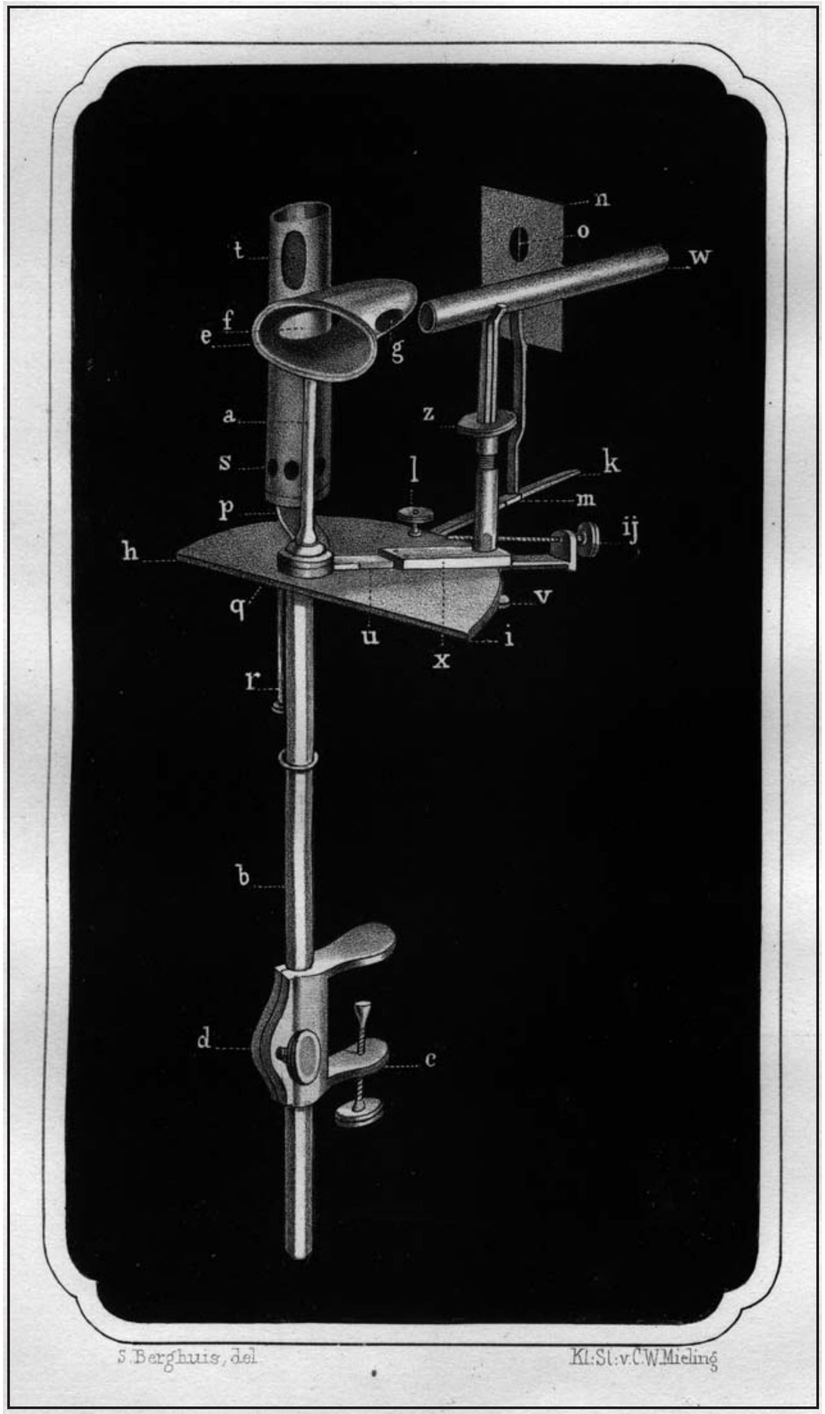

Antonie Cramer´s Ophthalmoscope

(see p.320-322)

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Ciliary Body Participation and Ocular Accommodation ever since the Ancients

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The expression "*ocular accommodation*" in the title refers to human accommodation and originates from Huygens who seems to have coined the word "*accommodation*" in ophthalmic optics by writing AD 1703 that the eye: "*ita nunc ad has nunc ad illas res se accommodet*" (adapts itself now to this, now to yonder matter).[1] Ocular accommodation stands for the potential of an eye to increase its refractive power to maintain a clear focus while changing from looking at distant to nearby objects. This essentially is a historical review on the accommodation mechanism and it does hardly center on the fact that accommodation is part of a near-reflex triad that also includes convergence and pupillary narrowing.

Accommodation from Aeschylus until Vesalius

Aeschylus (500 BC) knew that accommodation existed because he asked an old man: "Did you not see him in the distance, because close by you do not see anything?"[2] Aristotle (350 BC) mentioned that one did not know much about the inner organs of human beings, so that in your research you have to go back to the parts of other animals that are similar to you in configuration. We will see at the end of this review, that this was not a good advice while studying human ocular accommodation. Accommodation loss in old people leads to presbyopia and Aristotle thought that this occurred due to thickening of the cornea, while Galen (AD 200) attributed it to corneal wrinkling.[3]
The Greeks had no idea about the refraction of light in the eye. They thought that we see by a "pneuma" escaping from the eye in the shape of a cone or by ether that moved from objects to the eye. They explained accommodation by efforts of a "soul" in the eye, in analogy to a brain thinking about difficult questions.[3] Cassius mentioned pupillary narrowing on seeing small objects.[2] In Galen's era, one also observed accommodation loss by abuse of hyoscyamine, mandrake or opium.[2] Galen assumed that there were seven instead of six external eye muscles inserted around the optic nerve. He explained accommodation by muscle activity of the seventh (non-existent) external choanoides or retractor muscle. Vesalius still drew this seventh muscle in the middle of the 16th century *(Fig 1)*. [2, 4] Only 200 years later, the ciliary body became associated with accommodation, and thus we will first have a look at it.

The ciliary body, ligament and muscle

The ciliary body runs for 360^0 in the eye, on the inner side of the sclera at the iris base. It contains from the scleral side inwards the ciliary muscle, a vessel and connective tissue layer, the ciliary processes and in between them at their base the ciliary folds.[5] That Eustachius first named the ciliary muscle[5] is uncertain. Eustachius had fine engravings of anatomical plates made in 1564 *(Fig 2)* in which one can see the ciliary processes. These plates were re-published about six times after 1714 [6, 7] and if Eustachius had written any text at all, it was lost by that time. Two editions of Eustachio's plates have a quite different text and in the title of the last edition is mentioned that new explanations are given by the plates.[8] That the name of the ciliary body stems from cilia, hair [5] is refuted by

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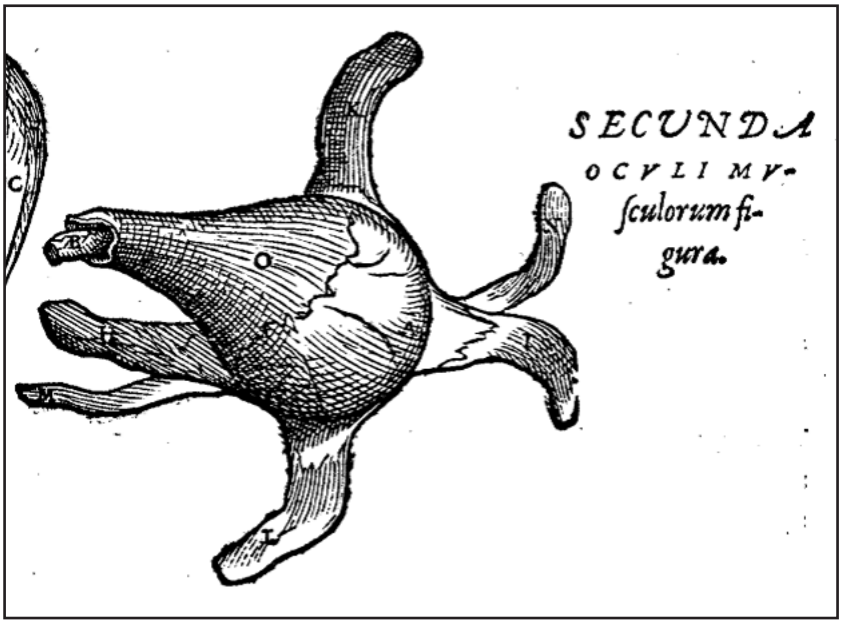


Fig 1. *The seventh ocular muscle O for accommodation, wrapped around the optic nerve.*[4]

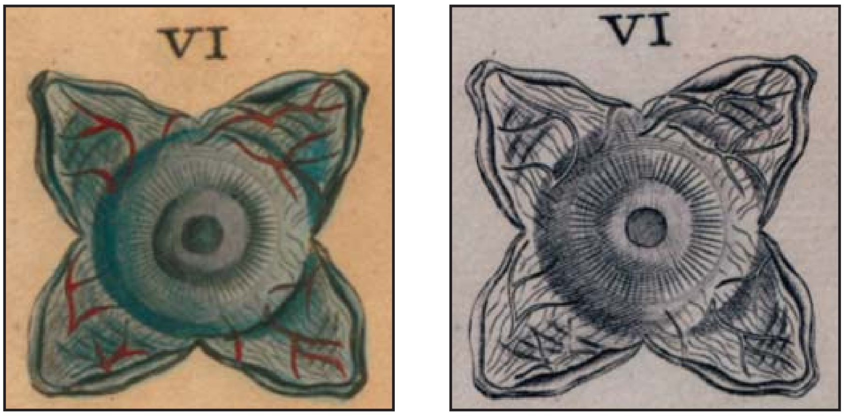


Fig 2. *Engravings from Eustachius of an eye from which the sclera has been cut and folded aside. Posterior view of the iris and radial ciliary processes after removing the retina, vitreous and lens. Published 140 years after the engravings were made.*[8]

Zinn [9]. He complained about the inconsequent nomenclature of many anatomists and used the term ciliary body that Fallopius, a contemporary of Eustachio, had introduced. [10] Cilium is the Latin word for eyelid and Zinn mentioned that even before Galen, anatomists compared the ciliary body with an eyelid having lashes. Lucretius, just before the beginning of our era, considered this body a belt that connected different tissues and strengthened the eye wall. Vesalius named the ciliary body a tunic derived from the uvea, resembling eyelashes attached to the lens equator. [4] Briggs thought that the ciliary processes were a duplex part of the iris.[11] Kepler hypothesized that the ciliary processes contract during accommodation and become shorter, pulling the lateral parts of the eye inwards, thus elongating the eye. [12] The suggestion that Boerhaave mentioned in 1708 muscular fibres in the ciliary muscle and that some Anglo-Saxon writers described these fibres before Brücke,[5] seems not to be correct. Boerhaave described in the various acroamatic editions of his lectures only muscle fibres in the iris and it remains unclear if he saw these or assumed them to be there because of the pupillary reactions.[13-15] Porterfield

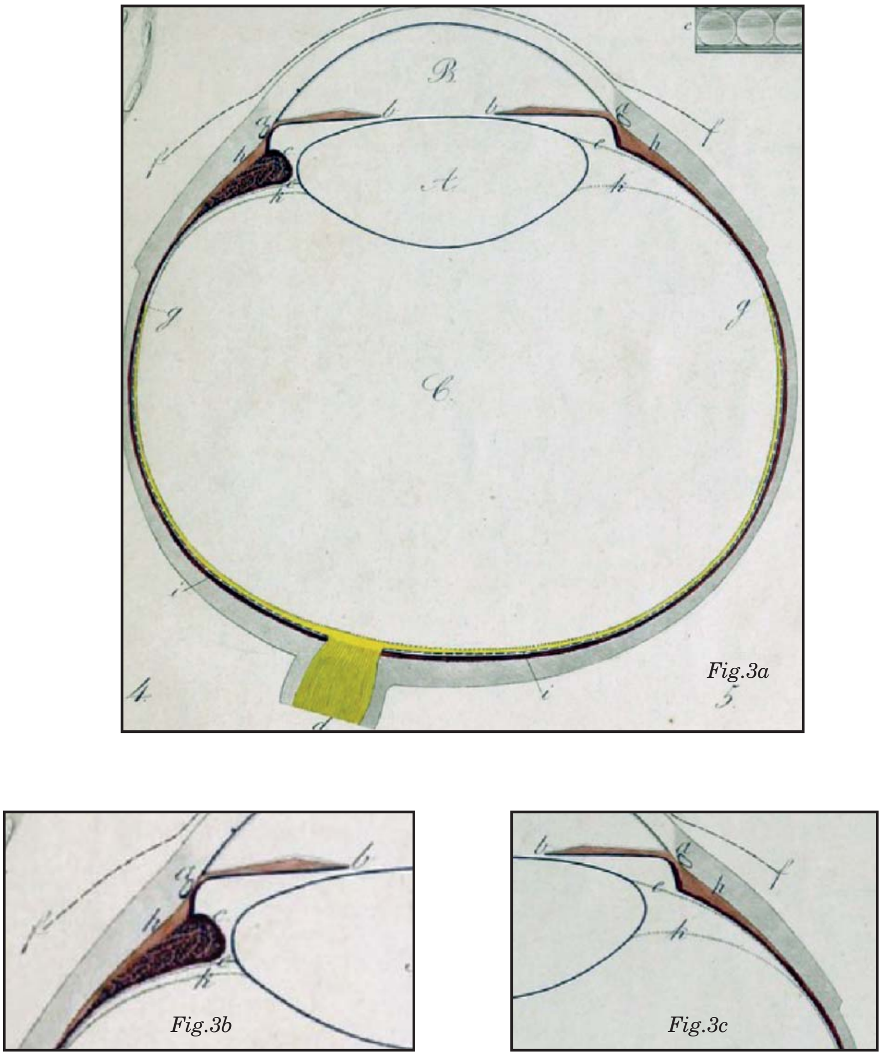


Fig 3a. *The choroidal tensor muscle h and ora serrata g. Lens A.* **Fig. 3b.** *Magnification of section exactly through a ciliary process on the left in 3a.* **Fig. 3c.** *Same of section on the right, in between two ciliary processes. a Schlemm's canal, b iris, c ciliary process, k hyaloid membrane.*[22]

named the muscularity of the ciliary ligament, mentioned by many anatomists but seems not to have found muscle fibres himself.[16] Many animals, from fish to lynx and rhinoceros, were later shown to have this ligament.[17] Wallace hypothesized, not having obtained human eyes, that contraction of these (hypothetical) muscle fibres compressed the ciliary veins, thus erecting and expanding the ciliary processes.[18] He referred to Knox who wrote extensively on the ciliary muscle (the white ring as he called it) but also Knox could not find muscle fibres, even with a microscope.[19] Despite controversies between anatomists, Camper believed that he could see fleshy fibres in the ciliary ligaments.[20] Around 1825, there was still uncertainty if the ciliary processes were glandular, muscular, nervous or vascular in origin.[21] Brücke described for the first time in the human eye the choroidal tensor muscle running in an axial direction in the ciliary body. This muscle is partly attached by an elastic maze to the inner wall of Schlemm's canal and to the corneal basement membrane *(Fig 3)*.[22] His teacher Müller added circular smooth muscle fibres parallel to the corneal limbus *(Fig 4)*.[23] The ciliary muscle seems to have

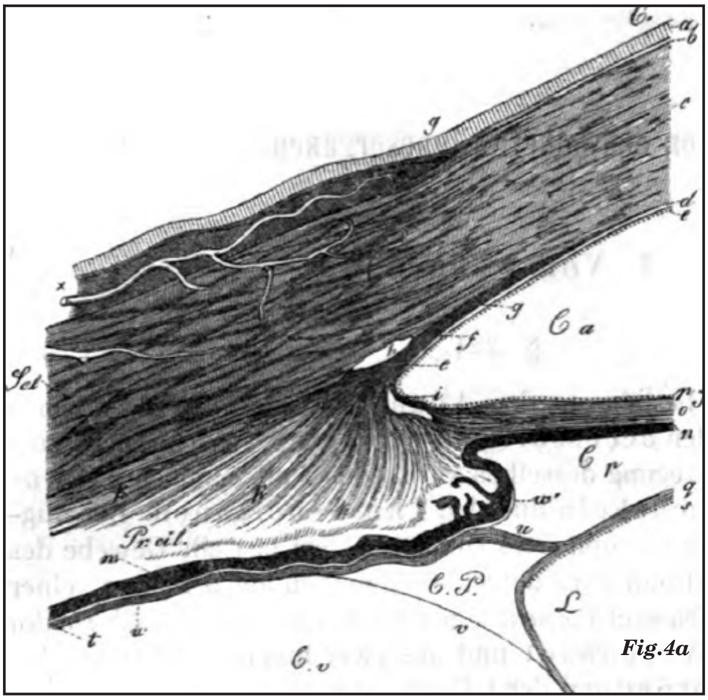


Fig.4a

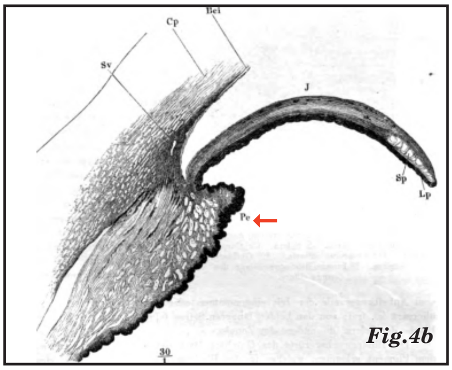


Fig.4b

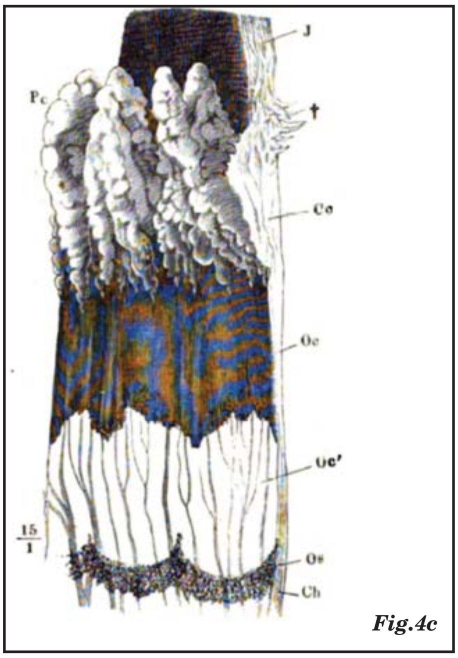


Fig.4c

Fig 4a-d. *Drawings of the human ciliary body.*

4a. The anterior chamber angle between the cornea C that merges into the sclera Scl, and the iris I. The ciliary body inserts at Schlemm's canal (h) and runs to the left on the lower side of the sclera. Ca anterior chamber, Cp Petit's canal, CP posterior chamber, Cv vitreous body, k ciliary muscle, L lens, Pr cil ciliary process, u anterior and v posterior layer of Zinn's zonules, w' anterior end of unpigmented epithelium of ciliary process. Meridional muscle fibres divide in one section going to w' and another into the iris; [79] after [80].

Fig. 4b The ciliary body with one ciliary process Pc← is depicted here more true-to-life than in 4a.[81]

Fig. 4c. Magnification of several ciliary processes. Ch choroid, Os serrated ora, Oc ciliary orbicularis, Cc ciliary body, Pc ciliary processes (Cc and Pc with pigment removed), J iris, † torn fibres connecting ciliary body with anterior chamber angle.[81]

Fig 4d. Schematic sketch of ciliary muscle fibres and bundles in the human eye; a cornea, b sclera, c iris, d ciliary process, e Schlemm's canal, f superficial, longitudinal muscle bundle, g cross-sectioned circular muscle bundle, h sectioned nerve.[23]

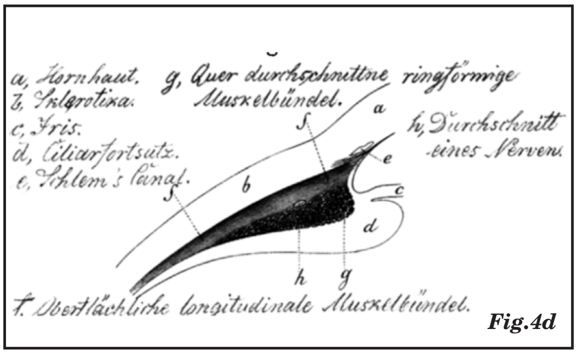


Fig.4d

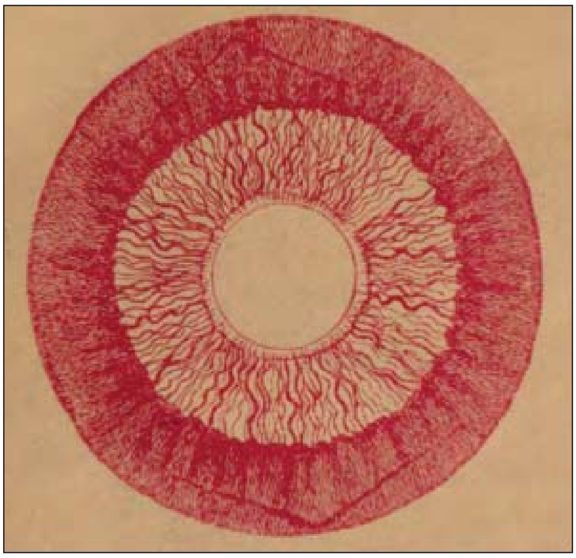


Fig. 5 *"Back view of the iris and ciliary processes in situ, showing the blood vessels, from a specimen of my own injection. The ciliary processes constitute the means by which, in my opinion, the refracting humours are altered to adjust them to objects of different distances." Magnified about 4½ diameters.*[24]

three sections; a. on the scleral side a longitudinal layer, running from the tendon attached to Schlemm's canal to the choroid; b. oblique fibres from the same tendon, splitting in the tails of the ciliary processes and the smooth ring in the heads of these processes near Schlemm's canal; c, meridional fibres, running forward with subsections going into the heads of the processes and into the iris.[5] Also, a vascular mechanism of accommodation came into being. When the ciliary processes are filled with blood, forwards and outwards pressure flattens the cornea, and the pressure on the vitreous carries the lens forwards *(Fig 5)*. [24]

For a long time people were confused about the innervation of the ciliary body. Cramer, the discoverer of the accommodation mechanism thought that the trigeminal and the sympathetic nerve were involved.[25] The author of a manuscript (with poor methodology) on accommodation loss in 92 patients with toothache came to the same conclusion.[26] Later the oculomotor nerve was proposed[27] and indeed, the presynaptic parasympathetic fibres run along with this nerve to the superior ciliary ganglion. About 97.5% of the ciliary muscle innervation seems to be parasympathetic and the remainder sympathetic.[28] The parasympathetic postsynaptic fibres from the superior ciliary ganglion run via the short ciliary nerves to the ciliary muscle, the sympathetic ones via the long ciliary nerves. When humans are startled, their pupils dilate and accommodation is relaxed, thus focusing on distant vision; possibly the main function of the sympathetic innervation of the ciliary muscle.[29]

The accommodation mechanisms from Descartes to Langenbeck

In the early 17th century, one thought that the ciliary processes move the vitreous and the lens forwards or backwards by contraction and relaxation. Thus they would flatten or bulge the lens, according to whether one is looking at objects far away or close by.[30, 31] Descartes (AD 1650) considered accommodation a voluntary process, even when a person is unaware of the fact that he accommodates, because he intends to see close objects well.[31] Van Leeuwenhoek mistook around 1700 fibres in the lens (and even fibres in the vitreous) for muscular fibre tendons[32] and this may have put subsequent researchers on the wrong track. Jurin theorized, spurred by a thesis of Pemberton,[33] that "For many reasons the most advantageous and convenient

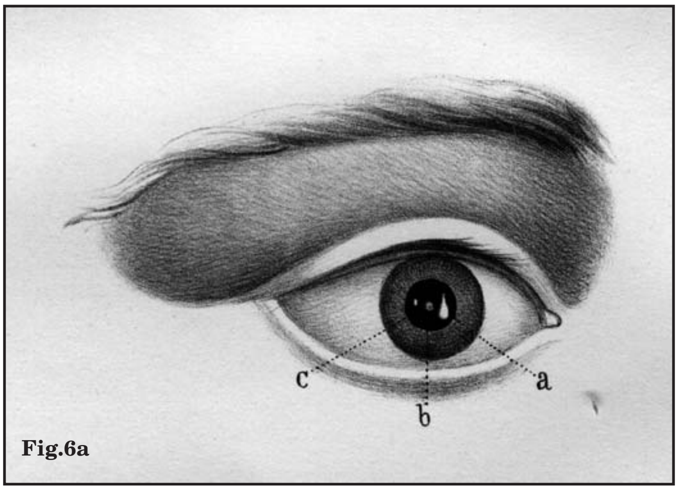


Fig.6a

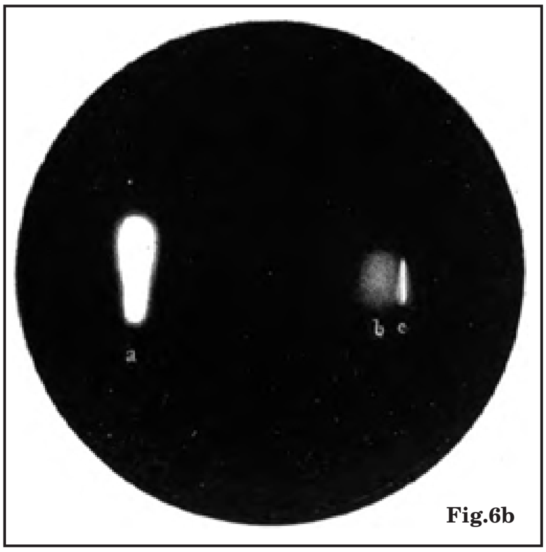


Fig.6b

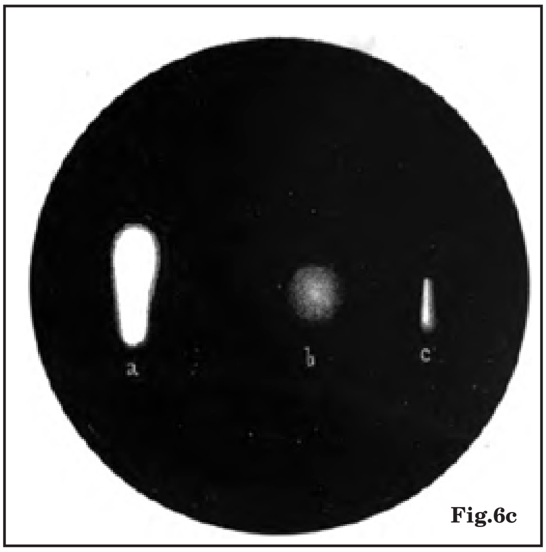


Fig.6c

Fig 6a *Reflections from a candlelight lateral to an accommodating eye, as seen from the contralateral side. a upright corneal epithelial image (brightest); b upright image (weakest) from the anterior lens surface; c inverted image (medium bright) from the posterior lens surface. While looking in an axial direction in the eye, a is in front, b is seen deepest and c is halfway between a and b. On moving the candle, a and b move in the same direction and c in the opposite one.*[(25)]

Fig **6b** *Pupil of a non-accommodating eye looking in the distance. a upright corneal image; b upright image from the anterior lens surface; c inverted image from the posterior lens surface.*[(25)]

Fig **6c** *During accommodation on a nearby object: a and c remain in place, proof that the lens position does not change; b changed its position and became slightly smaller.*[(25)] *Images 6b and 6c are from* [(25)]*. Could Cramer have been mistaken so that images b and c appear to be upside down?*

method for the eye to be accommodated to near objects seems by rendring the anterior surface of the crystalline more convex, while the hinder surface grows flatter. But this surely is too great a change for a substance of such a consistence as the crystalline humour to admit of."[34] Thus he found "No satisfaction in any of the hypotheses above related" and next focused on the cornea and uvea as the site where accommodation took place. The Table gives an overview of the wide variation in hypotheses and results of research on accommodation. Home tore instead of cut the rectus muscles from a human eye after death. Thus, he found that the rectus tendons became broader on approaching the cornea, forming a circle of which the cornea seemed to be the central continuation. This explained in his (false) view the change in corneal radius during accommodation.[35]

Fig. 7. *Antonie Cramer (1822-1855) who found the final proof that human accommodation is due to changes in the lens curvatures.*[46]

Scheiner described the reflection of a candle flame on the cornea.[30] Purkinje, a great (myopic) observer, discovered with bare eyes that there were, apart from this corneal image, more ocular candle light reflections. These originated from the corneal endothelium and from the anterior lens surface, acting as a convex mirror, as well as from the posterior lens or anterior vitreous surface (acting as a concave mirror).[36] The endothelial image and several more secondary images were hard to see. For practical purposes, authors restricted themselves to an upright image 1 (corneal epithelium), upright image 2 from the anterior lens surface and an inverted image 3 from the posterior lens surface *(Fig 6)*. Sanson independently re-discovered

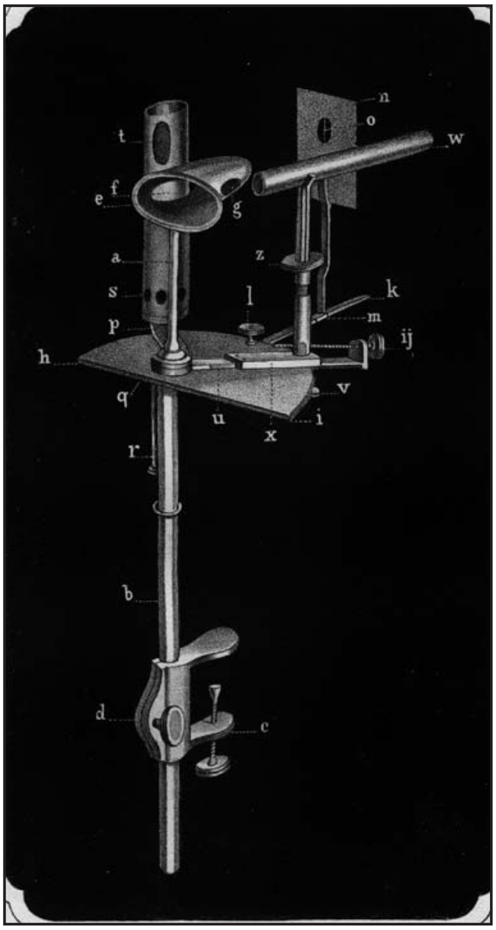


Fig 8. *Ophthalmoscope of Antonie Cramer. Cone-shaped 8 cm long tube fg with holes at its base and apex and on the sides. On the left side, a candle light from tube s t enters the cone and the candle can be moved up and down by r. On the right side, the eye to be examined, pressed to the wide end of the cone, can be observed via telescope w. This w can be adjusted in three directions with x, ij and z. Plate n can be moved towards or away from cone fg along horizontal rod k. Its opening o is in line with the axis from the eye through the hole in the top of cone fg. In front of o is a tightly stretched vertical wire and behind o is a flap that can be pulled up, closing o. Thus the eye can fixate at a distant point past o or only on the wire in front of o. Black bronzed apparatus in order to prevent reflections.*[25]

images 2 and 3 and described how one could use these images to differentiate between vision loss due to cataract or to other causes deeper in the eye.[37] Please, keep in mind that this was before the invention of the slitlamp or the ophthalmoscope. The German surgeon Langenbeck, stressed 11 years later (1849) the diagnostic value of the size, colour and relative distance of the Purkinje-Sanson images from each other. He examined, also bare-eyed, these images with a candle in front of an eye instead of to its side, thus hampering their observation because the images were nearly superimposed. Langenbeck wrote about the (in humans non-existent) "musculus compressor lentis accommodatorius," and mentioned that accommodation was due to a change in lens position; also, that the anterior lens surface became more convex during accommodation.[38] Hueck observed an increased bulging of the upper iris when a piece of meat on a string was approaching falcons or dogs, and flattening of the iris when the meat went back. He attributed this to a change in lens position. [39] Donders calculated that displacement of the lens could not account for the normal range of accommodation. He published his hypothesis that by carefully measuring the Purkinje images under telescopic magnification, one could solve the accommodation mystery. He predicted that during accommodation, the first and second Purkinje images would remain in place and that the third (middle one) would move, pointing to a change in curvature of the anterior lens surface *(Fig 6)*.[40] He wrote, "The mechanism of the accommodation capacity is still unclear. I believe I have sufficient reasons to position its origin inside the eye, without completely thus clarifying its mechanism. The hypothesis that the root of the accommodation capacity lies in the oblique eye muscles is unjustified."[41]

Cramer's solution of the accommodation mechanism enigma

In 1848, the Dutch Society of Sciences in Haarlem organized a competition to solve the accommodation issue. While participating, Cramer *(Fig 7)* published his preliminary results in 1851 and described the increasing curvature of the anterior lens plane.[42] In 1852, he received the first prize including a gold medal, and his prize winning manuscript was published in 1853, in which, by the way, he erroneously wrote that hyperopic eyes cannot accommodate.[25] Cramer, who acknowledged Donders's predictions how to solve the riddle in both publications, built an "ophthalmoscope" *(Fig 8)*. Cramer observed with a telescope, following Donders's forecast, the changes in position and height of the three reflex images on the cornea, the anterior and posterior lens capsule *(Fig 6)*. He performed many experiments to prove that the weak parts of the lens create the change in its anterior curvature during accommodation. Only then did it become clear that the 200-year-old hypotheses of Scheiner and Descartes and the one rejected by Jurin were correct. Now, also Langenbeck's observation became better known to the public. Cramer found that in accommodation, the middle image becomes smaller indicating a smaller radius of the anterior lens surface.[25] Donders had three modifications made of the "ophthalmoscope" of Cramer, who died in 1855,[43] and named these a "phacoidoscope." By using his phacoidoscope, Donders could see tiny changes in the distance of the posterior image b, sometimes approaching the corneal image, sometimes increasing its distance. The lens equator remained more or less in the same position during accommodation. Helmholtz started his article on accommodation by claiming priority over the discovery of Cramer and Donders.[44] He wrote that he overlooked their earlier publications as well as Langenbeck's one on this matter but later had to admit "After obtaining Cramer's work by the kindness of Mr. Donders, I convinced myself that the enigma of accommodation, in which so many researchers have in vain practiced their ingenuity, mainly was solved, and the intended investigation left me little more to do. "[44] Helmholtz measured more accurately the Purkinje images in the eyes of three humans aged 30 to 35 years with an ophthalmometer. He based its construction on the heliometer of astronomers, by which he obtained an accuracy of 0.01 mm on a moving eye. He found that the distance from the corneal apex to the pupillary plane was 3.7 to 4.0 mm and to the posterior lens surface, 6.9 to 7.1 mm. After death, lenses become thicker. During accommodation, the pupillary plane moved 0.36 to 0.44 mm forwards. Helmholtz confirmed Cramer's reduction of the middle image and wrote that the posterior lens radius became a little smaller.[44]

After Cramer's first publication

Cramer's work was translated in German[45] but Cramer was quite displeased about the result.[46] There still remained controversy about how exactly accommodation occurred. Helmholtz agreed with Cramer and Donders that the corneal curvature does not change during accommodation. He thought together with Brücke that ciliary muscle contraction pulls the choroid and the zonules forward towards Descemet's membrane, receding the iris, and slackening the zonules. Thus, the anterior lens surface bulges through its elasticity. Helmholtz assumed that in the relaxed state of the eye while looking in the distance, the zonules tighten and thus flatten the lens. He was uncertain whether the circular fibres in the ciliary muscle were the main active fibres and the radial fibres only auxiliary ones. His conclusion was: "So we hardly can deny the ciliary body some function in the accommodation process." The posterior surface of the lens remains in place and the lens volume does not change, so the centre of the lens becomes thicker[44] and others agreed.[47] After examining various bird eyes, Müller thought that the ciliary muscle increased in thickness by contraction of the longitudinal fibres. This way, the anterior part of the zonules slackened and the circular ciliary muscle and the iris exerted pressure on the peripheral lens part.[5, 23] Donders did not believe in this pressure of the circular fibers and the iris on the lens rim and considered it essential to measure first the circumference of the lens during accommodation.[48] Cramer used electrical currents in the ciliary region of enucleated seal and bird eyes to show that changes during stimulation occurred as long as the iris was intact, but nothing happened when he removed the iris or made radial cuts in it.[25] Weber and von Graefe assumed that there was a separate positive accommodation mechanism in myopic eyes and a negative one in hyperopic ones.[49] Knapp measured the planes and curvatures of the anterior and posterior lens surfaces. He found a high concordance between his measurements and the visual determination of accommodation by the push-up method of Donders. With this method, one moves a text along a ruler towards the eye, until the text becomes blurred. Accommodation in aphakia was highly questionable, not only by his measurements but also by the various experiments of Donders in Utrecht in which Knapp participated.[50] Tscherning challenged Helmholtz's suspicion that the lens is flatter seeing in the distance through the pull of the zonules. He considered the function of the iris for accommodation not proven and mentioned that von Graefe demonstrated intact accommodation in complete aniridia.[27] According to Tscherning, Helmholtz and Donders did insufficiently take into account the peculiar structure of the ciliary muscle. Henle stressed that the circular and meridional muscle fibres of the ciliary body had a separate function.[27] Iwanoff, Arlt and Sattler agreed with him and found hypertrophy of the circular fibres in hyperopia and of the meridional fibres in myopia.[27] Tscherning also mentioned the lack of knowledge about innervation of the ciliary muscle. He thought that the oculomotor nerve was the accommodation nerve and perhaps the sympathetic nerve also.[27] Tscherning postulated a downwards and backwards lens movement during accommodation as well as central vitreous liquefaction with dilation of Cloquet's canal.[51]

Lossing et al. demonstrated the complexity of the human ciliary muscle action by preliminary data obtained with anterior segment optical coherent tomography. During a 4 diopter accommodation stimulus, the maximum ciliary muscle thickness increased by 69.2 μm (18.1 μm per diopter) at about 1 mm posterior to the scleral spur but the muscle thickness decreased by 45.9 μm (-12.0 μm per diopter) at 3 mm from this spur. So indeed the portion of the ciliary body closest to the cornea bulges most. Unfortunately the zonules were absent on the images provided.[52] The most sophisticated measuring instrument, a scanning partial coherence interferometer, found that in an emmetropic 30-year-old human eye the anterior pole of the lens moved 228 μm forwards and the posterior lens pole 75 μm backwards when changing from distant vision to focusing on the near point. This ratio of three to one held for all 10 eyes tested.[53] Most remarkably, it seems that the absolute values found 160 years ago differed only by 0.1 to 0.2 mm from the present ones.

Only recently, Ott published a fascinating review on accommodation mechanisms in various animals.[54] Nearly all options mentioned over the centuries for these me-

Table Accommodation mechanisms

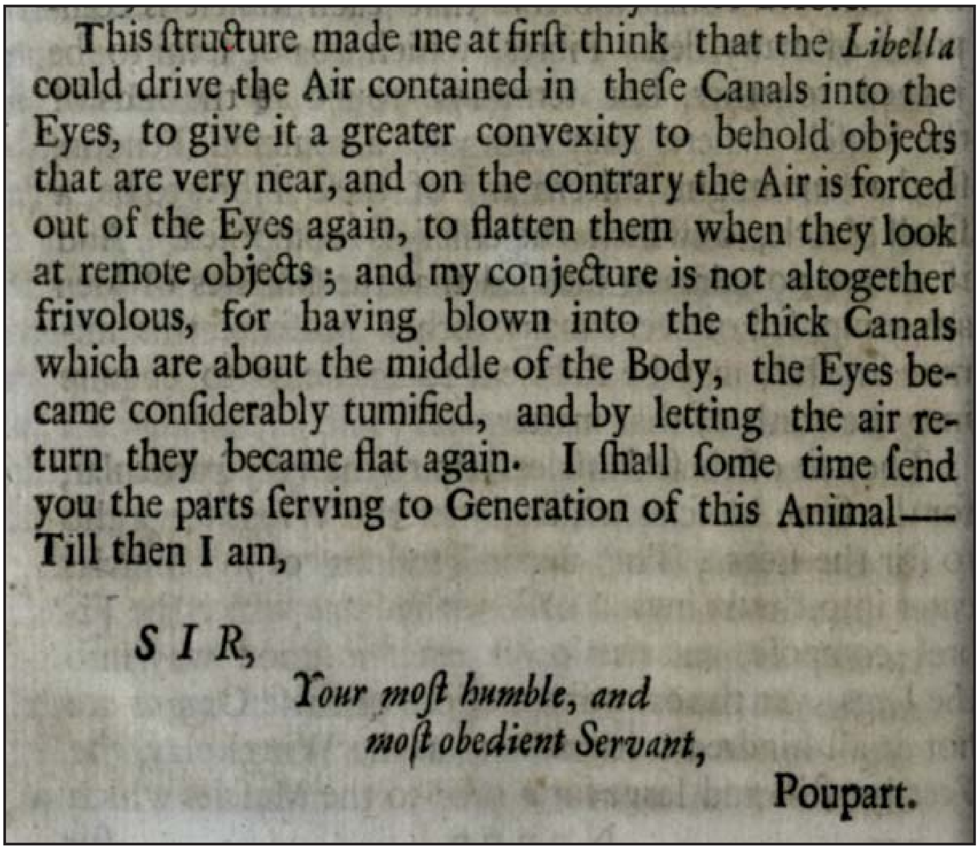
A: First author encountered, who mentioned this mechanism
B: Later authors doing the same.

Year	Mechanisms	A	B
1611	Axial eye elongation on inward pull of ciliary processes	(12)	
1611	Retinal movement by contraction of ciliary ligament leading to narrowing of equator of eyeball	(12)	
1619	Lens dislocation or bulging by ciliary processes	(30)	
1642	Lens bulging	(31)	(39,55-59)
1685	No change in lens form or position. No muscles in ciliary ligament	(60)	
1701	Air inflation in eyeball (in the libella)	(61)	
1703	Lens dislocation or bulging by pressure from external muscles	(1)	(59,62)
1719	Changes in cornea and uvea	(55)	(34,62)
1743	Contraction of oblique muscles	(63)	
1746	Contraction of muscular fibres in lens capsule or zonules	(20)	(39,64)
1751	Constriction of eye ball by rectus muscles	(15)	(65)
1758	Change in refractive index of ocular fluids	(66)	
1759	Lens becomes convex by muscular fibres in lens	(16)	(57)
1759	Contraction of ciliary ligament pulls lens forward compresses vitreous and makes cornea more convex	(16)	(57)
1780	Choroidal thickening	(62)	
1795	Diminishing corneal radius	(35)	
1795	Better accommodation in an aphakic eye	(35)	
1801	Lens swelling relatively more at posterior than anterior surface	(57)	
1801	Orbicular eyelid muscles flattening the cornea or shortening the visual axis (Monro, according to (39)	(39)	
1809	Zinn's zonules consisting of delicate vessels exerting force on lens rim	(68)	
1809	Aqueous forwarding lens capsule. Lens lacks movement mechanism	(68)	
1809	Presbyopia due to weaker zonule function	(68)	
1813	Contraction of tissue between scleral bony ring and tendinous corneal ring	(69)	
1821	No existent accommodative mechanism but mental brain process	(70)	
1821	Central hole in yellow spot detecting small differences in optical axis	(71)	
1824	Both voluntary and involuntary processes	(67)	
1826	Pupillary dilatation and narrowing	(19,72)	(39,73)
1826	Denial of accommodation existence	(72)	
1826	Refractive index of vitreous on lens side different from that on fundus side	(72)	
1826	Traction of ciliary muscle on external half of choroid	(19)	
1832	Fluid congestion in the iris	(65)	(73)
1835	No lens changes. Accommodation possible due to laminated lens structure	(73)	
1835	Shortening of the visual axis	(74)	
1839	Forward movement together with greater convexity of lens	(39)	
1841	Elongation eye axis, corneal bulging due to contraction rectus muscles	(75)	
1842	Near vision on iris contraction, far vision on iris expansion leading to corneal change	(76)	
1842	Sheathes around rectus muscles, connected to conjunctiva create corneal vaulting on rectus contraction	(76)	
1849	Rectus muscles by pulling eye against orbital fat padding, push vitreous and lens forwards and increase corneal convexity	(77)	

Table continued p.325

Table Accommodation mechanisms *(continued)*

	Mechanisms	A
1849	Lens compressing muscle. Lens movement and bulging anterior capsule	(38)
1850	Movement of lens nucleus within capsule	(78)
1853	Bulging of anterior lens capsule and iris pressure by simultaneous iris sphincter and dilatator contraction.	(25)
1853	Ciliary muscle contraction hinders posterior lens movement.	(25)
1853	No accommodation in hyperopic eyes.	(25)
1855	Ciliary contraction and thickening of lens centre plus anterior bulging	(44)
1855	Positive accommodation in myopic eyes negative in hyperopic ones	(49)
1857	Increasing thickness of longitudinal ciliary muscle, slackening zonules, circular muscle pressing on lens rim and pressure of peripheral iris	(23)
1864	Backwards movement of choroidal part of ciliary muscle	(48)
1904	Backwards and downwards lens movement	(51)
1904	Central vitreous liquefaction	(51)
1904	Dilatation of the canal of Cloquet in vitreous centre	(51)


This ſtructure made me at firſt think that the *Libella* could drive the Air contained in theſe Canals into the Eyes, to give it a greater convexity to behold objects that are very near, and on the contrary the Air is forced out of the Eyes again, to flatten them when they look at remote objects; and my conjecture is not altogether frivolous, for having blown into the thick Canals which are about the middle of the Body, the Eyes became confiderably tumified, and by letting the air return they became flat again. I ſhall ſome time ſend you the parts ſerving to Generation of this Animal— Till then I am,

SIR,

Your moſt humble, and
moſt obedient Servant,

Poupart.

Fig 9. *Fragment from letter of M.Poupart to M.Lister re the accommodation mechanism in the libella.*[61]

chanisms in humans *(Table)* occur in the animal kingdom. They range from independent monocular accommodation between paired chameleon eyes, combined as well as independent accommodation between the two eyes of hawks and vultures, influence of retinal thickness on accommodation in small eyes, corneal changes, and anterior lenticonus to shifting lens positions in cats. A sea otter is emmetropic above water and can see well under water because of a 60-diopter accommodation range. Humans and fish have a less perfect stimulus-response function for accommodation than lizards and turtles.[54] Ott did not mention insects, so he leaves us in the dark whether Poupart *(Fig.9)* was right[61]. This review shows that Aristotle was wrong re comparative anatomy or physiology and it is no wonder that our predecessors were for so long grouping in the dark, comparing animal eyes with human ones.

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