei der geringsten Neigung des Kopfes das bis an den oberen Rand reichende Wasser über." (52)

The concept of a "*custom-made gutta-percha cushion*" which *Czermak* imagined (53) was finally converted into reality by *Gerloff* some forty years later.

Arlt, meanwhile, constructed a bath with walls made from the heat-sensitive malleable latex gutta-percha, which he fitted to the skin surface and secured it there. Subsequently *Hasner* and also *Woinow* used the same method.

B - Orbito-palpebral bearing Surface

It is to the credit of *Hasner* and *Coccius* that they constructed a watertight orthoscope and one they could therefore use at the sick bed (54) by using two modifications.

These were:

a) reducing the dimensions of the device and applying it to the eyelids covering the eye (55),

b) closing off the upper wall of the orthoscope.

In addition, these changes suggested to *Hasner* the concept of using an orthoscope in the form of a dome or cupola. *Gerloff*, without making any reference to or acknowledgement of either *Hasner* or *Coccius* also used an orthoscope resting on the orbito-palpebral rim, the margin of the instrument being rendered watertight by a rubber band (56).

C – Ocular bearing Surface

The contact slide of *Coccius* and the photographic "*contact-spectacle*" of *Fick* are distinguished from orthoscopes by their direct application to the eye. *Coccius* proposes placing the glass cover slip used in microscopy with a drop of water on the cornea, but indicates that the foregoing is not the most comfortable experience. *Fick* benefits from cocaine local anesthesia, which *Koller* introduced in 1884, in order to place a lens cylinder filled with water and covered by a glass disc onto the cornea. His system "*can be fixed without difficulty and without further preparations on the eye and is easy to fill with liquid*" (57).

2.3.2 - The Quality, Compatibility and Toleration of the Liquid.

Neither *Czermak*, nor *Hasner*, nor *Coccius* were concerned about the physico-chemical quality of the liquid used to fill up the device. Probably, the brevity of ocular contact did not impose on them any reflection on this subject or they considered that they were using a physiological liquid. *Czermak* proposed adding white of egg or another viscous substance to the liquid in order to cause it to be better tolerated than just ordinary water, as he had

52. Hasner 1851, p. 167.

53. Czermak 1851, p. 160: "besonders gestaltener Besatz von Kaoutschouc" ("specially formed rubber trimming").

54. Hasner 1851, p. 166: "wie es fürs Krankenbett am bequemsten einzurichten wäre" ("as it would be most comfortably fitted for the patient's bed.").

55. Hasner 1851, p. 167:" im ganzen Umfange an das Auge gedrueckt" ("pressed on the eye over its entire circumference") There is no indication that the device is resting directly on the eye. My understanding is, rather that the device is pushed against the skin of the periphery of the lids covering the eye.

56. Gerloff 1891, p. 401, legend of figure 1: "Rand mit Gummiband befestigt" ("rubber band was attached to the margin of the device").

57. Fick 1892, p. 200: "die sich ohne Schwierigkeit und ohne weitere Vorrichtungen an dem Auge befestigen und mit einer Flüssigkeit füllen lässt".

used initially. *Hasner* stated that the liquid to be used would be better supported if it were to be heated to a lukewarm temperature and *Czermak* took up this recommendation. For his part, *Fick* proposed the utilization of a liquid of an index of refraction close to that of the cornea (58). *Woinow, Gerloff* and *Batten* used lukewarm physiologic saline. *Zehender* reports the appearance of corneal edema when, by mistake, he used distilled water instead of physiological saline:

"By way of experiment, distilled water was once taken instead of saline solution. After a certain time - I cannot say exactly how long the experiment lasted - I noted that the fundus could no longer be seen clearly. After removing the device from the eye, I noticed to my not inconsiderable astonishment that the entire cornea had become completely cloudy. The cloudiness disappeared however very quickly; it could not be explained other than as the result of edematous infiltration of the cornea in consequence of contact with salt-free water."

„Versuchsweise wurde einmal, anstatt der Salzlösung, destilliertes Wasser genommen. Nach einiger Zeit – die Versuchsdauer kann ich nicht mehr angeben – bemerkte ich, daß der Augengrund nicht mehr deutlich zu sehen war. Nach Abnahme des Apparates fand sich zu meinem nicht geringem Erstaunen die ganze Hornhaut vollständig trübe. Die Trübung verlor sich zwar bald wieder; sie konnte nicht anders als durch ödematöse Infiltration der Hornhaut in Folge des Contactes mit dem salzlosen Wasser erklärt werden. » (59)

2.3.3 - Optical Aspects

A-The Quality of the Optical Surface substituted for the Neutralized Cornea

Czermak had fitted his orthoscope with a glass plate. However, he calculated the power of a lens, which would compensate for the neutralized cornea, but his paper did not refer to the incorporation of such a lens in front of or inside the orthoscope.

Hasner advocated using a curved device (60). The context leads us to suppose that he had made experiments with glass cups, probably made of blown glass. The first attempts failed because of the shallow depth of the hemisphere and he then turned to a deeper cup with a larger volume, so as not to interfere with movement of the eyelids (61). Anticipating criticism of a shell with curved surface, *Hasner* also proposed the construction of a *"device with straight surfaces, then one could simply cut in a glass cube, the posterior wall of which would be open and the four walls would be ground to fit the periorbital area."* (62). Therefore *Hasner* did not make mention of optical correction by the curvature of the glass. *Arlt* utilized a container with a glass plate placed obliquely, from front to back, that would permit a better elimination of the reflections of the illumination available at the time: candle, paraffin oil lamp or natural illumination.

58. For the details of this incorrect proposition, see Chapter X: Adolf Eugen Fick's Contactbrille.
59. Zehender 1897, p. 133.
60. Hasner 1851, p. 167: "mit krummen Oberflächen." ("with curved surfaces").
61. Hasner 1851, p. 167-168: "Dies veranlasste mich, den Versuch mit gläsernen Augenwannen anzustellen, welche im ganzen Umfange an das Auge gedrückt werden. [...] Die bisher angewendeten Wannen boten, weil sie zu klein waren, den Augenlidern nicht genügenden Spielraum. [...] Ich habe mir daher eine solchen Augenwanne von größerem Rauminhalt anfertigen lassen."
("I arranged to set up the experiment with glass eyecups, which were pressed over the whole area surrounding the eye. [...] The previously used cups did not allow enough play for the eyelids because they were too small. [...] I had, for that reason, prepared for myself such an eyecup of greater capacity.")
62. Hasner 1851, p. 168: "Wollte man durchaus einen Apparat mit geraden Oberflaechen, so koennte wohl ein Cubus aus Glas geschliffen werden, dessen hinteren Wand offen, und dessen hintere vier Raender der Umgebung des Auges entsprechend zugeschliffen sind." ("If one wished, all said and done, to have a device with straight surfaces, then one could simply cut in a glass cube, the posterior wall of which would be open and the four walls would be ground to fit the periorbital area.")

Nevertheless, neither *Hasner* nor his successors, notwithstanding their confrontation by various corneal pathologies ever attempted, at least to our knowledge, the production of any optical correction of the neutralized cornea.

B-CORNEAL DIOPTRIC POWER NEUTRALIZATION BY A LIQUID

The concept that the cornea could be neutralized by a liquid placed against it, seemed to be accepted by the scientific and medical community of the end of the 19th century.

The objective of *Czermak* in conceiving and constructing the orthoscope was to make observations on the actual topographical relationships of the structures comprising the anterior chamber of the eye, with particular reference to the anterior crystalline lens surface, which was thought by certain observers to change position with accommodation. The true living anatomy of the iris, also described by *Czermak*, became more fully established and recognized when *Helmholtz* took up this subject in detail, with a diagram and a description of the orthoscope.

Hasner and *Arlt* adapted the basic design of the instrument for clinical examination of the anterior segment of the eye, using the protocol proposed by *Czermak* for its topographical study. This new clinical application of the orthoscope caused them to modify the instrument *Czermak* had invented.

Coccius referred to the experiment of *Jean Méry* interpreted by *Philippe de La Hire* for the examination of the fundus across a liquid surface. *Czermak* reminds us that it was *Francois-Pourfour du Petit*, who had already described and made use of an instrument for neutralization of corneal refractive power in order to study the anatomy of the anterior segment (63).

C-ELIMINATION OF CORNEAL REFLECTION

The first paper of *Czermak* and that of *Hasner* made no mention of the elimination of corneal reflection. Subsequently, *Czermak*, following modifications made by *Arlt*, gave more emphasis to that aspect. *Fick* and *Gerloff* neutralized the corneal reflection when they carried out their photographic experiments, suggesting to *"cover the cornea with a plane bordered layer of water" (Fick)* (64) and, by interposing *"a water-chamber, of which the anterior wall consists of parallel-sided glass plate"* and happened to make the remark that *"you can get the same result with a glass cover-slip using Dr Coccius-Ballarminoff's method"* (*Gerloff*). (65)

D-INCREASE IN HYPEROPIA

Czermak made a good description of the increase in hyperopia that occurred as the result of neutralization of corneal dioptric power. He even calculated the power of the lens required to make this correction, but neither he not his successors envisaged optical correction. The enlargement of the retinal image that resulted from the increase in hyperopia of the eye was utilized by *Fick* to improve the photographic result.

63. For Méry see Chapter V: Jean Méry's Neutralization of Corneal Dioptric Power in a Living Eye. For Petit, see chapter VI: François-Pourfour du Petit's Neutralization of Corneal Dioptric Power.
64. Fick 1892, p. 200: "Bedecken der Hornhaut mit einer eben begrenzten Wasserschicht."
65. Gerloff 1891, p. 399: "eine Wasserkammer, deren vordere Wand aus einer planparallelen Glasplatte besteht". There is a return to the following remark at the bottom of the page: "Man wird auch wohl mit einem Deckglas nach Dr. Coccius-Bellarminoff'schen Methode Ähnliches erreichen können".

2.4 - The Applications of the Orthoscope

A-For Studies of anatomical Topography

Czermak was the initiator of the study of the anatomical topography of the anterior segment that *"gives to the physiologist the opportunity to study a living eye in its true relationships"* (66). *Helmholtz* makes particular note of this point:

"In order to obtain a true observation of the iris in the living eye, J. Czermak has introduced an instrument called 'orthoscope' that consists essentially of a small bath with glass walls. [...] From the lateral view, the cornea protrudes forwards like a transparent vaulted bladder, whereas the iris falls back from it like an almost flat curtain.

« Um am lebenden Auge eine richtige Anschauung von der Iris zu erhalten, hat J.Czermak ein Instrument angegeben unter dem Nahmen Orthoskop, welches im Wesentlichen eine kleine Wanne mit Glaswänden ist. » [...] « Die Hornhaut tritt von der Seite gesehen als eine durchsichtige gewölbte Blase hervor, die Iris tritt als ein fast ebener Vorhang von ihr zurück. » (67)

B-For medical Diagnostics

The objective of *Hasner, Arlt* and *Coccius* was the use of the orthoscope and the "contact glass-slide" for diagnosing the topography of pathological entities in the anterior segment of the eye. *Fick* and *Gerloff* neutralized corneal dioptric power for fundus photography.

C-For Ophthalmoscopy

Coccius examined the retina through a glass plate, with a drop of water placed on the cornea. *Czermak, Arlt* and *Coccius* practiced ophthalmoscopy through an orthoscope. *Gerloff* and *Fick* actually neutralized corneal dioptric power with a contact device and made use of the enlargement obtained as the result of this in order to produce the first "*ophthalmoscopic photogramme*". *Batten* used a "*hydrophthalmoscope*", but with very limited success.

D-For therapeutic Applications

The therapeutic application of orthoscopes, e.g. with the contact of an antiseptic liquid on a corneal lesion was not envisaged by any of the cited authors.

2.5 - Terminology

The term *orthoscope*, which *Czermak* proposed was a good definition for an instrument destined to allow observation of the anterior segment of the eye through the cornea, but avoiding the refractive hindrance imposed by the power of the cornea and anterior chamber. The observer's *view* passes *right through* the cornea to the object of his regard. The term, as *Helmholtz* cautioned, would be used as a term of reference, even for devices derived from the orthoscope, i.e. closed devices, watertight devices and those of smaller dimensions.

66. Czermak 1851, p. 161: "gibt dem Physiologen Gelegenheit, ein lebendiges Auge in seinen wahren Verhältnissen zu studieren."
67. Helmholtz 1864, p. 14.

The authors used equivalent terms in order to designate their instruments: *Czermak* himself speaks of *"Kästchen"* (small box) before defining the term "orthoscope". *Hasner* occasionally uses the term *"Augenwanne"* (eye-bath) to designate the orthoscope and *Coccius "Glaswanne"* (glass-bath). *Helmholtz* described the orthoscope as a bath. *Gerloff* speaks of a *"Wasserkammer"* (water-chamber). It is not surprising that *Fick* uses the term *"Contactbrille'* (contact-spectacle) that he invented in 1888 for his description of the first contact glass.

2.6 - The Orthoscopes and the Neutralization of Corneal Refractive Power

The orthoscopes are, without any doubt, systems for the neutralization of corneal refractive power and for the elimination of corneal reflection. These effects were not researched with the intent to make an optical correction, but, rather, for the topographical and diagnostic examination of the ocular media, both normal and pathological. The orthoscopes made known the principle of neutralization of corneal refractive power and the elimination of corneal reflection by the apposition of a liquid.

Orthoscopes are the direct precursors of the "hydrodiascopes", instruments that were equipped with corrective lenses and used from 1896 to 1916 (68). There are also distant precursors of other instruments based on the neutralization of corneal dioptric power, notably contact lenses.

One can conclude, therefore, that *Czermak's* orthoscope was an experimental set-up for scientific use that he employed for the optical neutralization of the anterior corneal surface, when he was studying physiological optics and topographical anatomy.

After its citation by *Helmholtz,* the orthoscope also became a reference tool for the observation of the ocular media by virtue of the neutralization of the refractive power of the cornea and of the elimination of the corneal reflection. Its application external to the orbital cavity, however, made *Czermak's* orthoscope unusable for a period of time longer than just a few minutes.

The merit for having transformed the orthoscope into an instrument adapted to clinical practice should be credited to *Hasner, Arlt* and *Coccius.* Keeping the term of "orthoscope", *Hasner* and *Coccius* were the first to conceive a waterproof instrument that would rest on the peripheral cutaneous surface of the eyelids, inside the orbital rim.

Curiously, these authors are never cited, nor by *Gerloff* who used a similar instrument for fundus photography, nor later by *Lohnstein*, who did not hesitate to claim that he was the inventor of an orthoscope model loaded with corrective lenses, under the denomination of "hydrodiascope".

68. See Chapter XIX: The Era of Hydrodiascopes.

3 – A short History of Citations, Omissions and Misinterpretations

The important step of the orthoscopes is rarely cited in histories of ophthalmology. Nevertheless, this step of the first practical application of the neutralization of corneal refractive power therefore represents an important landmark. *Czermak's* discovery paved the way towards the following studies and inventions:

- topographical anatomy of the anterior segment of the living eye,
- observation of their true dimensions and topography of pathological processes in the anterior segment,
- ophthalmoscopy, because orthoscopes and derivative techniques allowed elimination of corneal reflections,
- ocular fundus photography,
- hydrodiascopes for correction of keratoconus,
- diagnostic contact lenses for the observation of both normal and pathological intraocular structures,
- contact lenses for the optical correction after neutralization of an abnormal ocular refraction.

Nevertheless, the active participants in this important step in the history of the neutralization of corneal dioptric power are seldom cited by historians of ophthalmology and never by contact lens historians.

Hirschberg however did draw attention to the importance of *Czermak's* discovery and to the papers of *Coccius* and *Arlt.* Such descriptions chiefly related to articles connected to the history of ophthalmoscopy.

Duke-Elder shows also the importance of these papers for the examination of the fundus:

"About the middle of the 19th century a great deal of ingenuity was expended on various alternative methods of viewing the fundus. Czermak (1851) introduced the orthoscope or hydro-ophthalmoscope, wherein a glass box filled with water is fixed in front of the eye so that the corneal refraction is eliminated, thus rendering the fundus more easily visible: this led to several modifications and may be considered the forerunner of the contact glass." (69)

This author also cites *Czermak* in the chapter on anatomy, but omits to mention *Coccius, Arlt, Gerloff* and *Fick:*

"As seen in the living eye, the image of the iris is magnified by about one eighth, since the cornea and aqueous act as a plano-convex lens (v. Helmholtz, 1856); moreover it seems nearer to the cornea than it actually is and appears to be convex. If, however, the eye is viewed through a box with glass sides filled with water so that the corneal refraction is eliminated, it appears in its natural form and position (the "orthoscope" of Czermak, Prag. Vjschr. Prakt. Heilk. 32, 154, 1851)." (70)

69. Smith in Duke-Elder VII 1962, p. 293-294. Note the mistake of this author, who attributes invention of the hydrophthalmoscope not to Batten (1910), but to Czermak (1851).
70. Duke-Elder II 1961, p. 168.

It seems that only *Levene* gave the most comprehensive references, but he used second hand sources (71):

"We could say that the de La Hire explanation not only provided the first correct explanation of the phenomenon, but that his discovery of the means whereby the eye could be examined under water laid the foundations for the later nineteenth century orthoscope of Czermak, later modified by von Arlt, and the "Bain of Coccius". The orthoscope, although by no means a replacement for the ophthalmoscope, forms an obvious link in the development of methods for examining the interior of the eye, and is also directly related to the concept of corneal neutralization and the contact lens. The orthoscope was essentially a polished plain glass-side box, with the top and one of its four sides missing. The subject face completed the missing, or posterior, side. Water was then introduced into the open top and the box could thus be filled. In order that there should be no leakage, the edges were " sealed" with vulcanized tubing. The box was provided with a small hard ring underneath, so that it could be held up against the face." (72)

Amongst the contemporary historians of the neutralization of corneal dioptric power, one would search in vain for an allusion to the invention and the descriptions of the orthoscopes of *Czermak, Arlt* and *Coccius. Albert* alone refers to *Fick's* photographic immersion procedure:

"Adolph Eugen Fick (1852-1937) was the first to use an indirect ophthalmoscope in fundus photography, he also used a water chamber to attempt to eliminate the corneal reflex." (73)

71. According to the notes 48 and 49, p. 315.
72. Levene 1977, p. 305. Note the mistake of this author, who positions Czermak's invention of the orthoscope not in 1851, but "at the end of the XIXth Century".
73. Albert 1996, p. 198. The text refers to figure 10.25 with the legend "Adolf Eugen Fick", the portrait is however mistaken, representing probably his paternal uncle who was also called Adolf. Adolf Rudolf Fick (1829-1901) was Professor of Physiology at Zurich and subsequently at Würzburg, invented a tonometer and described what became know as "Fick's law of diffusion."

Biographical Notices

George Biddel Airy

Airy, George Biddel (1801 – 1892)

George Airy was born in Northumberland as the eldest of four children of a farmer who through self-education acquired a post in the Excise. He spend most of his time with his uncle *Arthur Biddel*, a well-educated man who had a fine library containing books on chemistry, optics and mechanics. In 1819, he entered Trinity College, Cambridge with the financial support provided by his uncle. He graduated and in 1823 was awarded a fellowship at Trinity College. This allowed him to begin his academic career. In December 1826, he was elected *Lucasian* Professor of Mathematics at the University of Cambridge. In 1828, *Airy* was appointed *Plumian* Professor of Astronomy at the University and Director of the Cambridge Observatory. In 1835 he became Astronomer Royal and moved to Greenwich. He held this post until 1881 when he resigned and lived the rest of his life with his two unmarried daughters. *Airy* published eleven books on mathematics and over 500 printed papers. He liked poetry, history, theology, antiquities, architecture, engineering and geology. He also published papers on his other interests.

Albertus Magnus (ca. 1200 – 1280)

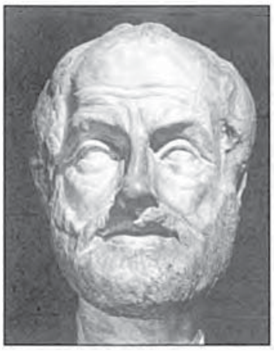
Albertus Magnus, scientist, philosopher and theologian was also known as "Albert the Great" and "Universal Doctor". He was born in approximately 1200 in Swabia and died in 1280 at Cologne. He was proficient in every branch of knowledge in his day and surpassed all of his contemporaries, with the possible exception of *Roger Bacon*. After his scholastic education, he studied at the University of Padua. In 1223 he joined the Order of St Dominic. In 1245 he received his doctoral degree at the University of Paris. Elected as Provincial of his Order in Germany, he journeyed to Rome and was appointed as a Bishop in Ratisbon. He was beatified in 1622 and canonized in 1931.

His complete works (*Opera Omnia*) contain various treatises on logic, physical sciences, biology, psychology, moral, theology and other subjects. Concerning the experimental sciences, *Albert* concentrated on various sources of information, as time permitted, and especially upon the scientific writings of *Aristotle*. His appreciation of *Aristotle* is critical. Like his contemporary, *Roger Bacon*, he was an indefatigable student of nature. He applied himself so energically and with such remarkable success to the experimental sciences that he was accused of neglecting the sacred sciences. He was an authority on physics, geography, astronomy, mineralogy, chemistry, physiology and, of course, optics and vision sciences.

Alhazan [Ibn Al-Hayatham] (965 – ca. 1039)

Alhazan (the Latinised form of the first name of *al-Hasan Ibn al-Haytham, Abu 'Ali al-Hasan Ibn al-Hasan*) was an Arabic-Islamic mathematician and philosopher. He was born in Basra on the Persian Gulf and died in Cairo. In regard to his life, there are several reports, but these are not always consistent. The subjects on which *Alhazan* wrote include logic, ethics, politics, poetry, music and theology; but neither his writings on these subjects nor the summaries he made of *Aristotle* and *Galen* have survived. His extant works belong to the field in which he was reputed to have made his most important contribution, namely optics, astronomy and mathematics.

Alhazan's theory of light and vision is neither identical with nor directly derived from any one of the theories known to have previously existed in antiquity or in Islam. His major work, the "*Optics*" or "*Kitab al-Manâzir*", is not a philosophical dissertation on the nature of light, but, rather, an experimental and mathematical investigation of its properties, with particular reference to vision. In his description of the eye, he adapted the geometry of his diagrammatic construction of that organ to suit his own explanation. Specifically, he assumed that both surfaces of the cornea opposite the pupil were parallel to the anterior surface of the crystalline "humor", each of these surfaces being spherical and having the centre of the eye as common centre. *Alhazan* also gave considerable space to the theory of refraction and stated the results of his experiments as rules that govern the relationships between the angle of incidence and the angle of deviation. In other works, *Alhazan* wrote on the light of the moon, halos, the rainbow, on spherical and paraboloidal burning mirrors, on burning spheres, on the formation of shadows and so on. Of all the optical treatises of *Alhazan* only the *Optics* and the *Treatise On Parabolic Burning Mirrors* are known to have been translated into Latin in the Middle Ages. The first Latin translations appear in the late twelfth or early thirteenth century entitled *Pespectiva* or *De Aspectibus*. Through these Latin translations *Alhazan's* doctrine was successfully conveyed to medieval, Renaissance, and seventeenth century philosophers in the West. *Bacon's Perspectiva* is full of references to *Alhazan*. *Pecham's Perspectiva communis* was composed as a compendium of the *Alhazan's Optics*.



Aristotle

Aristotle (ca. 384 – 322 B.C.)

Aristotle was a Greek philosopher and the so-called "father of the Natural Sciences". He spent twenty years in the company of Plato. After that, he was called to Macedonia, where, at the court of *Philip of Macedon*, he was appointed instructor to *Philip's* son *Alexander*, who was afterwards known as "Alexander the Great". *Aristotle* wrote numerous observations concerning human and animal eyes. These can be grouped as those relating to the human eye, including its anatomy, its physiology (as well as his theory regarding the nature of light), the pathology of the eye (for practical purposes, limited to errors of refraction and presbyopia) and his observations on the animal eye.

Ferdinand Ritter von Arlt

Arlt, Ferdinand Ritter von (1812-1887)

Carl Ferdinand Ritter von Arlt (1812 – 1887) was an Austrian ophthalmologist, who was born in Bohemia. He graduated in Prague in 1839. From October 1846 to July 1849 he worked as a supernumerary ophthalmologist and Assistant to the Professor of Ophthalmology in Prague. From August 1849 to July 1856, he served as Professor of Ophthalmology in Prague and from autumn of 1856 to July 1883 as Professor of Ophthalmology in Vienna. He lectured with world-renowned success at the University Eye-Clinic in Vienna. *Arlt* was undeniably one of the "pathfinders" in ophthalmology and influenced the development of the specialty of ophthalmology. His brilliant lectures attracted large numbers of students and a long succession of oculists who afterwards became famous were trained by him. One of them was *Albrecht von Graefe*. *Arlt* was a prolific writer, who wrote numerous books and articles. In 1855 he became, with *Franz Cornelis Donders*, a co-editor of *Graefe's Archiv für Augenheilkunde*.

Roger Bacon

Bacon Roger (ca. 1220 – 1294)

Roger Bacon was historically referred to as "Doctor mirabilis". He was an English scholastic philosopher, scientist and educational reformer. He was a major medieval proponent of experimental science in the middle ages. Educated at Oxford and Paris, he joined the Franciscan order in 1250. Well-versed in the classics, he also enjoyed the advantages of an early training in geometry, arithmetic, music and astronomy. *Bacon* was learned in Hebrew and in Greek and stressed the value of knowing the original languages in the study of *Aristotle* and of the Bible. He had an interest in natural science that was far in advance of his time, as well as in controlled experiments and the accurate observation of natural phenomena. He lectured at the University of Paris on *Aristotelian* and pseudo-*Aristotelian* treatises. In around the year 1247 and after his return to the University of Oxford and the influence of *Grosseteste*, he devoted himself to the study of optics, alchemy, astronomy and mathematics. *Bacon* did have a sort of laboratory for experiments and carried out some systematic observations with lenses and mirrors. He described spectacles, which also soon came in use, elucidated the principles of reflection, refraction and spherical aberration. He used a camera obscura to observe eclipses of the sun. *Bacon's* writings were numerous. Three of his most important works were written for *Pope Clement IV*: the *Opus Majus* (Great Work), the *Opus Minor* (Lesser Work) and the *Opus Tertium* (Third Work). Under attacks on the theologians and scholars *Bacon* was condemned to prison for certain "suspected novelties" in his teaching.

Brisseau, Michel (1676 – 1743)

Michel Brisseau was a French physician, anatomist and surgeon. He was the son of *Pierre Brisseau* (1631 – 1717), a senior surgeon to the French Royal Army in Flanders. *Michel* was born in Tournay, he studied medicine and surgery, enrolled to the Army and became "Médecin-Major des Hôpitaux du Roy" (Senior Surgeon to the Royal Hospitals in Flanders). In 1705, he wrote a letter to the French Academy of Sciences, claiming for the first time that cataract is the crystalline lens which has become opaque and that pushing down of the cataract consist of pushing down the crystalline lens and not pushing down of a membrane situated in the space behind the iris. In 1709, he summarized his observations on this "new theory on cataract" in his famous book *Traité de la Cataract et du Glaucoma*. In 1712, he became Professor of Anatomy and Surgery at the University of Lille/Douay. He quickly became a reputed eye-surgeon. He sent several observations to his friend *François-Pourfour du Petit* for him to read before the French Academy.

Coccius, Ernst Adolf (1825 - 1890)

Ernst Adolf Coccius was a German ophthalmologist, who studied at the Universities of Leipzig, Prague and Paris. After his return from Paris to Leipzig, he served for some years as assistant and "Privat-docent". In this period, he published two ground-breaking publications: *Ueber die Ernährungsweise der Hornhaut und die Serumführenden Gefässen im menschlichen Körper* (1852) and *Ueber die Anwendung des Augenspiegels nebst Angabe eines neuen Intrumentes* (1853), describing the neutralization of corneal dioptric power with a drop of water under a glass plate through which an examiner can visualize the fundus. *Coccius* was one of the earliest physicians to use the ophthalmoscope, and in fact was the first to make an important modification to the instrument that *von Helmholtz* invented.

Cramer, Anthonie (1822 – 1855)

Anthonie Cramer was a physician from the Netherlands, who received his M.D. degree from the University of Groningen in 1844. As member of the editorial board of the journal *Tijdschrift der Nederlandische Maatschapij tot Bevordering der Geneeskunde*, he described the correct anatomical position of the iris and also the orthoscope. He published in 1853 his essay on the orthoscope, *Ueber Czermak's Orthoskop*. *Cramer's* other researches concentrated on the accommodative process of the eye. He died at the age of 33 years.

Czermak, Johann Nepomuk (1828 – 1873)

Johann Nepomuk Czermak was an Austrian-German-Czech physiologist, who was born in Prague. His father and grandfather were physicians in Prague, whereas his uncle was Professor of Anatomy and Physiology in Vienna. *Czermak* studied in Prague, then in Vienna, and Breslau (the modern Wroc³av in Poland). He gained early benefits from the advice and sponsorship of *Purkinje*, who was then Professor of Physiology in Breslau. *Czermak* received his doctorate in Prague, became Professor of Physiology at Graz, followed by Krakow, then Pest. He fled from the anti-German Hungarian nationalist movement and opened his own private Neurophysiological Institute in Prague. In 1860 he became Fellow and Professor of Physiology at the University of Jena and, in 1865, he followed a call to Leipzig. Unable to comply with the requirements arising from the national aspirations of Czechs, Poles, and Hungarians to develop teaching in their own languages at their national universities, *Czermak* had to move several times and worked for some years as independent scientist. He improved and disseminated the use of the laryngoscope; because of this, he is usually regarded as the "Founder of Modern Laryngology". In 1851, *Czermak* conceived the "orthoscop", described the neutralization of the anterior dioptric power of the eye, and used this for the three-dimensional examination of the eye, both for anatomic and physiologic studies and for ophthalmoscopic diagnosis.

Daviel being conducted to immortality

Daviel, Jacques (1693 – 1762)

Jacques Daviel was a French physician and surgeon, also the first to operate on a cataract through a corneal incision. *Daviel* studied surgery at Rouen and Paris, was an assistant army surgeon and also served in numerous hospitals and as galley-surgeon. In 1720, he was a volunteer for Marseille and the surrounding district that was afflicted by the plague. In 1735, he began to devote himself to the study of eye diseases. In 1745 he extracted a crystalline lens through a corneal incision. In 1752 he presented his method to the Paris Academy of Surgery. In 1762, *Daviel* died in Geneva. His tomb, which is situated in the town Grand-Saconnex, was restored in 2002 with a contribution from the French Society of History of Ophthalmology (the birth date was rectified from an erroneous and usually cited 1696 to the true date of birth in 1693).

René Descartes

Descartes René (1596 – 1650)

René Descartes was a French philosopher and the so-called "father of the newer philosophy". His Latinized name was *Cartesius*. He received his education at La Flèche Jesuit College, which had just been founded by the king. There he studied Classics, Logic, and Traditional *Aristotelian* Philosophy. The only subject who gave him satisfaction was Mathematics. He was granted permission to remain in bed until 11 o'clock in the morning because his health was poor and he maintained that habit until the year of his death. *Descartes* spent a certain time in Paris, then he studied in Poitiers, where he received a law degree, then enlisted in military school. After two years in Holland, he traveled throughout Europe, joined the Bavarian army and spent time in Bohemia, Hungary, Germany, Holland, France and Italy. In 1628 he decided to settle down in Holland and began work on his treatise on physics *Le Monde ou Traité de la Lumière*. When *Galileo* was condemned he decided not to risk publication. *Descartes* then wrote his major work under the titre *Discours de la Méthode pour bien Conduire sa Raison et chercher la Vérité dans les Sciences*, with three appendices : *La Dioptrique*, *Les Météores* and *La Géométrie*. This treatise was published at Leyden in 1637. The work describes what *Descartes* considers as a more satisfactory means of acquiring knowledge than that presented by *Aristotle's* logic. Only Mathematics, *Descartes* feels, is certain, so all logical thought must be based on Mathematics. *La Dioptrique* is a work on optics and, although *Descartes* does not cite previous scientists for the ideas he puts forward, there is, in fact, little new. However his experimental approach was an important contribution. *Descartes* visited France in 1644 and again in 1647. In 1649 Queen *Christina of Sweden* persuaded him to visit Stockholm. Unfortunately he died after only a few months in the cold northern climate. His body was repatriated to France after his death and his skeleton is now in a tomb side by side with the tombs of *Mabillon* and *Montfaucon* in the Church of *Saint-Germain* in Paris. His skull is also preserved in Paris in a showcase in the *Musée de l'Homme* at the side of a pithecanthropus skull.


Friedrich Dimmer

Dimmer, Friedrich (1855 – 1926)

Friedrich Dimmer was an Austrian ophthalmologist, who was also the assistant of *Arlt* in Vienna, and he later became the Professor of Ophthalmology in the Universities of Innsbruck, Graz and Vienna. He developed many techniques for fundus photography that are summarized in his book, *Die Photographie des Augenhintergrundes* (Wiesbaden 1907).

Dodart, Denis (1634 – 1707)

Denis Dodart was a French physician, who graduated from the Faculty of Medicine in Paris, and become Professor at the School of Pharmacy in Paris. He had the title, but did not perform the function of physician-adviser to King *Louis XIV*. Most of *Dodart's* scientific activity took place within the framework of the Académie des Sciences of which he was a member. He was involved in the first debates on the anatomical position of cataract.


Franciscus Cornelis Donders

Donders, Franciscus Cornelis (1818 – 1889)

Franciscus Cornelis Donders was one of the greatest ophthalmologists of the 19th century. He attended Latin school, from with he graduated in 1835. He studied at the army medical school in Utrecht, was appointed health officer and in 1840 received the M.D. degree from the University of Leyden. In 1848, he became

Professor Extraordinarius in Anatomy and Physiology at the University of Utrecht. Little by little and because of his investigations into the anatomy and physiology of the eye, he was drawn to the specialty in which he was soon to become so famous. In 1851, he met *Albrecht von Graefe* in London at the house of the noted English oculist, *Sir William Bowman*. From this time, *Donders* devoted himself exclusively to ophthalmology. In 1852 he was made Professor Ordinarius of Ophthalmology in Utrecht. From that time forward he wrote more brilliantly than ever. His masterpiece was entitled *On the Anomalies of Accommodation and Refraction of the Eye with a Preliminary Essay on Physiological Dioptrics* (ed. New Sydenham Society, 1864). He also wrote innumerable other papers as well as other publications and acted as co-editor with *Arlt* of the *Graefe's Archiv für Ophthalmologie*. He founded a hospital for patients with eye diseases and invented a number of ophthalmic instruments and testing devices. In 1853, he inspired his pupil *Van Tright* to undertake his thesis on ophthalmoscopy and neutralization of the corneal dioptric power.

Fabrici, Girolamo (or Fabricius ab Acquapendente, Geronimo Fabrizio) (ca. 1533 – 1619)

Girolamo Fabrici

Girolamo Fabrici was both an anatomist and a surgeon. He was born in Acquapendente (near Orvieto, Italy). He first studied Greek and Latin at the University of Padua, then logic and philosophy. He went on to study medicine and took his degree in medicine and philosophy in Padua approximately in the year about 1559. He was pupil of *Gabrielle Falloppio*, and whom he succeeded as teacher of anatomy. Later he was nominated by the university to lecture in both anatomy and surgery. He retired from teaching in 1613, having served the University of Padua for near fifty years. As a scientist, *Fabrici* was an indefatigable and scrupulous observer, describing his results with exactitude. He was one of the most celebrated surgeons in the Renaissance period. He published the results of his observations on anatomy and surgery in several volumes. He is remembered for his study of the valves of the veins in the human body and as teacher of *William Harvey*. His descriptions of the ocular operations are essentially taken from the Greek and the Arabian tradition.

Fick, Adolf Eugen (1852 – 1937)

Adolf Eugen Fick was a German ophthalmologist and lecturer (Privat-docent) at the University of Zurich, Switzerland. He invented contact lenses in 1888, designating these as "Contactbrille" (contact-spectacles). In 1890, he used the principle of his newly discovered contact lenses to neutralize corneal dioptric power and eliminate corneal reflection. This enabled him to carry out fundus photography in a living rabbit. (A more detailed biography of *Fick* will be published in volume two of this History)

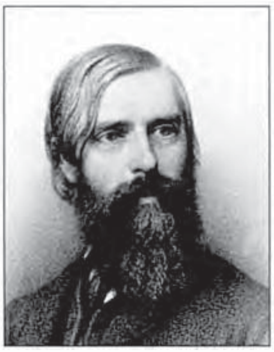
Fontenelle, Bernard le Bouvier (1657 – 1757)

Bernard de Fontenelle was a French philosopher and writer, who was born in 1657 and died in 1757. He was elected to the French Academy in 1691 and the Royal Academy of Sciences in 1697. He was named Permanent Secretary to the latter. In this capacity he was to devote himself to the dissemination and popularization of scientific advances that occurred during his era. His preface, together with commentaries and biographies was published in a clear elegant style that united science with literature that earned him a substantial audience. His famous observations and commentaries on the presentations of *La Hire, Méry* and *Pourfour du Petit* are essential to understand the context of this presentation and the state of knowledge of the epoch. If we take into consideration his faith in scientific advances and his belief in the rational allied with his hostility to what was obscure, it will be clear why *Fontenelle* is considered to be the first philosopher of the "Century of Light".

Galen

Galen (ca. 130 – ca. 200)

Galen was both physician and philosopher (the frequently cited forename *Claudius* is not documented). He lived six centuries later than *Hippocrates* and represents the apex of the Hellenistic medical tradition. It could be said that *Galen* symbolized the pinnacle of the best of the work of the Greek medical schools, which had preceded his own time. It is essentially in the form of *Gallenism* that Greek medicine was transmitted to the scholars of the Renaissance. *Galen* was born at Pergamon where he received instruction in philosophy. He became a "therapeutes" (attendant) to the god *Ascleipios*, the god of healing, whose sanctuary was in Pergamon. He furthered his medical education in Smyrna, Corinth and Alexandria. After he had returned to his native city, he gained practical experience as physician to the gladiators. By A.D. 161 he left Pergamon for Rome, where he established a medical practice and quickly became part of the intellectual life of the capital. He held public anatomical lectures and gave demonstrations. *Galen's* work fell into three main categories: medical, philosophical and philological. His medical writings encompassed nearly every aspect of medical theory and practice in his era. It is difficult to overstate the importance of *Gallen's* work for European medicine in the centuries that followed the fall of Rome and modern times.



Albrecht von Graefe

Graefe, Albrecht von (1828 – 1870)

Albrecht von Graefe was one of the greatest ophthalmologists of all time and was the inventor of iridectomy for glaucoma and the method of linear extraction for cataract. He received his early education at the French Gymnasium in Berlin, and then entered the study of medicine at Berlin University. He received his degree with high honors, then went to Prague, where he came under the influence of *Arlt*, who was then at the peak of his glory and a truly superb ophthalmologist. *Graefe* spent two years in Paris, and then went on to spend time in Vienna and in London. In 1850 he returned to Berlin to begin to practice and became "Privat-docent" in 1852. *Graefe* was one of the first to employ the ophthalmoscope after its invention by *Helmholtz* in 1851. In 1854 he founded the journal *Archiv für Ophthalmologie* which marked an important epoch in the development of ophthalmology.

Grosseteste, Robert (ca. 1175 – 1253)

Robert Grosseteste was a central figure in the intellectual movement that took place in England in the first half of the 13th century. He was educated at the University of Oxford, became its chancellor from 1215 to 1221. After this, *Grossteste* held a number of ecclesiastic positions. He became Bishop of Lincoln in 1235 and remained in this position until his death in 1253. *Grosseteste* worked on geometry, optics and astronomy. He wrote a commentary on *Aristotle* and made Latin translations of scientific writings from both Greek and Arabic. In optics, he experimented with mirrors and with lenses. *Grosseteste* considered that the properties of light had particular significance in natural philosophy and stressed the importance of mathematics and geometry in their study. He adhered to the view that was shared by the earlier Greeks, that vision involved emanations from the eye to the object perceived. *Roger Bacon* was a student of *Grosseteste*.

Hasner, Joseph Ritter von Artha (1819 – 1892)

Joseph Hasner was an Austrian ophthalmologist, who was educated in Prague and received his medical degree in 1848. He was "first assistant physician" (Secondärarzt) in Prague General Hospital. In 1852 he was made professor extraordinarius and, in 1856, professor ordinarius. In 1884, his clinic was divided and half of it assigned to the newly founded Czech University. This division gave him deep offense and he never fully recovered from this. *Hasner* wrote numerous publications on ophthalmic, anatomy, physiology, pathology, ophthalmoscopy and history of ophthalmology. For a long time, he was one of the associate-editors of *Prager Medicinischen Vierteljahresschrift*. In 1851, he described his "Wasserwanne" (water-bath) that was an adaptation of *Czermak's* orthoscope for ophthalmoscopy and ophthalmic examination.

Herrmann Ludwig Ferdinand von Helmholtz

Helmholtz, Herrmann Ludwig Ferdinand von (1821 – 1894)

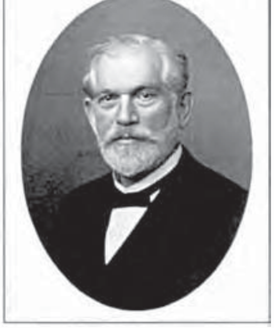
Herrmann Helmholtz was a German physiologist and he invented the ophthalmoscope. He was born in Potsdam and his main Gymnasium interest turned early to physics, but his father did not have sufficient money to send his son to the university and persuaded him to turn to medicine. He entered in the army medical school in Berlin, passed his first degree, taking chemistry, physiology, mathematics and private instruction in philosophy. Under the great physiologist *Johannes Muller*, he worked with

Ernst Brücke and *Emil du Bois-Reymond* on their program for the advancement of physiology. *Helmholtz* received his M.D. degree in 1842 and was appointed regimental surgeon at Potsdam. However, he maintained his scientific connections with Berlin. In 1848 he was appointed associate professor of physiology and general pathology at Königsberg and from that time, he led a life of tireless labor at his researches. During his residence in Königsberg he published his work on the discovery of the ophthalmoscope: *Beschreibung eines Augenspiegels zur Untersuchung der Netzhaut im lebenden Auge"* (1851). In 1855, he became professor of anatomy and physiology at the University of Bonn and, three years later, professor of physiology at the University of Heidelberg. In 1871, he moved to Berlin in order to accept the chair of physics. He never had a private medical practice and he never practiced ophthalmology as a specialist. In 1877, when *Von Siemens* founded the Physico-Technical Institute in Berlin, *Helmholtz* was chosen as its first director. In 1883, because of his many highly significant discoveries in physical science, he was ennobled. His book *Handbuch der Physiologischen Optik* (1856-1867, second edition 1885-1895) altered the subjects of optics for all time.

Sir John Frederick William Herschel

Herschel, Sir John Frederick William (1792-1871)

John Frederick William Herschell was a British astronomer and the son of *Sir William Herschel*. He was born in Slough and educated at Eton and St John's College, Cambridge, where, in 1813, he was senior wrangler and first *Smith's* Prize-man. He applied himself especially to astronomy and wrote numerous treatises on that subject. In 1827 he wrote his *Treatise on Sound and on Light*, which appeared in 1831 in the *Encyclopedia Metropolitana*. In this work, he gave the idea of correction of irregular corneal astigmatism with an intaglio glass, often considered as a precursor of molded contact lenses. In the same chapter, *Herschel* described the neutralization by water of the corneal dioptric power of the fish eye, but he did not make any connection in his treatise with his speculative proposition of correction of irregular astigmatism by a glass lens with a posterior surface as intaglio of the irregular cornea.



Julius Hirschberg

Hirschberg, Julius (1843 – 1925)

Julius Hirschberg was a German ophthalmologist and world-renowned historian of ophthalmology. Born in Potsdam, he received his M.D. degree in 1866 at the University of Berlin where he became assistant to *Graefe*. He established his own clinic in 1869 and from 1879 lectured at the University, where he became Professor in 1779. He wrote a vast *Geschichte der Augenheilkunde* (in 25 parts with index, 1899 – 1918) and founded and edited the *Centralblatt für Augenheilkunde*, in which he ran a regular chronicle, publishing numerous papers.

Christian Huygens

Huygens, Christian (1629 – 1695)

Christian Huygens was both astronomer and mathematician. He was born in the Netherlands at The Hague. He was the son of the secretary to the Prince of Orange. After his earliest instruction, which he chiefly received from his very learned father, he then studied mechanics and mathematics at Leyden, and later, jurisprudence at Breda. Soon however he abandoned his legal studies and returned to mechanics, mathematics and optics. In 1665, he invented a new and highly successful method of grinding lenses and, with the aid of some of the lenses of his own production, he discovered a satellite of Saturn and, for the first time in history, announced the existence of the Saturnian's rings. *Huygens* also invented the pendulum-clock, solved the problem of the center of oscillation, invented cycloid checks for clocks, as well as other devices. In the field of optics he established the wave theory of light and discovered the polarization of light as described in his *Traité de la Lumière*. From 1666 to 1685 he was invited to Paris by *Colbert*, who was prime minister of France at the time, in order to continue his studies at the foundation of the French Academy of Sciences before which he presented the results of his investigations.

Johannes Kepler

Kepler (or Keppler), Johannes (1571 – 1630)

Johannes Kepler was an astronomer, theologian and physicist, who was born in Würtemberg at Weil-am-Rhein, (close to Bâle). He received his bachelor's degree at Leonberg and, in 1588, entered the University of Tübingen. Here he received instruction in the new *Copernican* astronomy. In 1594, he accepted the chair of astronomy at the University of Graz. In 1598, as a result of the edict of the Archduke Ferdinand that was directed against Protestant preachers and professors, he fled to Hungary. In 1600, he departed for Prague where he became assistant to the celebrated astronomer *Tycho Brahé* whom he succeeded. In 1604, *Kepler* published the first part of his astronomic work *Astronomiae Pars Optica* entitled *Ad Vitellionem Paralipomena* in which he clearly described the mechanism of image formation in the eye and other aspects including visual fields, central vision, after-images, binocular vision and accommodation.

Kussmaul, Adolf (1822 – 1902)

Adolf Kussmaul was a German physician, who was born near Karlsruhe and studied in Heidelberg from 1840 to 1845. *Kussmaul* practiced as a general physician, and then proceeded to Würzburg. In 1855 he qualified as "Privatdocent" in Heidelberg and in 1857 was made Professor Extraordinarius. He accepted a full professorship in internal medicine in 1859 at the University of Erlangen and, in 1863, in Freiburg im Breisgau. From 1876 to 1886 he was professor of internal medicine in the Kaiser-Wilhelm University of Strasbourg where he constructed a new clinic. In 1845, while he was still a student in Heidelberg, he published an original composition entitled *Die Farben-Erscheinungen im Grunde des Menschlichen Auges*. The University Faculty at Heidelberg acclaimed this work, which is the first description showing that the retina of human and other mammals is, in fresh condition, absolutely transparent. For his experiments, he used a "contact-device" placed on the cornea.

La Hire, Philippe de (1640 – 1718)

Philippe de La Hire

Philippe de La Hire was a mathematician, astronomer and physicist. He was the son of the painter *Laurent de La Hire* (1606 – 1656). He first studied painting in Rome, but, on his return to Paris, he devoted himself to the sciences, especially mathematics. In 1678 he was made a member of the Académie des Sciences. In 1683 he was appointed to the chair of mathematics at the Collège Royal and in 1687 to the chair of architecture at the Académie d'Architecture. In 1694 he published his "*Dissertation des Différents Accidents de la Vue*", in which gave an explanation of myopia and hyperopia and their optical correction with glass spectacles. In order to simplify his demonstration, he made the assumption that the lenses were positioned directly on the cornea. This is often interpreted historically as a description of the earliest contact lens. In 1707, *La Hire* was opposed to the "new theory of cataract" in which it was asserted that cataract was an opacification of the crystalline lens.
In 1709, *La Hire* repeated the submersion experiments of *Jean Méry* that were performed on the eyes of living cats and was the first to provide the correct solution to the most important question raised by *Méry's* experiments. *Méry's* basic experiment (1704) was this: He submerged a cat under water and then observed the animal's fundus oculi in its full color and detail, including the entrance of the optic nerve, the vessels and all the various hues of the brilliant choroidal coat. *Méry's* explanation of his own experiment was, however, quite misleading. He believed that the reason why the fundus could be observed in the submerged, but not in the unsubmerged eye, was that the water "smoothed out" various tiny "inequalities" which *Méry* believed to exist on the anterior corneal surface. *La Hire* came forward with the correct explanation. He made it abundantly clear that the explanation of why the fundus of the submerged eye could be perceived was that the water eliminated all the corneal refraction of light. He also incidentally observed that all the disturbing light-reflexes which appear on the cornea in the air, are eliminated by submersion. *La Hire* also made extensive observations in the mapping project of France. The chief contributions of *La Hire* were, however, in the area of pure geometry. Familiar with the analytic method of *Descartes*, *La Hire* continued the work on cone geometry by *Desargues* and *Pascal*. *La Hire* enjoyed the patronage of *Louis XIV* and his court. He died at the age of 78 years. *La Hire's* works was reedited posthumously by *Fontenelle* in 1730 as volume IX of the *Mémoires de l'Académie royale des sciences depuis 1666 jusqu'à 1699*.

La Hire Gabriel-Philippe (1677 – 1719)

Gabrie-Philippe de La Hire was the eldest son of *Philippe de La Hire* He studied anatomy, astronomy and architecture. In 1699, he was made member of the Académie des Sciences. In 1708 and in opposition to his father's opinion, he approved the new theoretical position for the Academy that cataract is "really the crystalline lens which has been opaque". He presented the demonstration that an eye deprived of the crystalline lens could have vision, provided that a convex lens corrected it. He died at age of 42.

Leonardo da Vinci (1452 – 1519)

Leonardo da Vinci was a famous painter, sculptor, architect, musician, engineer, expert in optics and physiologist of the Renaissance. He was born in Vinci, near Florence, as the illegitimate son of a lawyer. *Verrochio*, who became his teacher, discovered his artistic ability. *Leonardo* developed a high degree of originality and was not content only with imitation or interpretation of classical models. He worked successively for *Prince Ludovic* in Milan (1483 – 1499), for the *Florentine Republic* (1500 – 1506), for the *French Princes* in Milan (1506 – 1512), and for King *François I* of France (1513 - 1515). In his notes, he wrote on the known facts of his time, with critical remarks on the theories advanced. *Manuscript D*, today entitled *On the eye*, contains in folios 3 verso and 7 verso drawings of glass cups before a head illustrating, as the text beside these described, an artificial eye and curved mirrors. These drawings are often interpreted, out of context with other sketches and texts in the the folio, as being contact lenses.

Mackenzie, William (1791 – 1868)

William Mackenzie

Sir William Mackenzie was a Scottish ophthalmologist and founder of the Glasgow Eye Infirmary. He was born in Glasgow and studied at Grammar School in Glasgow and also at the Glasgow School of Art and the University of Glasgow. For a time, intending to become a minister, he studied at Divinity Hall, but in 1810, after deciding to be a physician, he entered Glasgow Royal Infirmary. From 1815 to 1818 *Mackenzie* studied ophthalmology in London, Paris and Vienna, as well as in several Italian cities. Returning to England, he settled as ophthalmologist in London, but without much success. He returned to Glasgow where he was successful. He never entirely abandoned general medicine or surgery, but he gave to ophthalmology the greater portion of his time. In the Anderson School of Medicine he lectured on anatomy, materia medica and medical jurisprudence. In 1824, he established the Glasgow Eye Infirmary. Many years later he was appointed Instructor in Diseases of the Eye at Glasgow University, which position he held until he died. His *Practical Treatise on the Disease of the Eye* appeared in multiple editions (1830, 1835, 1839, 1854) in addition to several French and German editions.

Maître-Jan, Antoine (1650 – 1725)

Antoine Maître-Jan was a French surgeon, who was particularly noted for his description of the true nature and situation of cataract. Born at Méry-sur-Seine, he studied at Paris and, after he returned to his native town, his success as a surgeon was almost immediate. In 1706, he wrote a letter that was read before the Académie des Sciences by *Jean Méry*, in which he maintained that cataract results from opacification of the crystalline lens and that operating on it was really just pushing down the crystalline lens. But after a lecture given by *Philippe de La Hire*, the Academy decided to maintain its traditional opinion. In the following year, *Antoine Maitre-Jan* published his *Traité des Maladies de l'œil et des remèdes propres pour leur guerison* (1707, 1722 and 1741) this work marking, in fact, a great improvement over all preceding ophthalmologic treatises. He devoted much attention to ocular anatomy and physiology and the treatise contained a section on physiology that included a description of the camera obscura, reflection of light and its refraction. In the section on pathology he takes the then very new position that cataract is not a skin in the space between the pupil and the lens, but, rather, the lens itself in a hardened and clouded condition. This description caused the Académie des Sciences to change its official opinion and accept the new theory of cataract.

Mariotte, Edmé (1620 – 1684)

Edmé Mariotte was the French physicist who discovered the "blind spot" of the eye. Born in Burgundy, he became a priest in Beaune. He was one of the early members of the Académie des Sciences, which was founded in the same year in which he discovered the blind spot. *Mariotte* publicized the presence of the blind spot throughout the scientific world.

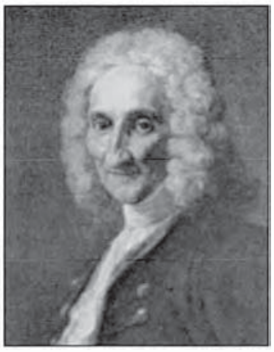

Jean Méry

Méry, Jean (1645 – 1722)

Jean Méry was a French anatomist and surgeon. He was born as a surgeon's son in Vatan, in Berry. Intent on following in his father's profession, he studied surgery at the Hôtel-Dieu in Paris. In addition to his regular studies, Méry undertook clandestine anatomical dissections whenever fresh human material became available to him. In 1681, he was appointed surgeon, and, in 1700, chief-surgeon at the celebrated Hôtel-Dieu hospital in Paris. He was also appointed senior surgeon at Les Invalides (Institute for military pensioners). In 1684 *Méry* was elected to the Académie des Sciences. From that time onwards he devoted himself with great assiduity to this function. In 1704, he described his famous cat-submersion experiment in which he visualized the fundus oculi by neutralization of the corneal dioptric power to the Academy. This presentation was followed until 1712 by a series of controversies with the physicist and academician *Philippe De La Hire*. Méry was also involved in the "cataract-controversy". He gave many papers on his ocular dissections. In 1706 he read a letter from *Antoine*

Maître-Jan to the academy, wherein the latter made the assertion that a cataract was derived from opacification of the crystalline lens. *Méry* and his Academy colleagues rejected these assertions. However, in 1708, after having assisted the surgeon *Jean-Louis Petit* in the extraction through a corneal incision of a cataract located in the anterior chamber, he reported this cataract as being actually a crystalline lens, which had become opaque. This new assertion convinced the members of the Academy to adopt a new position on this controversial subject. In the 1709 register of Proceedings of the Academy, it was mentioned again that *Méry* had brought eyes to the academy and had found a crystalline lens that was becoming opaque.

Petit, François-Pourfour du (1664 – 1741)



François-Pourfour du Petit

François-Pourfour du Petit was a French anatomist and surgeon and also a member of the Académie des Sciences. He received a conventional classical education at the College of Beauvais and a medical education from the University of Montpellier degree in 1690. Next, he became a military surgeon in Flanders. In 1713, on leaving the army, he returned to Paris and continued the medical and scientific studies necessary for the completion of his surgical training. In 1722 he was elected member of the Académie des Sciences. Three years later he obtained the place of "pensionnaire anatomiste" that had been vacated by *Duverney*. *François-Pourfour du Petit* is known for his surgical skill and for a number of important discoveries, including that of the "Petit's canal", which is the space between the anterior and posterior suspensory ligament of the crystalline lens. His name is associated with physiological experiments in which he showed that the origin of the sympathetic nerve was not the cranium. In his presentations to the Académie des Sciences between 1723 and 1730, *Petit* worked particularly on the mechanism of the operation of pushing downwards for cataract. His first measurements were on frozen eyes and, in a second memoir, he determined at which point one should incise the eye when needling a cataract. Finally he described various methods for measuring the size of the aqueous chamber in human and other mammal eyes. For these experiments, *Petit* designed special instruments, including a device for neutralizing corneal dioptric power and an "ophthalmometer". In the Académie des Sciences, *François-Pourfour du Petit* was surnamed "le médecin" (the physician) for distinguish him from his contemporary who was also a member of the Academy, *Jean-Louis Petit* (1674 – 1760), surnamed "le chirurgien" (the surgeon). *François-Pourfour du Petit* is also often confused with his son, the physician *Etienne-Pourfour du Petit*.

Purkinje, Johannes Evangelista von (1787 – 1869)

Johannes Evangelista Purkinje was German-Czech physiologist, who was born at Libochowitz, where he at first determined to become a priest. At the age of 21, however, he turned his attention to medicine, and, in 1819, at the age of 32, he received his medical degree at the University of Prague. In 1823 was appointed to the chair of physiology and pathology at the University Breslau, which position he held for 26 years. He then moved to Prague, in order to accept the chair of physiology in the University at that place. He is known for his discovery of the *Purkinje* images.

Saint-Yves, Charles de (1667 – 1733)

Charles de Saint-Yves was a French surgeon and oculist who was born at Maubert-Fontaine near Rocroy. He entered the College of Saint Côme in Paris where he studied and practised ophthalmology for more than 25 years, establishing his own private Infirmary for Eye-Patients in 1711. *Saint-Yves* is to be remembered for a number of very important innovations, most of which are described in one great volume entitled *Nouveau Traité des Maladies des Yeux, les Remèdes qui y conviennent, & les Opérations de Chirurgie que leurs guérisons exigent ; avec de nouvelles Découvertes sur la structure de l'œil, qui prouvent l'Organe immédiat de la Vue* Paris, 1722 (translated as *New treatise on the Diseases of the Eye, the Remedies which are Proper Therefore, and the Surgical Operations which their Cure Requires, with the Discoveries on the Structure of the Eye which Demonstrate the mediate Organ of Vision,* London 1741).

Schauenburg, Karl Hermann (1819 – 1879)

Karl Schauenburg was a German physician and author of ophthalmologic writings. He received his medical degree at the University of Berlin in 1843. He practiced in many places and was also a poet and dramatist. He translated the works of *Cramer* and *Donders* into German and made adaptations these works in that language.

Scheiner, Christoph (1575 – 1650)

Christoph Scheiner was a German physiologist and astronomer, who was commonly called "Pater Scheiner". He was born at Walde, in Swabia. He entered the Jesuit Order in 1595, became professor of Hebrew and mathematics first in Freiburg im Breisgau, and later in Ingolstadt and then taught for a number of years at Rome. In his work *Oculus hoc est: Fundamentum opticum*, he described the formation of the retinal image in a ox eye and the role of the crystalline lens in accommodation. He constructed an astronomical telescope, a pantograph and made several astronomical observations.

Snel van Royen, Willebrord [or Villebrordius Snellius] (1580 - 1626)

Willebrord Snel van Royen, also known as *Villebrordius Snellius* was a mathematician and physicist, who was born in the

Netherlands. His father was professor of mathematics at the University of Leyden. At an early age, *Snel* became interested in mathematics. He published extensively in pure mathematics and, in 1613, succeeded his father at the University of Leyden, becoming professor of mathematics in 1615. His chief work was *Eratosthenes Batavus* (1617), which described a triangulation method of measuring the earth. *Snel* is generally credited with the discovery of the "law of the refraction of light", often attributed to *Descartes*.

Herman Snellen

Snellen, Herman (1834 – 1908)

Herman Snellen was as ophthalmologist from the Netherlands who invented the "*Snellen* chart test types" that are used for the determination of visual acuity as well as several others widely used devices. He was born in 1834 in Zeist near Utrecht where he received his medical degree from the university in 1857. He settled in Utrecht and, in 1862, he was the first ophthalmic physician and docent for ophthalmology in the Netherlands Hospital for Eye Patients in Utrecht. In 1877 he became professor of ophthalmology there.

Van Tright, Adrien Christophe (1825 – 1864)

Adrien Christophe Van Tright was an ophthalmologist from the Netherlands. In 1835, he received his M.D. degree from the University of Utrecht with a dissertation on the ophthalmoscope that was inspired by *Donders, Dissertation de speculo oculi*. In this work, he also described neutralization of the corneal dioptric power using a drop of water under a glass lamella. He practiced in Amsterdam, but died young at the age of 39.

Mikhail Mikhailovitch Woinow

Woinow, Mikhail Mikhailovitch (1844 – 1875)

Mikhail Mikhailovitch Woinow was a Russian ophthalmologist, who studied under *Helmholtz*, *Becker* and *Arlt*. He established a highly successful ophthalmologic practice in Moscow, lectured at the University and published three monographs in German and a number of articles on topics in physiological optics. In 1869, he described the use of an orthoscope in his studies on accommodation.

Thomas Young

Young, Thomas (1773 – 1829)

Thomas Young was a British physician, physicist, and Egyptologist, who was born in Milverton. At two years of age he was able to read. When he was nearly nine years of age, he was sent to a school at Compton in Dorset, where he studied Latin, Greek, Mathematics and Natural Philosophy. After four years at this school he returned to Milverton, where he continued his studies, taking up Hebrew, Chaldean, Syrian and Persian. He also began making optical instruments at this time. When he was fourteen years of age, he became a tutor in the Classics, pursuing his studies and acquiring considerable acquaintance with French, Italian and Spanish. Between 1792 and 1799 he studied medicine in London, Edinburgh and Göttingen. He settled in London from 1800 and, until 1814, maintained a part-time medical practice, however devoting most of his energies to scientific research. On 30th May 1793, while still a medical student, *Young* submitted a paper entitled *Observations on Vision* before the Royal Society of London, in which he erroneously attributed accommodation to a muscular structure within the crystalline lens. This was published in the Philosophical *Transaction of the Royal Society of London* and led to his election, on 19 June 1794, as a member of the Royal Society. From 1801 until 1803 he was appointed professor of natural philosophy at the Royal Institute. In 1802 he was appointed foreign secretary to the Royal Society and held that office until his death. In 1803 he was admitted to the degree of M.B at the University of Cambridge and, in 1808, took the degree of M.D. In 1811 he was elected physician to St George's Hospital, London, which position he retained till his death. He was also superintendent of the "Nautical Almanac", secretary of the Board of Longitude. In 1827, Young was elected and became one on the eight foreign members of the French Academy of Sciences. Young has been justly called "the Founder of Physiological Optics" (*Tscherning*). His memoir *On the Mechanism of the Eye* that was presented on 27th November 1800 to the Royal Academy contained the first description and measurement of astigmatism using the neutralization by immersion in water of the corneal dioptric power and a table of optical constants of the eye in close agreement with modern determinations. He first explained color sensations as being due to the presence in the retina of structures, which responded to three fundamental colors. He advanced a wave theory of light and demonstrated its application to crystalline refraction and dispersion phenomena. *Young* also made important advances in mechanics. He provided the key to understanding Egyptian hieroglyphic writings: he translated the demotic characters on the *Rosetta* Stone, making the important discovery that these characters were not alphabetic, but rather symbols derived from the hieroglyphs on the stone. *Young* also presented many other contributions connected with his profession, including the function of the heart and "consumptive diseases".

Zander, Adolf (- 1863)*

Adolf Zander was a German ophthalmologist, who studied medicine in Leipzig and established himself in Chemnitz. He wrote a successful book on the ophthalmoscope *Der Augenspiegel. Seine Formen und sein Gebrauch nach den vorhandenen Quelles zusammengestellt*" (Leipzig 1859, 1862, 1864). For the neutralization of the corneal dioptric power he described various water-contact procedures.

For the bibliographic references and exhaustive details on the life and work of personages cited in the History, see the *International Biography and Bibliography of Ophthalmologists and Vision Scientists* (IBBO, ed. Wayenborgh, Ostend), the *Dictionary of Scientific Biography* (ed. Charles Scribner's sons, New York), the *American Encyclopedia of Ophthalmology*, the *Dictionary of National Biography* (ed. Sideney Lee, London), *Biographisches Lexicon der hervorragenden Aerzten aller Zeiten und Völker* (Hurlt & Hirsch, ed. Urban, Wien), *Nouvelle Biographie Générale depuis les temps les plus reculés jusqu'à nos jours* (F. Hoeffer, ed. Firmin et Didot, Paris), *Biographie Universelle Ancienne et Moderne* (ed. Michaud, Paris) and *Geschichte der Augenheilkunde* (J. Hirschberg, 1899-1918).

Bibliography

ABEL Peter, THIELE W., *Handbuch der Optometrie, 1968.*

ADAM Charles, TANNERY Paul, *Œuvres de Descartes en 10 volumes, Discours de la Méthode et essais,* VI, 1896, reprint Paris, CNRS/Vrin, 1973, 1996.

AIRY George Biddel, "On a Peculiar Defect in the Eye and a Mode of Correcting it", *Transactions of the Cambridge Philosophical Society,* 1827, 2, 267-271.

AIRY George Biddel, "On a Peculiar Defect in the Eye and a Mode of Correcting it with Observation by the Editor", *Edimburg Journal of Science*, 1827, 7, 322-326.

ALBERT Daniel M., "Ocular Refraction and the Development of Spectacles", p. 107-123 in ALBERT Daniel M., EDWARDS Diane D., *The History of Ophthalmology,* Cambridge MA, Blackwell, 1996.

ALPERN Mathew B., "Contact Lens Experiments of Thomas Young", *American Journal of Optometry and Archives of the American Academy of Optometry*, 1948, 25, 198.

ANDRIESSE C. D., *Christian Huygens. Biographie*, Paris, Albin Michel, 1998.

ARGENTIERI Domenico, "L'Ottica di Leonardo", in: *Editione curatan della Mostra di Leonardo da Vinci in Milano,* Novara, Instituto Geografico de Agostini, 1939.

ARGENTIERI Domenico, "Leonardo's Optics", p. 405-436 in: *Leonardo da Vinci*, New York, Reynal, 1956 (numerous reprints).

BATTEN Rayner D., "The Hydrophthalmoscope. An instrument for the Examination of the Eye under Water", *Transactions of the Ophthalmological Society of the U.K.,* 1909-1910, 30, 102.

BATTEN Rayner D., "The Hydrophthalmoscope. An Instrument for the Examination of the Eye under Water", *The Ophthalmoscope*, 1910, 8, 92-94.

BATTEN Rayner D., "The Hydrophthalmoscope: its Clinical Value", *Transactions of the Ophthalmological Society of the U.K.,* 1920, 40, 357-361.

BEST A.E., "Pourfour du Petit's Experiments on the Origin of the Sympathetic Nerve", *Medical History*, 1969, 13, 153-174.

BIRCHLER Walter, *Die Augenanatomie des Fabricius ab Aquapendente 1537-1619. Übersetzung von „Oculi dissecti historia" mit Kommentar,* Zurich, Juris Druck-Verlag, 1979.

BITBOL-HESPERIES Annie, VERDET Jean-Pierre, *Descartes René: Le Monde, l'Homme,* Paris, Seuil, 1996.

BLAY Michel, *Christiaan HUYGENS. Traité de la Lumière où sont expliquées les Causes de ce qui lui arrive dans la Réflexion et dans la Réfraction et particulièrement du Cristal d'Islande*, Paris, Dunod, 1992.

BLAY Michel, "Huygens", p. 277-281 in: BLAY Michel, HALLEUX Robert, *La Science Classique. XVIe-XVIIIe Siècle. Dictionnaire Critique*, Paris, Flammarion, 1998.

BOULLAUD Bernard, *Œil et Optique dans les Carnets de Léonard de Vinci*, Doctoral Thesis in Medicine, Universtity of Limoges, France (11.12.1987).

BRACHNER A., *Hundert Jahre Kontaktlinse. Vom Lesestein zur Kontaktlinse*, München, Vereinigung deutscher Contactlinsenspezialisten (VDC), 1988.

BRIAN Eric, DEMEULENAERE-DOUYERE Christiane (under the direction of -), *Histoire et Mémoire de l'Académie des Sciences. Guide de Recherches*, Paris, Lavoisier, 1996.

BRIDOUX André, *Descartes, Œuvres et Lettres*, Paris, Bibliothèque de la Pléiade Nrf/Gallimard, 1953.

BRISSEAU Pierre, *Traité de la Cataracte et du Glaucoma*, Paris, D'Houry, 1709 (second edition. Douay, Javerne, 1716) (reprint Anvers, Buschmann, 1921).

CHALKLEY Katherine, "Comments and Communications: Corneal Contact Lens Reference?", *Science*, 110, 1949, 693.

COCCIUS Adolf Ernst, *Ueber die Ernährungsweise der Hornhaut und die Serum führenden Gefässe im menschlichen Körper*, Leipzig, Müller, 1852.

COCCIUS Adolf Ernest, *Ueber die Anwendung des Augen-Spiegels nebst Angabe eines neuen Instruments*, Leipzig, Müller, 1853.

COCHET Paul, AMIART Hugues, "Contact Lens History and Parameters", *International Ophthalmic Clinic*, 1969, 9, 231-241.

CORBEAU André, TONI Nando de, *Léonard de Vinci. Manuscrit D de l'Institut de France*, Grenoble, Roissard, 1964.

COUSIN Victor, *Œuvres de Descartes*, (11 vol.), Paris, Levrault, 1824-1826.

CRAMER Anthonie, *Physiologische Abhandlung über das Accommodations-Vermögen der Augen. Aus dem Holländischen übersetzt von Doden*, Lahr, Prätorius & Seyde, 1855.

CZERMAK Johann Nepomuk, "Ueber eine neue Methode zur genaueren Untersuchung des gesunden und kranken Auges", *Vierteljahrschrift für praktische Heilkunde*, 1851, 8 (32), 154-165.

CZERMAK Johann Nepomuk, "Beiträge zur Ophthalmoskopie", *Vierteljahrschrift für praktische Heilkunde*, 1853, 10 (38), 137-141.

DAXECKER Franz, "Christoph Scheiner's Eye Studies", *Documenta Ophthalmologica*, 1992, 81, 27-35.

DESCARTES René, *Discours de la Méthode pour bien conduire sa raison et chercher la vérité dans les sciences plus la Dioptrique, les Météores et la Géométrie qui sont des essais de cette Méthode*, Leiden, Ian Maire, 1637.

DESCARTES René, *Œuvres et Lettres*, Paris, Bibliothèque de la Pléiade Nrf/Gallimard, 1953.

DESCARTES René, *Œuvres*, collected by ADAM Charles, TANNERY Paul, in 12 volumes, 1896, Paris, Vrin, 1896, reed. Vrin/CNRS 1973, 1996.

DIMMER F., *Die Photographie des Augenhintergrundes*, Wiesbaden, Bergmann, 1907.

DONDERS Frans Cornelius, *On the Anomalies of Accommodation and Refraction of the Eye, with a Preliminary Essay on Physiological Optics, translated by William Daniel Moore*, London, The New Sydenham Society, 1864.

DUDRAGNES Raymond A., "Contribution à l'Histoire du Contact Optique et à ses Applications", *Optica Internationalis*, 1965, 2, 32-39 & 46-49.

DUKE-ELDER Sir Stewart, WYBAR Kenneth C., "The Anatomy of the Visual System" in: *System of ophthalmology*, Vol. II, London, Kimpton, 1961.

DUKE-ELDER Sir Stewart & coll., "The Foundations of Ophthalmology", in: *System of ophthalmology*. Vol. VII, London, Kimpton, 1962.

DUKE-ELDER Sir Stewart, ABRAMS David, "Ophthalmic Optics and Refraction", in: *System of Ophthalmology* Vol V, London, Kimpton, 1970.

EHRICH Wulf, "Zur physiologischen Optik bei Leonardo da Vinci", *Kurz und Gut*, 1974, 8 (3), 21-24.

EHRICH Wulf, "Leonardo da Vinci und die Kontaktlinse?", *Contactologia*, 1979, 1, 158-161.

EHRICH Wulf, HEITZ Robert, "Ist die "Luce" im Manuscript K (Folio 118 verso) von Leonardo da Vinci ein Hornhautmodell oder gar eine Kontaktlinse?", *Contactologia*, 1988, 10, 1-3.

ENOCH Jay M., "Descartes' Contact Lens", *American Journal of Optometry and Physiological Optics*, 1956, 33, 77-85.

ENOCH Jay M., HEITZ Robert F., LAKSHMINARAYANAN Vasudevan, "John Frederick William Herschel on testing for Astigmatism in 1845", *Ophthalmic Physiological Optics*, 1988, 8, 349-350.

ERGGELET Heinrich, "Ueber die Fickschen Haftgläser und den Stand ihrer Entwicklung", *Münchener Medizinische Wochenschrift*, 1930, 77, 1955-1956.

FATER Sabina, "Hydrodiaskop und Keratokonus", *Klinische Monatsblätter für Augenheilkunde*, 1906, 44, 93-109.

FERRERO, Nino, "Leonardo da Vinci, of the Eye", *American Journal of Ophthalmology*, 1952, 35, 507-521.

FICK Adolf Eugen, "Einige Bemerkungen über das Photographieren des Augenhintergrundes", *Klinische Monatsblätter für Augenheilkunde, (Bericht der 21. Versammlung der ophthalmologischen Gesellschaft Heidelberg, 1891)*, Beilageheft, 1892, 29, 197-201.

FICK Adolf Eugen, "Jedem das Seine", *Archiv für Augenheilkunde*, 1894, 28, 422-423.

FISCHER Edward J., "The Development of Contact Lenses", p. 369-382 in: ROSENTHAL, William J. (ed.), *Spectacles and other Vision Aids. A History and Guide to Collecting*, San Francisco, Norman Publishing, 1996.

FONTENELLE Bernard le Bovier de, "Sur l'Iris de l'Oeil", *Histoire de l'Académie Royale des Sciences pour l'Année 1704*, 12-17, Paris, Jean Boudot, 1704.

FONTENELLE Bernard le Bovier de, "Optique - Sur quelques Faits Particuliers d'Optique", *Histoire de l'Académie Royale des Sciences pour l'Année 1709*, 90-92, Paris, Jean Boudot, 1711.

FONTENELLE Bernard le Bovier de, "Sur l'Iris de l'Oeil", *Histoire de l'Académie Royale des Sciences pour l'Année 1710*, 33-36, Paris, Jean Boudot, 1712.

FONTENELLE Bernard le Bovier de, "Sur le Principal Organe de la Vision et sur la Structure du Nerf Optique", *Histoire de l'Académie Royale des Sciences pour l'Année 1712*, 30-35, Paris, Compagnie des Libraires, 1714.

FONTENELLE Bernard le Bovier de, "Sur l'Expérience des Yeux du Chat Plongé dans l'Eau", *Histoire de l'Académie Royale des Sciences pour l'Année 1712*, 73-74, Paris, Compagnie des Libraires, 1714.

FONTENELLE Bernard le Bovier de, "Éloge de M. de La Hire", *Histoire de l'Académie Royale des Sciences pour l'Année 1718*, 76-89, Paris, Imprimerie royale, 1719.

FONTENELLE, Bernard le Bovier de, "Sur les Cataractes des Yeux", *Histoire de l'Académie Royale des Sciences pour l'Année 1722*, 15 – 18, Paris, Imprimerie royale, 1724.

FONTENELLE, Bernard le Bovier de, "Sur les deux Espaces que l'Humeur Aqueuse occupe dans l'Oeil", *Histoire de l'Académie Royale des Sciences pour l'Année 1723*, 19-22, Paris, Imprimerie royale, 1725.

FONTENELLE, Bernard le Bovier de, "Sur les Cataractes", *Histoire de l'Académie Royale des Sciences pour l'Année 1725*, 7-9, Paris, Imprimerie royale, 1727.

FONTENELLE, Bernard le Bovier de, "Sur les Yeux de l'Homme et de Différents Animaux", *Histoire de l'Académie Royale des Sciences pour l'Année 1726*, 21-24, Paris, Imprimerie royale, 1728.

FONTENELLE, Bernard le Bovier de, "Sur la Structure des Yeux", *Histoire de l'Académie Royale des Sciences pour l'Année 1728*, 17-19, Paris, Imprimerie royale, 1730.

FONTENELLE, Bernard le Bovier de, "Sur le Cristallin", *Histoire de l'Académie Royale des Sciences pour l'Année 1730*, 33-38, Paris, Durand, 1732.

GERLOFF O., "Ueber die Photographie des Augenhintergrundes", *Klinische Monatsblätter für Augenheilkunde*, 1891, 29, 397-403.

GRAHAM Robert, "The Evolution of Contact Lenses", *American Journal of Optometry and Archives of American Academy of Optometry*, 1959, 36, 55-77.

GRMEK Mirko, *Les Maladies à l'Aube de la Civilisation Occidentale*, Fayard Paris (second edition), 1994.

HAAS Emile, "Les Verres de Contact", Rapport Annuel, *Bulletin de la Société d'Ophtalmologie de Paris*, 1937, I-CLV.

HALES Robert H., *Contact Lenses. A Clinical Approach to Fitting*, Baltimore, Williams & Wilkins, 1978.

HAMMOND J.H., *The Camera Obscura. A Chronicle*, Bristol, Adam Hilger, 1981.

HASNER Joseph von, "Ueber einige Hilfsmittel der Ophthalmoscopie", *Vierteljahrschrift für praktische Heilkunde*, 1851, 4 (32), 166-176.

HEITZ Robert, HEITZ Pascale, "Philippe de La Hire et les Lentilles de Contact", *Contactologia*, 1982, 4, 224-234.

HEITZ Robert F., "Leonardo da Vinci did not invent Contact Lenses", *The CLAO Journal*, 1983, 9, 313-316.

HEITZ Robert F., "History of Contact Lenses", p. I.1 - I.19 in: Oliver DABEZIES, (ed.), *Contact Lenses. The CLAO Guide*, Orlando, Grune & Stratton, 1984.

HEITZ Robert, ENOCH Jay M., "Leonardo da Vinci. An Assessment of his Discourses on Image forming in the Eye", p. 19-26 in: FIORENTINI A., GUYTON D.L., SIEGEL I.M. *Advances in Diagnostic Visual Optics*, Berlin, Springer, 1987.

HEITZ Robert, ENOCH Jay M., "Das Kontaktrohr von Descartes", p. 41-48 in M. TOST, (ed.), *10 Jahre Julius-Hirschberg-Gesellschaft*, Halle, 1996.

HEITZ Robert, "Perfectionner la Vision au Moyen d'un Tuyau plein d'Eau (Descartes)", *Mémoires de la Société Francophone d'Histoire de l'Ophtalmologie*, 1996/97, 4, 63-66.

HEITZ Robert F., "Descartes' Contact Tube: A Contribution to Contact Lens History", p. 309-312 in: Vasudevan LAKSHMINARAYANAN (ed.), *Basic and Clinical Applications of Vision Science*. Documenta Ophthalmologica Proceedings 60, Dordrecht, Kluwer, 1997.

HEITZ Robert, "La Découverte de l'Anesthésie locale à la Cocaïne en Ophtalmologie (1884)", *Les Cahiers d'Anesthésiologie*, 2000, 48, 307-313.

HEITZ Robert F., *De la Neutralisation Cornéenne aux Verres de Contact. Etude historique des Principes et des applications des Systèmes de Contact oculaire dans le Contexte des Connaissances du XVIe Siècle à la première Moitié du XXe*, Dissertation for the degree Doctor of Philosophy in historical and philological Sciences, Ecole Pratique des Hautes Etudes, Paris, 2001.

HELMHOLTZ Hermann Ludwig F. von, *Beschreibung eines Augenspiegels zur Untersuchung der Netzhaut im lebenden Auge*, Berlin, Förstner, 1851.

HELMHOLTZ Hermann Ludwig F. von, *Handbuch der physiologische Optik*, *IX. Band* in KARSTEN G. *Allgemeine Encyklopädie der Physik*, Leipzig, Voss, 1864, (second edition 1867, third edition 1909).

HELMHOLTZ Hermann Ludwig F. von, *Optique Physiologique*, French translation by Louis E. JAVAL & KLEIN, Paris, Masson, 1867.

HELMHOLTZ Hermann Ludwig F. von, *Handbuch der physiologische Optik*, translated by SOUTHALL J.P.C., The Optical Society of America, 1924.

HERSCHEL John Frederick William, "Of the Structure of the Eye, and of Vision", *Encyclopaedia Metropolitana* 4, "Light" § 12, 396-404, London, Smelley Fellow and Rivington, 1829-30, (Reprint 1845).

HERSCHEL John Frederick William, *Traité de la Lumière*, French translation by VERLUST et QUETELET, Paris, Malher 1829 (tome 1), Hachette, 1833 (tome 2).

HIRSCHBERG Julius, "Geschichte der Augenheilkunde", in: *Handbuch der gesamten Augenheilkunde*, Leipzig - Berlin, Engelmann & Springer, 1899-1918.

HIRSCHBERG Julius, "Glasswanne von Joh. Nep. Czermak (1851)", XII § 337 p. 418 note 1, in: *Geschichte der Augenheilkunde* in: *Handbuch der gesamten Augenheilkunde*, Leipzig - Berlin, Engelmann & Springer, 1899-1918.

HIRSCHBERG Julius, "Joh. Nepomuk Czermak (1828-1873)", XV, § 1025 p 106, note 5, in: *Geschichte der Augenheilkunde* in: *Handbuch der gesamten Augenheilkunde*, Leipzig - Berlin, Engelmann & Springer, 1899-1918.

HIRSCHBERG Julius, "Philipp de La Hire", §456, p. 417, in: *Geschichte der Augenheilkunde*, in: *Handbuch der gesamten Augenheilkunde*, Leipzig - Berlin, Engelmann & Springer, 1899-1918.

HIRSCHBERG Julius, "Thomas Young", § 459-466 in: *Geschichte der Augenheilkunde*, in: *Handbuch der gesamten Augenheilkunde*, Leipzig - Berlin, Engelmann & Springer, 1899-1918.

HOANG Sylvie, *L'œil et la Vision dans les Carnets de Léonard de Vinci*, Doctoral thesis in Medicine, University of Créteil, Paris-Val de Marne – France (22.05.1984).

HOEPLI Ulrice, *Il Codice Atlantico di Leonardo da Vinci nella Biblioteca Ambrosiana di Milano*, Milano, Accademia dei Lincei, (8 vol.), 1894-1904.

HOFSTETTER Henry W., GRAHAM Robert, "Leonardo and Contact Lenses", *American Journal of Optometry and Archives of American Academy of Optometry*, 1953, 30, 41-44.

HOFSTETTER Henry W., "Leonardo's Contact Concept", *Contact Lens Forum*, 1984, 9 (12), 15-16.

HOLTMANN Hans, "Esquisse d'une Histoire des Lunettes", p. 5-17 in: POULET W. (ed) *Les lunettes. Traité Historique en trois Volumes*, French translation by HEITZ Robert, Bonn, Wayenborgh, 1980.

HUISINCK Liesbeth, *Die Abhandlung über das Sehen von Hieronimus Fabricius ab Aquapendente (1537-1619). Übersetzung von „De actione oculorum" mit Kommentar*, Zürich, Juris-Druck, 1984.

HUYGENS Christian, *Traité de la lumière où sont expliquées les causes de ce qui lui arrive dans la réflexion et dans la réfraction et particulièrement dans l'étrange réfraction du cristal d'Islande*, Leide Pierre Van Der Aa, 1690 (reprint Paris, Dunod, 1992).

HUYGENS Christiaan, "Propositio XI, Tractatus de refract. Et telesc. Liber II - Proposition XI, Traité de la réfraction et des telescopes", p. 224-229 in : *Œuvres complètes de Christiaan Huygens en 20 volumes (1888 - 1950)*, tome XIII, fasc.1, *Dioptrica* I, (1653; 1666), Hollandsche Maatschappig van Wetenschappen, Den Haag, Martinus Nijhoff, 1916.

KEELE K.D., "Leonardo da Vinci on Vision", *Proceedings of the Royal Society of Medicine*, 1955, 48, 384-390.

KEELE K. D., "Leonardo da Vinci's Influence on Renaissance Anatomy", *Medical History*, 1964, 8, 360-370.

KEPLER Johannes (KEPLERI Joannis), *Mathematici dioptrice seu demonstratio...*, Augsburg, 1611.

KNOLL Henry A., *Personal communication* (letter dated 28th May 1980).

KOELBING Huldrich M., *Renaissance der Augenheilkunde. 1540-1630*, Bern - Stuttgart, Hans Huber, 1967.

KOELBING Huldrich M., "Between Alhazan and Kepler: The Treatise 'On Sight' by Fabricius ab Aquapendente, Venice 1600", p. 11-14 in: A. FIORENTINI, D.L. GUYTON, I.M. SIEGEL *Advances on Diagnostic Visual Optics*, Springer, Berlin 1987.

KUSSMAUL Adolf, *Die Farben-Erscheinungen im Grunde des menschlichen Auges*, Heidelberg, Groos, 1845.

LA HIRE Philippe de, *Personal Folder 'Philippe de La Hire'*, Paris, Archives of the French Academy of Sciences.

LA HIRE Philippe de, "Lecture", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences (from 25th June 1683 to 5th April 1686)*, vol.11, 133 recto - 134 recto, (Sessions of 7th and 21st July 1685) Archives of the French Academy of Sciences.

LA HIRE Philippe de, "Dissertation sur la Conformation de l'Oeil", *Journal des Sçavans*, 23, 196-200 (30th July) &25, 219-224 (20th August), 1685.

LA HIRE Philippe de, "Traité des Différens Accidens de la Vuë, Divisé en deux Parties", in : *Mémoires de Mathématique et de Physique*, Paris, Imprimerie royale, 1694.

LA HIRE Philippe de, "Remarques et Réflexions sur la Nature des Cataractes qui se forment dans l'Oeil", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences (from 6th January to 22nd December 1706)*, 25, 52 verso to 55 recto, Paris, Archives of the French Academy of Sciences.

LA HIRE Philippe de, "Remarques et Réflexions sur la Nature des Cataractes qui se forment dans l'Oeil", *Mémoires de l'Académie Royale des Sciences pour l'Année 1706*, 20-24, Paris, Jean Boudot, 1708.

LA HIRE Gabriel Philippe de, "Remarques sur la Cataracte et la Glaucoma", *Mémoires de l'Académie Royale des Sciences pour l'Année 1707*, 553-555, Paris, Jean Boudot, 1709.

LA HIRE Philippe de, "Explication de Quelques Faits d'Optique et de la Manière dont se fait la Vision", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences (from 9th January to 20th December 1709)*, 28, 103 recto - 113 recto, (20th March) Paris, Archives of the French Academy of Sciences.

LA HIRE Philippe de, "Explication de quelques Faits d'Optique et de la Manière dont se fait la Vision", *Mémoires de l'Académie Royale des Sciences pour l'Année 1709*, 95-106, Paris, Jean Boudot, 1711.

LA HIRE Philippe de, "Dissertation sur les Différens Accidens de la Vüe", p. 530-636 in: *Œuvres Diverses de M. de La Hire, Tome IX des Mémoires de l'Académie Royale des Sciences depuis 1666 jusqu'à 1699*, Paris, Compagnie des Libraires, 1730.

LAUGIER S., RICHELET G., *Mackenzie. Traité Pratique des Maladies des Yeux. Traduit de l'Anglais avec Notes et Additions par S. Laugier et G. Richelet.* Paris, Dusillon, 1844.

LAURENZA Domenico, *Léonard de Vinci, Artiste et Scientifique*, Paris, Pour la Science, 2000.

LEONARD DE VINCI, *Les Manuscrits de Léonardo da Vinci : Manuscrits de la Bibliothèque de l'Institut. (6 vol.)* transcription by RAIVAISSEN-MOLLIEN Charles, Paris, Quantin, 1881-1891.

LEONARDO DA VINCI, *Il Codice Atlantico di Leonardo da Vinci nella Biblioteca Ambrosiana di Milano,* Milano, Accademia dei Lincei, U. Hoepli, (8 vol.), 1894-1904.

LEONARD DE VINCI, *Manuscrit D de l'Institut de France,* (transcription and Italian translation by NANDO de Toni, French translation by CORBEAU André), Grenoble, Roissard, 1964.

LEVENE John R., "Sources of Confusion in Descartes's Illustrations, with Reference to the History of Contact Lenses", *History of Science,* 1967, 6, 90-96.

LEVENE John R., *Clinical Refraction and Visual Science,* London, Butterworth & Co, 1977.

LINDBERG David C., *Theories of Vision from Al-Kindi to Kepler*, Chicago, The University of Chicago Press, 1976 (second edition, 1981).

LINDBERG David C., *Roger Bacon and the Origins of Perspectiva in the Middle Ages - A critical Edition and English Translation of Bacon's Perspectiva with Introduction and Notes*, Oxford, The Clarendon Press, 1996.

LINDBERG David C., "La Réception Occidentale de l'Optique Arabe", 355-367 in: RASHED Roshdi, *Histoire des Sciences Arabes.* Vol II, Paris, Seuil, 1997.

LUMBOSO Pierre, *Séminaires Pratiques de Contactologie,* Marseille, Diffusion Générale de Librairie, 1977.

MACCURDY E., *Les Carnets de Léonard de Vinci,* Paris, Gallimard, 1942.

MACKENZIE William, *A Practical Treatise on the Diseases of the Eye*, London, Longman, Orme, Brown, Green and Longmans, 1830 (Second edition 1835, Third edition 1840, Fourth edition 1854).

MACKENZIE William, *Praktische Abhandlung über die Krankheiten des Auges.* Weimar, Verlag des Landes-Industrie-Comptoires, 1832.

MACKENZIE William, *Traité Pratique des Maladies des Yeux. Traduit de l'Anglais avec Notes et Additions par S. Laugier et G. Richelet.* Paris, Dusillon, 1844.

MACKENZIE William, *Traité Pratique des Maladies de l'Oeil. Traduit de l'Anglais et augmenté de Notes par E. Warlomont et A. Testelin (d'après la 4e édition)*, 2 vol. Paris, Masson, 1856-1857.

MACKIE Ian, "Contact Lenses. History", p. 713-716 in: Sir Stewart DUKE-ELDER (ed.), *System of Ophthalmology, Vol.V, Ophthalmic Optics and Refraction,* London, Kimpton, 1970.

MAITRE-JAN Antoine, *Traité des Maladies de l'Oeil et des Remèdes propres pour leur Guérison, enrichi de plusieurs Exemples de Physique.* Troyes, Lefevre, 1707 (Second edition Paris, d'Houry, 1722).

MANDELL Robert B., *Contact Lens Practice*, (4th ed), Springfield, Thomas, 1988.

MANN Ida, "The History of Contact Lenses", *Transactions of the Ophthalmological Society of the United Kingdom*, 1938, 58, 109-136.

MARIOTTE Edmée, "De structura oculorum", 69-73, Caput VI, in: *Regia scientiarum Academiae Historia* (in qua praeter ipsius Academiae ...) Sect. IV De actis annorum 1668 & 1669, Paris Deslespine, (Secunda Editio, 1701).

MARLY Pierre, *Les Lunettes*, Paris, Hachette, 1980.

MAZZOLINI Renato G., "The Mery-La Hire Controversy (1704-1710)", p. 30-44, in: *The Iris in Eighteen-Century Physiology*, Bern, Hans Huber, 1980.

MEISSNER G., "Zur Photographie des Augenhintergrundes", *Centralblatt für praktische Augenheilkunde*, 1896, 20, 275.

MÉRY Jean, "Des Mouvements de l'Iris et par Occasion de la Partie Principale de l'Organe de la Vue", *Record of the Proceeding of the Sessions of the Royal Academy of Sciences for the Year 1704*, 23, 277 verso - 284 recto, (12th November), Archives of the French Academy of Sciences, Paris.

MÉRY Jean, "Des Mouvements de l'Iris et par Occasion de la Partie Principale de l'Organe de la Vuë", *Mémoires de l'Académie Royale des Sciences pour l'Année 1704*, 261-271, Paris, Jean Boudot, 1707.

MÉRY Jean, "Réponse à la Critique de M. de La Hire du 20 Mars 1709", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences 1710*, 29, 175 recto-188 verso, Paris, Archives of the French Academy of Sciences.

MÉRY Jean, "Réponse à la Critique de M. de La Hire du 20 Mars 1709 - Première Partie", *Mémoires de l'Académie Royale des Sciences pour l'Année 1710*, 374-381, Paris, Jean Boudot, 1712.

MÉRY Jean, "Réponse à la Seconde Partie de la Critique de M. de La Hire du 20 Mars 1709 - Problèmes de Physique - Savoir quelle est de la Rétine ou de la Choroïde la Partie Principale de l'Oeil, où se fait la Sensation des Objets Colorés et Lumineux, Résolu par M. Méry", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences 1712*, 31, 36 recto-52 verso, Paris, Archives of the French Academy of Sciences.

MÉRY Jean, "Réponse à la Troisième Partie de la Critique de M. de La Hire du 20 Mars 1709", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences 1712*, 31, 319 recto-334 recto, Paris, Archives of the French Academy of Sciences.

MÉRY Jean, "Sur la Structure de l'Oeil - Réponse à la Question posée le 27 Juillet 1712", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences 1712*, 31, 305 recto-307 verso, Paris, Archives of the French Academy of Sciences.

MÉRY Jean, "Sur le Nerf Optique", *Record of the Proceedings of the Sessions of the Royal Academy of Sciences 1712*, 31, 313 verso-316 recto, Paris, Archives of the French Academy of Sciences.

MÉRY Jean, "Observations sur le Nerf Optique", *Mémoires de l'Académie Royale des Sciences pour l'Année 1712*, 253-258, Paris, Imprimerie royale, 1714.

MÉRY Jean, *Œuvres Complètes (Anatomie, Physiologie, Chirurgie), Réunies par L.H. Petit*, Paris, Alcan, 1888.

MÜNCHOW Wolfgang, *Geschichte der Augenheilkunde*, Stuttgart, Enke, 1984.

NADDEO-SOURIAU I., *Christiann Huygens, Traité de la lumière où sont expliquées les causes de ce qui lui arrive dans la réflexion et dans la réfraction et particulièrement du cristal d'Islande*, Paris, Dunod, 1992.

NOTTINGHAM J., *Practical Observations on Conical Cornea and on the Short Sight and other Defects of Vision connected with it*, London, Churchill, 1854.

PANAS Photinos, "Discussion", in: CHEVALLEREAU A. "Traitement du Kératocône", *Bulletins et Mémoires de la Société Française d'Ophtalmologie*, 1893, 11, 385-392.

PANAS Photinos, "Discussion", in: CHEVALLEREAU A., "Traitement du Kératocône", *Revue Générale d'Ophtalmologie*, 1893, 12, 306-308.

PERROD G., "La Diottrica Oculare di Leonardo da Vinci", *Archivo di Ottalmologia*, 1907, 14, 368-381 & 462-497.

PETIT François Pourfour du, "Mémoire sur les Yeux Gelés dans lequel on détermine la Grandeur des Chambres qui Renferment l'Humeur Aqueuse", *Registre of Proceedings of the Sessions of the Royal Academy of Sciences for the Year 1723*, 43, 91 recto - 103 recto, Archives of the Academy of Sciences, Paris.

PETIT François Pourfour du, "Mémoire sur les Yeux Gelés; dans lequel on détermine la Grandeur des Chambres qui Renferment l'Humeur Aqueuse", *Mémoires de l'Académie Royale des Sciences pour l'Année 1723*, 38-55, Paris, Imprimerie royale, 1725.

PETIT François Pourfour du, "Mémoire dans lequel on détermine l'Endroit où il faut piquer l'Oeil dans l'Opération de la Cataracte", *Registre of Proceedings of the Sessions of the Royal Academy of Sciences for the Year 1726*, 45, 514-524, Archives of the Academy of Sciences, Paris.

PETIT François Pourfour du, "Dissertation sur l'Opération de la Cataracte", *Mémoires de l'Académie Royale des Sciences pour l'Année 1725*, 6-20, Paris, Imprimerie royale, 1727.

PETIT François Pourfour du, "Mémoire sur plusieurs Découvertes faites dans les Yeux de l'Homme, des Animaux à quatre Pieds, des Oiseaux & des Poissons", *Mémoires de l'Académie Royale des Sciences pour l'Années 1726*, 69-83, Paris, Imprimerie royale, 1728.

PETIT François Pourfour du, "Mémoire dans lequel on détermine l'Endroit où il faut piquer l'Oeil dans l'opération de la Cataracte", *Mémoires de l'Académie Royale des Sciences pour l'Année 1726*, 262-272, Paris, Imprimerie royale, 1728.

PETIT François Pourfour du, "Pourquoi les Enfants ne voient pas Clair en venant au Monde, et quelque Temps après qu'ils sont Nés", *Mémoires de L'Académie Royale des Sciences pour l'Année 1727*, 246-254, Paris, Durand, 1729.

PETIT François Pourfour du, "Démontrer que l'Uvée est Plane dans l'Homme", *Mémoires de l'Académie Royale des Sciences pour l'Année 1728*, 206-224, Paris, Imprimerie royale, 1730.

PETIT François Pourfour du, "Différentes Manières de Connaître la Grandeur des Chambres de l'Humeur Aqueuse dans les Yeux de l'Homme", *Mémoires de l'Académie Royale des Sciences pour l'Année 1728*, 289-300, Paris, Imprimerie royale, 1730.

PETIT François Pourfour du, "Sur le Cristallin de l'Homme, des Animaux à quatre Pieds, des Oiseaux et des Poissons", *Mémoires de l'Académie Royale des Sciences pour l'Année 1730*, 4-26, Paris, Durand, 1732.

PETIT François Pourfour du, "De la Capsule du Cristallin", *Mémoires de l'Académie Royale des Sciences pour l'Année 1730*, 435-449, Paris, Durand, 1732.

RAIVAISSEN-MOLLIEN Charles, L*es Manuscrits de Léonardo da Vinci : Manuscrits de la Bibliothèque de l'Institut.* (6 vol.), Paris, Quantin, 1881-1891.

RASHED Roshdi, *Histoire des Sciences Arabes, Vol.2: Mathématiques et Physique,* Paris, Seuil, 1997.

ROHR Moritz von, "Zwei Abhandlungen von Thomas Young", *Zeitschrift für ophthalmologische Optik,* 1923, 11, 102-147.

ROHR Moritz von, "Die Entwicklung der Fernrohrbrille", *Zeitschrift für ophthalmologische Optik,* 1916, 3, 1-17, 33-41, 145-160, 161-163 & 1918, 6, 25-35 & 1920, 8, 33-39 & 1925, 13, 8-14.

ROSENTHAL William J., *Spectacles and other Vision Aids. A History and Guide to Collecting,* San Francisco, Norman Publishing, 1996.

ROTH Hans-Walter, "Ein Beitrag zur Geschichte der Kontaktlinse", p. 28-34 in: POULET W. (ed), *Atlas zur Geschichte der Brille mit Einschluss der Kontactlinse,* Bonn, Wayenborgh, 1978.

RUBEN Montague, *Contact Lens Practice,* London, Balliere Tindall, 1975.

RUBEN Montague, *Kontaktlinsenanpassung, (translated by H-W ROTH),* Stuttgart, Fischer, 1978.

RUBIN Melvin L., HOPE Marion G., "Optics and Refraction. A Review", *Ophthalmology, Centennial Supplement*, 1996, 103 Suppl., 102-108.

RUSSELL Güll A., "La Naissance de l'Optique physiologique", p. 319-354 in RASHED Roshdi, *Histoire des Sciences Arabes*, vol II, Paris, Seuil,1997.

SABELL A. G., "The History of Contact Lenses", p.1-27 in: STONE Janet, PHILLIPS Anthony (ed.) *Contact Lenses. A Textbook for Practitioner and Student*, London, Butterworths, 1972, 1976, 1980.

SAINT-YVES Charles de, *Nouveau Traité des Maladies des Yeux*, Paris, Lemercier, 1722.

SAMLAND H., "Zur Geschichte der Kontaktlinse", *Klinische Monatsblätter für Augenheilkunde*, 1966, 148, 734-736.

SCHAUENBURG (K)Carl Hermann, *Der Augenspiegel, seine Anwendung und Modificationen, nebst Beiträge für Diagnose unserer Augenkrankheiten. Nach dem holländischen des Van Tright mit Zusätzen bearbeitet*, Lahr, Schauenburg, 1854 (Second edition, 1859).

SCHEINER Christoph, *Oculus, hoc est Fundamentum Opticum*, Oeniponti, Apud Danielem Agricolam, 1619.

SCOTT Joseph F., *The scientific Work of René Descartes*, London, Taylor & Francis, 1952.

SIEGEL Rudolph, *Galen on Sense Perception*, Basel, Karger, 1970.

SMITH Redmond J. H., "Ophthalmoscopy. Historical", p. 290-294 in: DUKE-ELDER Sir Stewart and all., *System of Ophthalmology*. Vol. VII: *The Foundations of Ophthalmology*, London, Kimpton, 1962.

STREBEL J., "Zur Geschichte des Kontakt- oder sog. Haftglases", *Schweizer Medizinische Wochenschrift*, 1948, 78 (32), 796-797.

STRONG Donald Sanderson, *Leonardo da Vinci on the Eye: The Ms D in the Library of the Institute of France, Paris, Translated into English and annotated with a Study of Leonardo's Theories of Optics*, Dissertation for the degree Doctor of Philosophy in Art History, University of California, Los Angeles, 1967.

SULZER David E., "Antwort auf die Verwahrung von A.E. Fick", *Archiv für Augenheilkunde*, 1894, 28, 236-237.

SULZER David E., "Astigmie – Historique", p. 411-416 in: *Encyclopédie Française d'Ophtalmologie III*, Paris, Doin, 1904.

TONKELAAR Isolde den, HENKES Harold E, LEERSUM Gijsbert K. van, "The Utrecht Ophthalmic Hospital and the Development of the Ophthalmoscope", *Documenta Ophthalmologica*, 1988, 68, 65-69.

TONKELAAR Isolde den, HENKES Harold E, LEERSUM Gijsbert K. van, "Antonie Cramer's Explanation of Accommodation", *Documenta Ophthalmologica*, 1990, 74, 87-93.

TONKELAAR Isolde den, HENKES Harold E, LEERSUM Gijsbert K. van, *Eye and Instruments. Nineteenth-century Ophthalmological Instruments in the Netherlands*, Amsterdam, Batavian Lion, 1996.

TOWN Arno E., "Contact Glasses for Correction of Refractive Errors in Monocular Aphakia. Production of Binocular single Vision", *Archives of Ophthalmology*, 1939, 21, 1021-1026.

TRIGT Adrienus Christophilus van, *Dissertatio ophthalmologica inauguralis de Speculo oculo*, Utrecht, 1853.

TRIGT Adrienus Christphilus van, *Der Augenspiegel, seine Anwendung und Modificationen mit Zusätzen bearbeitet von C. H. Schauenburg*, Lahr, second edition, 1859.

TSCHERNING Marius, *Œuvres Ophtalmologiques de Thomas Young, traduites et annotées*, Copenhague, Andr-Fred Hörst & Sön, 1894.

WALLS Gordon L., "Sir John Herschel and Contact Lens", *Science*, 1950, 109, 501.

WARLOMONT Evariste, TESTELIN A., *Mackenzie W. Traité Pratique des Maladies de l'Oeil. Traduit de l'Anglais et augmenté de Notes par E.Warlomont et A.Testelin (d'après la 4e édition)*, 2 vol., Paris, Masson, 1856-1857.

WINSLOW Jacques B., "Observations sur la Mécanique et des Muscles obliques de l'Oeil, sur l'Iris, & sur la Porosité de la Cornée Transparente", *Mémoires de l'Académie Royale des Sciences pour l'Année 1721*, 310-322, Paris, Imprimerie royale, 1723.

WOINOW, M., "Zur Frage der Akkommodation", *Archiv für Ophthalmologie*, 1869, 15, 167-172.

YOUNG Thomas, "Observations on Vision (communicated by Richard Brockesby, read before the Royal Society, May 30, 1793)", *Philosophical Transactions of the Royal Society of London*, 1793, 83, 169-181 & plate.

YOUNG Thomas, "On the Mechanism of the Eye (The Bakerian Lecture read before the Royal Society, November 27, 1800)", *Philosophical Transactions of the Royal Society of London*, 1801, 91, 23-88 & plate. II-VII.

YOUNG Thomas, "On the Mechanism of the Eye", p. 573-606, in: *A Course of Lectures on natural Philosophy and the Mechanical Arts in two Volumes*, vol. II, V, 573-603 & plates 9-19, 604-606, London, Johnson, 1807.

YOUNG Thomas, "On the Mechanism of the Eye", p .12-63 in: PEACOCK George: *Miscellaneous Works of late Thomas Young including his Scientific Memoirs*, London, John Murray, 1855.

YOUNG Thomas, *Œuvres Ophtalmologiques de Thomas Young,* translated and annotated by M. TSCHERNING, Copenhague, Andr-Fred Hörst & Sön, 1894.

ZANDER Adolf, *Der Augenspiegel. Seine Formen und sein Gebrauch nach den* *vorhandenen Quellen zusammengestellt*, Leipzig Heidelberg, Winter'sche Verlag, 1859. (second edition 1862).

ZEHENDER Karl-Wilhelm von, "Note" p. 133 in: LOHNSTEIN Th., "Erwiderung auf die vorstehendre Bemerkung des Herrn Dr. E.A. Fick in Zürich zu meinem Hydrodiaskop", *Klinische Monatsblätter für Augenheilkunde*, 35, 1897, 132-134.

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