

A Medieval Fallacy: The Crystalline Lens in the Center of the Eye.

Supplemental Information.

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Modern Statements about Ancient Views on the Centrality of the Crystalline Lens.

Magnus (1901).

"According to his closing views, Celsus had assumed an unusually large posterior chamber. For in Book VII, 7, 13B de natura oculorum et eorum suffusione, he says that under both outermost layers of the eyeball, ie., under the κερατοειδής [keratoeides] and χοροειδής [choroeides] exists a locus vacuus. Toward the end of the same section, he also makes statements about the size of this posterior chamber. He says that if one inserts the Staar needle between the outer corneal margin and the outer corner of the eye (inter nigrum oculi et angulum temporii propriorem), it enters into an empty space (inani loco excipitur). Celsus must have thought this empty space to be very spacious if, on so doing, the needle fell into a cavity extending far into the space of the globe. *One may well assume* [italics ours] that Celsus had thought the posterior chamber occupied half of the inner space of the eye behind the iris. (See Plate I, Fig. III of our work.) [Figure 1 in the present paper.] This assumption corresponds to the concepts of the relations held during the Middle Ages...

After what has been said, there can be no doubt that Rufus with his views of the inner space relations of the eyeball had come very close to our modern concepts. Galen later made these views of Rufus at least partly his own. Nevertheless, the post-Galenic era unfortunately then departed from these very clear concepts and developed speculatively an arrangement of inner relations which joined not just partly those of Celsus, but surpassed by far even that concerning the posterior position of the lens in the vitreous body." (Magnus 1998 pp. 142-143)

Magnus' figure purporting to depict Celsus' anatomy with a central lens has been described (Wade 2005, p. 63) or reproduced without being challenged by multiple historians (Chinn 1941; Duke-Elder 1961; Snyder 1964; Rucker 1965; Wade 1998; Albert 1996, p. 23; Lovicu 2004, p. 6; Bobrow et al 2013), including Julius Hirschberg and Thomas Hall Shastid in the early twentieth century (Hirschberg 1982, p. 100; Shastid 1913). This figure has been assumed to reflect the views of not only Celsus, but also his "contemporaries" (Snyder 1964; Rucker 1965). The American Academy of Ophthalmology states that the figure was drawn by Celsus himself (Bobrow et al, 2013).

Meyerhof (1928).

“The *first treatise* [of Hunain] gives the anatomy of the eye, following Galen’s *De Usu Partium* book X. It repeats carefully the teleological idea of Galen, viz., that everything in the body and in the eye has been created for a definite use. And in this manner it repeats all the errors of the Galenic anatomy, which were dominant for more than 1400 years. The crystalline lens (translated into Arabic under the name of *ice-like humour*) is falsely placed in the centre of the eye-ball and made the principal organ of vision...We must not forget that the Greeks and Arabs could not make autopsies of human beings and were limited to the knowledge of the anatomy chiefly of domestic animals. As for the afore-mentioned anatomical errors, we find that the great anatomist Vesalius in his celebrated work repeats them still in the middle of the sixteenth century...The right position of the lens in the anterior part of the eye was first described by Fabricius ab Aquapendente about 1600 A.D. ...” (Meyerhof’s introduction to Hunain 1928, pp. XXXIX-XL).

Polyak (1941 and 1968).

Polyak reviewed Galen’s anatomy in detail (Polyak 1941, pp. 97-103). He never actually found any statement by Galen indicating that the lens was in the center of the eye. But Polyak does identify language which he believes to be a “contradiction”:

“The iris, Galen curiously states, is of a blue color and is in contact with the cornea...It is vascular in order to furnish nourishment to the cornea. It is soft so that it will not harm the crystalline lens which it touches.” (Polyak 1941, p. 98)

“The space between the lens and the cornea, the present anterior chamber of the eye, although well described by Galen, is not mentioned by name. That it is large is evidenced by his reference to the fact that instruments, when introduced into it, as during cataract operation, may be moved in various directions, up and down, or from right to left, without touching the adjoining parts...

The description of the anterior eye chamber illustrates well the frequent contradiction encountered in Galen’s writings: a few pages later he speaks of a direct contact between the cornea and the iris. (Polyak 1941, p. 99)

“The two chief errors of the Greek anatomy--the location of the lens in the center of the eyeball and the channeling in the center of the optic nerve--have been faithfully copied by the Arabs.” (Polyak 1941, p. 107).

“On the other hand, the striking similarity between the conceptions current among the Arabs and those of the Greeks, notably of Galen, forces one to accept the second assumption (cf., e.g., Hunain ibn Ishak or Ibn Sina, and the tenth book in Galen’s *On the Utility of Parts, etc.*). In agreement with this is the fact that the principal ideas concerning the structure and function of the visual organ--viz., the view of the crystalline lens as the actual photoreceptor, its central

location in the eyeball,...--besides many other details, were common both to the Arab and to the Greek conceptions. That these concepts were practically identical is finally attested by the express admission found in Hunain ibn Ishak's book that he used Greek sources, especially Galen. This acknowledgment is also reason for suspecting that the diagrams found in the Arabic manuscripts may likewise have been redrawn from Greek originals or patterned after them. Owing to the loss of the latter, however, there is no positive evidence on this matter." (Polyak 1941, p. 123)

"Otherwise Platter's diagram of the inner eye structures shows considerable improvement, compared with that by Vesalius...Consequently, the crystalline lens was moved from the center--the position given to it by Galen and by the Arabs, and which it still had in Vesal's diagram (1543; cf. Fig. 21 in this volume)--and assigned its proper place in the anterior portion of the eyeball..." (Polyak 1941, p. 135)

It is fascinating that Polyak is so willing to assume that the Greek authors, in particular Galen, were the source of the central lens in the Arabic writings. Polyak actually reviewed Galen's work in detail, and nowhere does Polyak find in Galen's work any clear statement that the lens is located centrally.

"Whereas the Greeks missed or erred in but a few of the anatomical details, their functional interpretation of the structures of the eye was, for the most part, faulty. They were mistaken when they believed the lens to be in the center of the eye." (Polyak 1968, p. 11)

"Knowing the derivative character of the Arab ophthalmological sciences, it is not surprising to see Arab students of the eye repeating all the familiar mistakes found in the Greek originals: central location of the crystalline lens..." (Polyak 1968, p. 17)

Mailer (1966).

"The evolution of the modern word "glaucoma" takes a difficult and variegated course after Aristotle...The lens was thought to be at the center of the eye. Galen, in the first century AD, was the first to explain the difference between "glaukoma" and "hupochuma."

Lindberg (1976).

"In the first of the Ten Treatises, Hunain presents a wholly traditional account of ocular anatomy and physiology, drawn primarily from book 10 of Galen's De usu partium. The central feature of the eye is the icelike or crystalline humor (our crystalline lens)...The crystalline humor occupies the central position in the eye..." (p. 34)

Fronimopoulos (1991).

“According to Celsus, the lens sat in the center of the eye bulb and was considered to be the essential organ of vision.”

Finger (1994).

“Galen maintained that spirits traveling down the optic nerve emerged at the retinal tunic and then made their way to the centrally located crystalline lens.” (Finger 1994, p. 69)

[Writing of Avicenna’s Canon of Medicine from 1025 AD] “From this passage it can be seen that the doctrines of the classical authorities were held in such high esteem in the Middle East that both their advances and their errors tended to be accepted. In particular, the following ancient ideas did not change significantly during the Middle Ages:...(2) that the lens was located in the middle of the eye.” (Finger 1994, p. 71)

Howard (1995).

“Galen did not dissect humans...He based his anatomy of the eye on Herophilus. A spherical lens at the centre of the eye was considered to be the essential organ of vision and an extension of the brain.” (Howard 1995, p. 5)

Edwards (1996).

“...Galen found a place for the structures of the eye he described in such works as On the Eyes and Their Accessory Organs...According to his schema, the pneuma flowed through the optic nerves to the retina and then to the crystalline lens (which was still thought to be in the center of the eye).” (Edwards 1996, p. 263)

Enoch (1997).

“The Claudius Galen’s (Greco-Roman, AD 130 to 200) concept of the eye, which has antecedents in the work of Hippocrates and Celsus, dominated vision science until the end of the 16th century and the early part of the 17th century. The ancients apparently believed the eye lens was situated in the center of the eye and was the site of visual sensation.”

Realini (1998).

“Galen and Vesalius both were convinced the lens lay in the center of the vitreous cavity, but Fabricius, in 1601, finally placed the lens snugly behind the iris, paving the way for David Campbell to describe the etiologic characteristics of pigment dispersion syndrome.”

Kovacs (1998).

“The Alexandrine school, even though recognizing the existence of a lens thought to be situated in the center of the globe, considered as source of the disease the brain from where corrupt humor collected in the “empty space” between the pupil and the lens. This misconception was perpetuated by Celsus and Galen and others until the eighteenth century,…”

Jampel (1998).

Writing of the ancient period, and using the language of Celsus:

“The lens was located in the center of the eye, and in front of it was an empty space (the locus vacuus).”

Crone (1999).

“Hunayn’s book includes the oldest known illustration of the anatomy of the eye...Following the example of Herophilus, the lens is placed in the middle of the eye and the optic nerve is hollow.”

Lindberg (2003).

“The most important piece of content for the future history of optics was Hunayn’s claim (following Galen) that the sensitive organ of the eye is the crystalline lens, situated in the center of the eye.”

Kalloniatis (2005).

“The ideas of the Greeks from centuries B.C. were perpetuated and preserved by the writings and drawings of the Arab world until well into the Middle Ages A.D. Thus, one of the earliest diagrams of the eye was from an ancient Arab manuscript (circa A.D. 860), and this was probably a copy of an older Greek illustration now lost [showing Hunain’s figure with the central lens]. According to early ideas, the eye had a central crystalline lens that had a photoreceptor role.”

Glaser (2008).

“According to Galen, ‘...a round lens in the middle of the eye...is the principal instrument of vision, a fact clearly proved by what physicians call cataracts, which lie between the crystalline humor and the cornea and interfere with vision until they are couched.’”

Zipser (2009).

“The two major Galenic works on the anatomy of the human body, *anatomicae administrationes* and *de usu partium* have a three liquid/four tunic system, whereas the fragment only mentions two of these structures each.

Most of the Greek texts which have come down to us contain an almost identical understanding of the anatomy of the eye...The lens is situated in the middle of the eye, and it was believed to be the organ of perception.” (Zipser 2009)

Mark (2010).

“To Galen, as to Celsus, the lens was the organ of vision, fairly centrally located in the globe.”

De Laey (2011).

This article shows a figure with a central lens labelled: “Ocular anatomy according to Galen.” In fact, this diagram is actually from “A New Most Highly Useful Little Book, and Anothomy of an Open Eye, Together with Its Explanation, Well-tried Purgation, Application, Poultice, Fine Salves, Powders and Waters, and How to make Them and To Use Them” by Heinrich Vogtherr, printed in Strassburg, 1539 (Polyak 1968, p. 28).

DeLaey continues:

“A few schematic descriptions of the eye are known of, especially from Alhazen and Hunain Ibn Ishak. These continued to be based on the Galenic concepts: the optic nerve was hollow and the crystalline lens, which was considered the most essential part of the eye, was centrally located and connected to the optic nerve.”

Howard (2012).

“Galen dissected pigs, oxen, goats, and tailless apes, but not humans...A spherical lens at the center of the eye was thought to be the recipient organ and an extension of the brain. Galen regarded the retina as an organ that nourishes the lens. It has been suggested that the lens was placed at the center of the eye because it tends to migrate there in the dead eye.” (p. 16)

Grzybowski et al., (2013).

“According to Galen (1968), the optic nerve was pierced, and the fluid circulating the brain flowed freely in the eye and surrounded the lens, which was an organ of vision and was located in the middle of the eye’s axial length.”

Ancient Statements on the Position of the Crystalline Lens.

Hippocrates (c. 460-c. 370 BC).

The Hippocratic book on Fleshes [17, 606] records:

“...I have already seen viscous moisture running out of a wounded eye. As long as it is warm, it is moist; however, when it became cold, it became dry like transparent incense.”(Magnus 1998, part 1, p. 53)

Some historians believe that “transparent incense” refers to the lens, but there is no way to be sure.

Herophilus (330/320 BC -- 260/250 BC).

Celsus noted that the primary Alexandrian anatomist, Herophilus, performed dissections on living criminals (Von Staden 1989, pp. 138-190). Scholars have debated the veracity of this claim, but the historian Heinrich Von Staden considers it plausible. In any event, it is agreed that Herophilus performed human dissections. Celsus also notes that Herophilus coined the name *arachnoidem* for the retina (7.7.13B; Celsus 1938), due to its resemblance to a cobweb (Von Staden 1989, pp. 205-6). Herophilus mentioned that the iris surface is rougher on the interior side (Von Staden 1989, p. 205; Rufus 1879, p. 171). It is plausible that Herophilus might have seen the lens, but no record of this observation has survived.

Celsus (c. 25 BC -- c. 50 AD).

Celsus is covered more extensively in the manuscript. Celsus introduced the lens as: “a drop of humour like white of egg, from which comes the faculty of seeing; it is named by the Greeks *crystalloides* [κρυσταλλοειδής]” (7.7.13; Celsus 1938)

Demosthenes Philalethes (early 1st century AD).

A surviving fragment of Demosthenes’ work relates to the crystalline lens in glaucoma (Von Staden 1989; Leffler 2015), but not to the position of the lens.

Rufus of Ephesus (80-150 AD).

The anatomist Rufus of Ephesus in his primary discussion of ocular anatomy does not seem to have been specific about the anteroposterior location of the lens (Hirschberg 1982, vol 1, pp. 167-169; Rufus 1879, pp. 135-137). Interestingly, we cannot find any historians who have specifically cited Rufus as an anatomist who placed the lens centrally. In fact, common depictions of Rufus’ anatomical understanding place the lens quite anteriorly (Shastid 1913, p. 8588; Magnus 1999, part 2, p. 467)

This common view of Rufus anatomy may result from the fact that nothing in Rufus' descriptions requires major deviations from the real gross anatomy of the eye. Moreover, an anonymous letter attributed to Rufus noted (Rufus 1879, p. 172):

"The anterior half of the crystalline lens lies on the hole of the iris." (Hirschberg, 1982, vol 1., p. 169).

Rufus' anatomical descriptions do include some points which proved important in the derivation of modern ophthalmic terms (Rufus 1879, pp. 135-137). Rufus noted that "the pupil derives its name from the image seen in the center of the 'vision'" (Hirschberg 1982, vol 1, p. 168). Rufus also mentioned the various coats and humors of the eye, and stated that the layer surrounding the crystalline fluid was called "lens because of its shape or crystalline coat because of the fluid it surrounds." (Hirschberg 1982, vol.1, pp. 168-169).

Galen of Pergamon (c. 129-199 AD).

Galen is covered more fully in the manuscript. Magnus' interpretation of his ocular anatomy included an anterior lens (Shastid 1913).

Speaking of the insertion of the retina into the lens:

"This indeed is the largest circle on the crystalline body and divides it into two parts;...It was reasonable too to keep the vitreous humor from passing forward at this same circle, so that thanks to it the crystalline humor rests in the midst of the vitreous like a sphere cut in half in water...this circle, which I have said is the largest one on the crystalline humor, joins them together (the inner side that resembles a hemisphere of the crystalline)...for the netlike body [the retina] as well, and for the choroid tunic as a fourth member."(X.II.60; May 1968, vol. 2, pp. 467-8)

Speaking of the union of all 7 circles around the circumference of the lens, at the point which he calls the *iris* or crown, Galen writes:

"Thus the hard membrane [the sclera] is joined securely to the choroid, the choroid in turn is joined to the netlike body, and this to the vitreous and crystalline humors, to the vitreous over its whole surface, and to the crystalline only at the *iris*...Close upon this same circle [the sclera] comes a sixth, outer tunic, inserted into the hard tunic, the aponeuroses of the muscles moving the eyes, and besides these there is another, the seventh, which is the insertion of a periosteal tunic [the fascia bulbi and conjunctiva]..." (X.II.61; May 1968, vol. 2, pp. 468-9)

"This place [the ciliary region] is called iris...some call it the wreath, and if you go about the dissection of the circles in the right way...you will see the seven lying one upon another in this region and varying in thickness and color..." (X.II.61; May 1968, vol. 2, p. 469)

“...show us any other of the seven circles at the iris that would be better suited to give rise to the hornlike tunic [the cornea]...” (X.II.64; May 1968, vol. 2, p. 471)

“...the roughness on the inner side of the tunic [the iris] that surrounds the crystalline humor. For these are moist and soft like a sponge, and where they touch the crystalline humor they render painless the association of the whole tunic with it.” (X.II.69; May 1968, vol. 2, pp. 474-5)

“...where this hornlike tunic [the cornea] grows off from the *iris* [the ciliary region], it will seem to you to be very close to the crystalline humor, since all the humors and tunics of the eye are united in this region, but as it gets farther toward the outside, it withdraws more and more, its greatest possible separation being at the pupil, as one can learn from dissection and couching cataracts. For since cataracts arise in the space between the hornlike tunic and the crystalline humor, the instrument that is introduced to draw them aside, when moved around through the large, free space, up, down, to the sides, and in short, circularly in all directions, does not touch either of the bodies in question [the lens and cornea] because the distance between them is very great.” (X.II.70-71; May 1968, vol. 2, pp. 475-6)

“...consider the nature of the grapelike tunic [the iris]; for the part of it touching the crystalline humor is very like a soaked sponge...” (X.II.74; May 1968, vol. 2, p. 478)

“The covering [the iris] next to this is full of veins, soft, dark, and perforated;...soft, in order not to cause pain when it touches the crystalline humor.” (X.II.75; May 1968, vol. 2, p. 479)

pseudo-Galen (c. 2nd or 3rd century AD).

The couching procedure was briefly described by an unknown author, termed pseudo-Galen, in the work “Introductio, seu medicus”, or “Introductio, sive medicus”. This work was traditionally attributed to Galen, but modern scholarship indicates that the author was a contemporary of Galen, or lived shortly thereafter (Mattern 2011).

The following translation of pseudo-Galen’s couching technique has been offered (Lascaratós 1982):

“ ... as far as hypochymas are concerned , we depress them by performing a paracentesis near the limbus on the side of the temporal angle until [the instrument] reaches an empty space [in the region between the front surface of the lens and the back surface of the iris, i.e. in the posterior chamber]; then, after we have laid [the instrument] horizontally on the limbus, we depress the humour that exists on the pupil [the hypochyma] with the instrument's tip and we wedge it so that it does not return to its previous position.”

The original Greek text is readily available from several sources (pseudo-Galen 1827, p. 784; pseudo-Galen 2015):

“τὰ δὲ ὑποχύματα κατάγομεν, παρακεντοῦντες περὶ τὴν ἴριν, ἐκ τοῦ πρὸς τῷ μικρῷ κανθῷ μέρους μέχρι κενεμβατήσῃ καὶ παρακεντήσῃ· εἶτα πλαγιάζοντες ἐπὶ τὴν ἴριν τῷ ἄκρῳ αὐτοῦ τὸ συνεστὸς κατὰ τὴν κόρην ὑγρὸν κατάγομεν ξύοντες καὶ σφίγγοντες, ὥστε μὴ ἀναβλέψαι.”

A medieval Latin translation is also available (pseudo-Galen 1827, p. 784):

“Suffusiones deducimus pungentes circa irim ex minori Angulo, donec acus penetrarit et loco vacuo excipiatur: deinde per obliquum ad iridem perducentes summa ejus parte compactum circa pupillam humorem deducimus, delignates e stringentes, ut non aspiciat.”

Oribasius (325-403 AD).

Ocular anatomy according to Oribasius (325-403 AD) was taken from Galen’s *De Usu Partium* (Oribasius 1858, pp. 294-304).

The French translation of Oribasius contains a passage which is analogous with Galen’s work:

“Comme l’implantations dont nous venons de parler se fait de toutes parts sur le milieu (circonférence) du cristallin, qui est rond, elle donne nécessairement lieu à la formations d’un cercle parfait, et ce cercle est un grand cercle du cristallin, et le divise [par conséquent] en deux parties égales. Il était raisonnable d’empêcher, au niveau de ce cercle, l’humeur vitrée d’avancer, disposition qui fait flotter le cristallin au milieu sur cette humeur, comme une sphere coupée en deux par l’eau.” (Oribasius 1858, pp. 296-297)

We might translate this passage as:

“As the implantations of which we just spoke are everywhere around the middle (circumference) of the crystalline, which is round, it necessarily results in the formation of a perfect circle, and this circle is the greatest circle of the crystalline, and divides it [consequently] into two equal parts. It is reasonable to prevent, at the level of this circle, the vitreous humor from advancing, a provision which makes the crystalline float in the middle on this humor, like a sphere cut in two by water.”

This analogy of the lens floating on top of the vitreous like a sphere floating on water (with the waterline dividing the sphere—i.e. the lens—in two) is easier to understand.

Aetius of Amida (502-574 AD).

Aetius described the crystalline lens without making precise statements about its location (Hirschberg and Aetius 2000, p. 2-4).

Paulus Aegineta (625-690 AD).

In his description of glaucoma, Paulus referred to the crystalline lens, but not to its position (Paulus 1834, p. 273).

In book 6, chapter 20, Paulus Aegineta recorded Galen's words defining the *iris*, or *corona*, as the meeting point of all the ocular structures. Speaking of hypopyon, Galen wrote: "...oftentimes we evacuate the pus freely by dividing the cornea a little above the place where all the coats of the eye unite. This place is called by some the iris [ἶρις, irin], and by others the corona [στεφάνην, stephanen].' These are the words of Galen in his work 'On the Method of Cure.'" (Paulus 1846, vol. 2, 6.20, p. 278)

The original terms for iris and corona are found in the Greek text on p. 59 (Paulus Aegineta 1924, p. 59, line 32).

The couching procedure is also discussed by Paulus (Paulus 1846, vol 2., book 6, Section 21, p. 279-280):

"SECT. XXI, ON CATARACTS.

The cataract is a collection of inert fluids upon the cornea at the pupil, obstructing vision, or preventing distinct vision. It arises most commonly from a congelation and weakness of the visual spirit, and on that account the disease rather attacks old persons, and those who are debilitated by protracted illness. It is occasioned also by violent vomiting, a blow, and many other causes. Those kinds of cataract which are but commencing, as not being proper objects of surgery, have been treated of in the Third Book. We shall now give the characters of those which are fairly formed and have acquired consistence. All those, therefore, who have cataract see the light more or less, and by this we distinguish cataract from amaurosis and glaucoma; for persons affected with these complaints do not perceive the light at all. Wherefore, again, Galen well instructs us as to the consistence and difference of cataracts and which kinds ought to be operated upon. Having shut the eye affected with the cataract, and with the large finger pressing the eyelid to the eye, and moving it with pressure to this side and that, then opening the eyelids and observing the cataract in the eye; if it has not yet acquired consistence, a certain flow takes place from the pressure of the finger, and at first it appears broader, but straightway resumes its former figure and magnitude. But in those which have acquired consistence no change takes place as to breadth or figure from the pressure. But since this appearance is common to those which are of moderate consistence, and those which are over-

compacted, we distinguish these cases from one another by their colour. For those which are of an iron, caerulean [κυανόχροα, kuanochroa], or leaden colour, are of moderate consistence, and fit for couching; but those which resemble gypsum and hailstones are over-compacted. After ascertaining these circumstances as directed by Galen having placed the patient opposite the light, but not in the sun, we bind up carefully the sound eye, and having separated the lids of the other, at the distance from the part called the iris towards the small canthus, of about the size of the knob of the specillum, we then with the point of the perforator mark the place about to be perforated; and if it is the left eye we operate with the right hand, or if the right eye with the left; and turning round the point of the perforator, which is bent at its extremity, we push it strongly through the part which was marked out, until we come to an empty place. The depth of the perforation should be as great as the distance of the pupil from the iris. Wherefore, raising the perforator to the apex of the cataract, (for the copper of it is seen through the transparency of the cornea,) we push down the cataract to the parts below, and if it is immediately carried downwards, we rest for a little, but if it reascends we press it back again. After the depression of the cataract we turn round the perforator and extract it gently. After this, bathing with water and injecting into the eye a little Cappadocian salts, we apply externally some wool soaked in the white of an egg with rose-oil, and bind it up, and at the same time bind up the sound eye, that it may not move. Then lodging the patient in an apartment below ground, we order him to remain in a state of perfect rest, and upon a spare diet; and the bandages are to be kept on, if nothing prevent, until the seventh day, after which we loose them, and make trial of the sight by presenting him with some object: but this we disapprove of during the operation and immediately after it, lest by the intense exertion the cataract reascend. If the inflammation become urgent we loose the dressing before the seventh day, and must direct our attention to it.”

We might comment on the color κυανόχροα [kuanochroa] which was translated as “cerulean”, and was noted by Paulus to imply an excellent surgical prognosis. This translation might at first seem to contradict the writing of Celsus that suffusions of the color caeruleus had a poor surgical prognosis (Leffler, *Clinical Ophthalmology*, 2015). Caeruleus in Latin was generally a blue or gray hue, but could also describe green objects, such as plants. Caeruleus was used to describe the lighter eyes of the Germans (Leffler, *Clinical Ophthalmology*, 2015).

The term used by Paulus, κυανόχροα, is derived from the color κυάνεος [kuaneos], the cognate of cyan (Leffler, *Clinical Ophthalmology*, 2015). Hippocrates noted in the era before couching that a κυάνεος pupil saw poorly (Leffler, *Clinical Ophthalmology*, 2015). Aristotle noted that deep water was darker, and could be κυάνεος (Leffler, *Clinical Ophthalmology*, 2015). Although κυάνεος is often thought to be a shade of blue, and did have connotations as dark blue, with respect to the eyes, κυάνεος represented a dark eye color (Irwin 1974, pp. 79-110). It seems that dark eyes were represented more commonly by κυάνεος in poetry, and by μέλας in prose (Irwin 1974, pp. 97-101). Thus,

with respect to eyes, κύνεος could represent brown or black, and therefore did not correspond with eyes of the color *caeruleus*.

The Greek text of Paulus' description of the couching procedure is available online (Paulus Aegineta 1924, pp. 60-61). The term for entering the empty space (κενεμβατήσεως, kenembateseos) is on p. 61, line 12.

Theophilus Protospatharius (7th century AD).

By the 7th century, Theophilus Protospatharius incorporated Christ's teachings on the eye being the lamp of the body (Matthew 6:22) into Galen's understanding of the ocular anatomy, including the crystalline lens (Theophilus 1842, pp. 150-173).

Medieval Statements on the Centrality of the Crystalline Lens.

Hunain Ibn Ishaq (809–877 AD), known later as Johannitus.

“We will now begin with the discussion of the ice-like humour [lens]...It is situated in the middle of the eye, like a point which we imagine to be in the centre of a globe.” (Hunain 1928, p. 3)

“If we mentioned, moreover, that its place is in the centre of the eye, then this is a proof that all that surrounds it in the eye was created for it, either to protect it from injury or to be useful to it. Therefore those parts surround it from all sides, whilst it is in the middle itself.” (Hunain 1928, p. 4)

“It is like the following diagram:--” [with central lens diagram] (Hunain 1928, p. 5)

“I have already explained to you that the ice-like humour (the lens) is in the centre of the eye...” (Hunain 1928, p. 6)

“Where is the location of the glacial humor in the eye?
In the center...It is placed in the center being given the rank that it occupies in relation to the other organs.” (Hunain 1938, p. 83)

[We should note that in the manuscript we use the term “Mesopotamia” to describe the region in which Hunain lived in the same sense that it was used by Hunain’s biographer Max Meyerhof (1928), to describe the region of around the Tigris and Euphrates rivers.]

Ali ibn Isa el-Kahhal (c 940–1010 AD), known later as Jesu Hali.

“The crystalline body is colorless, transparent, luminous and rounded--not a perfect sphere but somewhat flattened. It is placed in the middle of the eye, marking the central point of the globe...”

The position of the crystalline body in the middle of the eye not only insures the best protection from injury but also allows it to be most readily nourished by surrounding tissues.” (Ibn Isa 1936, pp. 12-13)

Abu Ali al-Husain Ibn Sina (c 980–1037 AD), known later as Avicenna.

“The crystalline humor is colorless, clear, and reflects the light...Its position is in the center of the eye....

It is placed in the middle of the eye for the following reasons: As already said, every other part of the eye is created to serve the crystalline humor, either to ward off danger or to bring it nourishment...It, however, must always lie in the middle (of the eye)...

Galenos asserted that none of the three humors contained blood-vessels, either pulsating or pulseless.

Oreibasius asserted in the seventh part of his work that they are nourished by the route of the sweating process.” (Stricker 1909, pp. 403-413)

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