

“De oculis”, a chapter on ocular anatomy by Constantinus Africanus

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Abstract

Purpose: The publication of the compendium *Pantegni* by Constantinus Africanus in the monastery of Monte Cassino in the eleventh century CE was a pivotal moment in the history of medicine in Western Europe. The work is predominantly based on the *Liber regalis* by Haly Abbas (Baghdad, tenth century CE). The earliest available manuscript of the *Pantegni* (KB 73 J6) is handwritten and has been supervised by Constantinus himself. It includes a chapter on ocular anatomy. In this paper we try to distill the anatomic description by Constantinus.

Methods: The chapter “*de oculis*” on ocular anatomy as found in chapter 13 of book 3 in KB 73 J6 is interpreted in the historical context and translated into Modern English.

Results: We present an English translation of the concerning chapter.

Conclusion: Constantinus bequeathed a compact but comprehensive account of the anatomy of the eye, which can be rendered into a contemporary representation with use of the historical context.

Keywords

Pantegni; Constantine the African; anatomy, history; ophthalmology, history.

Introduction

The history of European medical knowledge has a turning point in the middle of the eleventh century CE. A significant role at this moment has been played by Constantinus Africanus, the first translator of medicine from Arabic to Latin. He produced more than 30 different texts, whereas in the three ages before in Western Europe in total only about 70 different medical texts circulated with only minor impact (Glaze, 2019). One of the texts by Constantinus Africanus is the *Pantegni*, which reached an impressive circulation and remained influential for ages (Green, 2018). In the Royal Library of The Hague lies the oldest available version of the *Pantegni* (KB 73 J6).

Recently, more and more about this specific parchment manuscript has been elucidated (Green, forthcoming; Hogewind and Coebergh, 2021; Kwakkel and Newton, 2019). KB 73 J6 is written by known Cassinese scribes, supervised by Constantinus himself. He based this work predominantly on the Arabic medical compendium *Al-Kitāb al-Malakī* (Latinized name *Liber regalis*; Figure 1) by ‘Ali ibn al-‘Abbas al-Majusi (Latinized name Haly Abbas, Baghdad, tenth century CE), although he did not refer to Haly

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Figure 1. Digitalised scan of chapter 13 from book 3 of the *Al-Kitāb al-Malākī* by 'Alī ibn al-'Abbas al-Majusi, Leiden University Library, Or. 94 a, 176-180. The scanned manuscript is an undated paper copy, written in the 13th century (Voorhoeve, 1980; Witkam, 2007).

Abbas (Zargaran et al., 2013). In order to evaluate the extend of the impact of the *Liber regalis*, Russell (1994) extensively studied how Haly Abbas addressed the ocular anatomy. She thereto analyzed part 1, discourse 3, chapter 13 in the Arabic text as edited by de Koning (Majūsī, 1903) and exposed the underlying distinguishing concepts of 'Abū Zayd Ḥunayn ibn 'Ishāq al-'Ibādī (Latinized name Johannitius, Baghdad, ninth century CE [Dalfardi et al., 2016]) and Galen (Rome, second century CE [Laios et al., 2016]). The purpose of this paper is to elucidate what Constantinus wrote on ocular anatomy.

Materials and methods

We accessed the *Pantegni*, manuscript KB 73 J6, via the website of the Royal Library of the Netherlands and we transcribed book 3, chapter 13 (Africanus, circa 1080c). In cases where legibility was impaired because of the handwriting, abbreviations or wormholes, we used as cross-reference the transcription of another manuscript of the *Pantegni*, which has been dated back to the same era (Kaltio, 2011 and 2020). Hereafter we distilled the content and translated the text into Modern English.

Results

Figure 2 shows a scan of the relevant chapter. Below we respectively depict the transcription in Latin and the translation of the text.

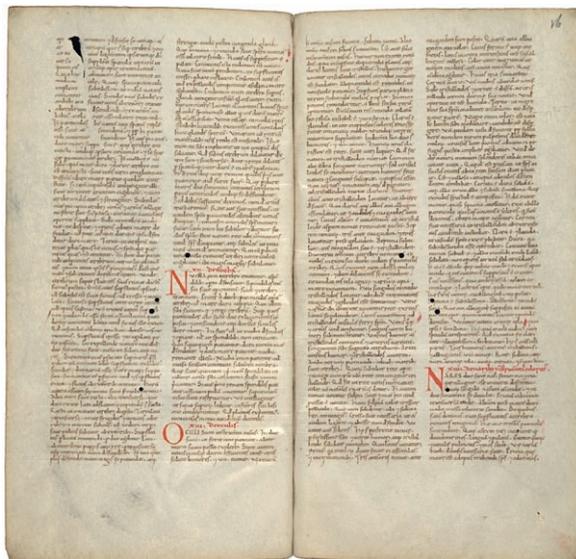


Figure 2. Digitalised scan of chapter 13 “de oculis” from book 3 of the medieval parchment manuscript *Pantegni*, Dutch National Library, KB 73 J6, folio 15^r and 16^r. Written around 1080 AD under supervision of Constantinus Africanus in the abbey of Monte Cassino, Italy (Kwakkel and Newton, 2019).

xiii. deoculis.

OCULI sunt instrumenta uisus, hi duo sunt, ut forte uno patiente, alter uicem suam possit explere. Sunt autem uniuscuiusque decem efficientes cause, tres scilicet humores, et vii, tunice. Nontamen hæc omnia uisum faciunt, sed una tantum. Alia omnia eius rei solius sunt iuuamenta.

Est autem solum instrumentum uisus, humor non ex toto rotundus, quia insuperficie aliquantulum planus atque clarus, lucens sicut cristallus. Hic humor graece uocatur *cristalleidos*, cuius in medio tunicarum est fundatio. Aliquantulum est rotundus, ut non facile patiatur. Superficies parum plana, ut rem sentiendam melius percipiat. Si enim penitus rotundaretur, non bene sensui rerum aptaretur. Omnis enim res, rotunda in latera sua redisa instabilis est et non firma. Clarus est et lucidus, ut cito in oppositos colores transferatur in tunicarum medio, ne undique careret iuuantium supplemento.

Indumenta sua duo sunt humores, et vii. tunice. Humorum unus clarissimus est retro, sicut uitri liquor. Quod fecit natura, ut *cristalleidon* nutriat. Cum enim alia membra sanguine nutriantur, sed *acristalleidos* se moueat, uitreum humorem fecit natura quis sanguinem suscipiat, et inipisus essentiam uertat, et mutatum atque depuratum ad *cristalleidon* mittat clarum.

Humor alius ante *cristalleidon* locatur, ut ab aere desiccetur. Qui clarus atque albus oui albugini assimilatur, ut et *euagaidos* uocatur. Cuius alterum est iuuamentum, ut *acristalleide* asperum tunice remoueat tactum. Septem tunicarum, tres ante *euagaidon*, et tres locantur post *gelaidon*. Septima subtilior, inter *euagaidon* sita est, et *cristalleidon*.

Chapter 13, about the eyes

The eyes are the instruments of vision. There are two of them, so that if one were to suffer, the other can take over. Each of the two consists of ten components: three humours and seven tunics. Yet not all realize vision, only one does; all other parts are supportive elements.

The only instrument we use to see is a humour, not quite spherical since its surface is somewhat flattened, and which is clear and shining as crystal. This fluid is called *cristalleidos*, by its Greek name. It is situated in the middle of tunics. It is somewhat spherical, making it less susceptible to damage. Its surface is a bit flattened, so as to better encompass all that is to be perceived. Moreover, if it was spherical all-around, it would be unstable and not firmly fixed in place. The *cristalleidos* is clear and bright, enabling it to quickly change into the different colours confronting it; it is centred between tunics so as not to lack the support from the surrounding structures.

The *cristalleidos* itself is covered by two humours and seven tunics. Of these humours one, situated behind the *cristalleidos*, is very clear, translucent as molten glass is; it was made like this by nature to nourish the *cristalleidos*. Whereas other parts of the body are nourished by the blood, the *cristalleidos* is an exception, nature has made the *humor vitreus* to receive blood, change it into the essence of the *cristalleidos* and so, altered and purified, to deliver it to the *cristalleidos* as a clear fluid.

The other humour is situated in front of the *cristalleidos*, to prevent it becoming desiccated by the air. This fluid is clear and whitish and is being compared to *albugo oui* [egg white]. It is called *euagaidos*. Its second function is to prevent a rough contact of the *cristalleidos* with the tunic. Of the seven tunics three find themselves in front of the

Duo nerui concaui acerebro uenientes ad oculos in exitu sui duobus induti sunt panniculis cerebri. Quos exuunt cum adossa oculorum ueniunt, et dum dilatantes se extendunt, circumdat eos tela uenarum et arteriarum apia matre exeuntium. Horum singulus inmedio cristalleidos locatur, ubi due extremitates euagaidos et gelaidos esse sentiuntur. Vene et arteriae ibi contexte uocantur rete, ex retis tantum similitudinem. Cuius iuuamentum ad cristalleidos uisualem ferre spiritum.

Venis quoque et arteriis unde conficitur, sanguis uitreo humori subministratur. Vitreus humor et cristalleidos cum uenis et arteriis, careant, sanguinem sibi sugendo attrahunt. A reti uitreus humor, et cristalleidos auitreo. Ambo neruorum panniculi, aduabus matribus sunt cerebri. Quorum subtilior rete operit et iungit cum ipso ubi rete coniungitur cristalleido. Quod fit ut rete uenis nutriatur, calor uero naturalis ex arteriis detur. Hęc autem tunica uocatur secundina sicut et mater pia unde processit est uocata. Hanc secundinam uelat crossior pellicula. Quę cum solidetur, ubi et secundina reti coniungitur. Crossa fuit necessaria, ut et oculum ligaret, et ab osse eum defenderet. Vocatur autem scliros.

Hęc sunt postremę tunicę, perfectissime sibi et uitreo humoris atque cristalleido solidate in medio. Qui locus uocatur yreus, quia in colorum diuersitate ei assimilatur, et incircuitionibus.

euagaidos and three behind the *gelaidos*. The seventh, a delicate tissue, is positioned in between the *euagaidos* and the *cristalleidos*.

Two hollow nerves approach the eyes where they exit from the brain, they are covered by two meninges, that enter the ocular orbits with them, where they separate, expand and stretch out over the length of the nerves, covering them with a network of veins and arteries which emerges from the *pia mater*. Each of these [nerves] is found halfway [at the equator] of the *cristalleidos*, where the two edges of the *euagaidos* and the *gelaidos* can be seen. This is called *rete* since the web of veins and arteries resembles a *rete* [network]. The *rete* serves to convey the *spiritus visualis* to the *cristalleidos*.

Blood coming from veins and arteries out of the retina, is provided to the *humor vitreus*. Since the *humor vitreus* and the *cristalleidos* are devoid of veins and arteries, they attract blood by suction. The *humor vitreus* from the *rete*, and the *cristalleidos* from the *humor vitreus*. Both the meninges of the nerves are from the two meninges of the brain. Of these the thinner covers the *rete* and is attached to it where the *rete* is attached around the *cristalleidos*. This layer serves to nourish the *rete* by the veins, and to supply natural warmth by the arteries. This tunic is also called the *secundina*, just as the *pia mater* from which it originates, is sometimes called *secundina* [Gerard Baader 1967]. This *secundina* is covered by a fairly thick coat, which is tightened where it joins with the *secundina* and the *rete*. This layer was needed to keep the eyes located as well as to protect them from the hardness of the bone. It is called *scliros*.

These are the posterior tunics, they are firmly connected with one another and with the *humor vitreus* and the *cristalleidos*, exactly halfway [at the equator]. This spot is called *yreus*, because in its variety of col-

Tres anteriores tunice, ante euagaidon sunt posite. Quarum una albuginem oui uelat. Cuius forma est uue medietas. Lenis inantea intrinsecus uersus albuginem uillosa. Color inter nigrum et uenetum medius, unde uuea uocatur. Que asecundina egreditur. Huius tria sunt iuuamenta. Corneam nutrit. Unde multis abundat uenis. Secundo cristalleidos et cornee est differentia, ne cristalleidi cornea duritie sua noceat. Vnde oportuit ut esset humida. Tertio, ut nigredine sua spiritum coadunet uisibilem, ne dispergatur per aerem. Nigro enim colorus est naturale lumen sibi coadunare, candido uero dispergere.

Vnde quidam uisu deficiente propter splendorem nimium parum palpebras claudunt oculorum, ut uisus licet paruus adueam refugus, postea amplior egrediat. Vnde dedit natura nimium splendorem in hac concauitate uuea. Que etiam est pertusata ut spiritus uisualis exiens abea rem sensam ilico percutiat. Est et uillosa, ut aquam adoculos descendentem combibat.

Cornea est dura solida, atque alba cornu albo et subtili simillima. Que ex multis frustulis est composita. Hec dum excorticatur, quasi squama auellitur. Exit ab illo panniculo qui supra uocatus est scliros, qui sicut diximus, adura matre egreditur. Cornea fuit necessaria ut cristalleidon ab extrinsecus accidentibus custodiat. Clara est et lucida, ut uisualem spiritum exire prohibe-

ours and in its circumference it resembles an *yreus* [rainbow].

Three more tunics are positioned in front of the *euagaidos*. One of these veils the *albugineus* and its form is that of the inside of a grape. It is smooth anteriorly and it's furrowed inside lies against the *albugineus*. The colour is in between black and blue. It is called *uuea* and originates from the *secundina*. This structure has three supportive functions. One is to nourish the *cornea*, to which end the *uuea* contains multiple veins. The second function is to keep the *cornea* separated from the *cristalleidos*, so as to prevent the *cornea* being injured by the hardness of the *cristalleidos*. For that reason the area needs to be moist. The third function is to ensure, by its blackness, to keep the *spiritus visibilis* (on the use of *spiritus visualis* and *spiritus visibilis* see Russell [1994]) collected so that it does not get scattered by the air. After all, black is the colour in which by nature all light comes together, whereas it is scattered by white.

Therefore, if too much light hampers vision, one closes the eyelids a bit, so only a little vision effuses from the *uuea*, after which the *spiritus visibilis* emerges amplified. For that reason nature has provided an abundance of light in the cavity that is formed by the *uuea*. Since it is perforated, the *spiritus visualis* can directly exit to reach the perceived object. The *uuea* is furrowed, so that if water descends to the eyes, it swallows it.

The *cornea* is hard, firm and colourless, very similar to the fine and white structure of horn, and consists of numerous small parts. When one removes the outer layer one can, as it were, peel of lamellae. The *cornea* is a continuation of the coat that we have previously called *scliros* which, as we have already mentioned, is itself a continuation of the *dura mater*. The *cornea* is need-

at. Dura, atque subtilissimam esse oportebat.

Coniunctiva tunica subtilis est, et alba in omnibus oculi lateralibus solidata, non operiens corneam sed circumdans. Hęc illa est albedo quę uidetur in oculo et exiens a panniculo, qui inter cutaneus suppositus est craneo. Eius necessitas, quia undique ossibus oculum circumligat, et lacertos operit quibus mouentur oculi.

Hęc sunt tres tunicę, ouię albugini antepositę. Septima est subtilissima, albissima, et nitidissima. Quę ouię albugini supposita eam tantum partem operit, quam vitreus humor operiendam dimisit. Vocatur autem araneę tela, quia ipsi est simillima. Hęc est quam in oculo uidemus, cum speculum conspicimus. Quod ex nimia fit claritate, et lucentissima sorbitione.

Hęc sunt omnes oculi partes. Tres humores, vitreus, crystallinus, et albugineus. vii. tunicę Rete, secundina atque dura araneę tela, uuea, cornea, et coniunctiva.

ed to protect the *cristalleidos* from external injury. It is clear and transparent, and to avoid any loss of the *spiritus visualis* to the outside, it needs at the same time to be hard and very delicate.

The *coniunctiva* has a fine structure and is white, everywhere firmly attached to the sides of the eyes, including around the *cornea*, but not covering it. It is the white of the eyes that one sees, which derives from the membrane underneath the skull. It's function is that it binds with the bone all around the eye, additionally it covers the muscles by which the eyes are moved.

These are the three tunics positioned in front of the *albugineus ovi*. The seventh tunic is very delicate and lustrous, and of a bright white colour. It is placed underneath the *albugineus ovi*. It covers only that part [of the *cristalleidos*] that ought not to be touched by the *humor vitreus*. It is called *tela arachnoidea* [spider's web] since it very much resembles it. This [the *tela arachnoidea*] is what we see in the eye, every time we watch in a mirror. It is of the most transparentness and is dissolved even by the brightest light.

These are all parts of the eye. Three humours: *humor vitreus*, *cristalleidos* and *albugineus*. Seven tunics: *rete*, *secundina*, *dura*, *tela arachnoidea*, *uuea*, *cornea* and *coniunctiva*.

Discussion

First of all, the interpretation of ancient texts is a hazardous challenge, requiring a thorough historical comprehension (Hogewind et al., 2013). However in the recent years ample insights have been gathered on the setting and the period that Constantinus supervised the writing of this specific manuscript KB 73 J6 (Hogewind and Coebergh, 2021; Kwakkel and Newton, 2019). Nonetheless, although we attempted to choose the most accurate Modern English words for anatomical terms in the translation in order to obtain a contemporary rendering, the right historical interpretation of words like blood, nerve, meninx, orbit, artery, vein, eyelid, skull and muscle remains of course an important caveat.

As to the form, Constantinus identifies two cerebral meninges around the optic nerve and describes the eyeball as an elongation of these membranes which envelope three so called humours (*humor vitreus*, *cristalleidos* and *euagaidos*). The outer meninx or *dura mater* continues as the *scliros*, which on its turn continues as the *cornea*. The inner meninx or *pia mater* perpetuates as the *secundina* till the equator of the eye and is perpetuated as the *uvea* anteriorly of the equator. The optic nerve itself prolongates within the eyeball as the *rete* encompassing only one humour: the *humor vitreus*. *Rete*, *secundina*, *scliros* and *humor vitreus* are intertwined with each other at the circumference of the *cristalleidos*. This junction lies at the equator of the eyeball and is called *yreus* (De Koning, 1903). (Note that Constantinus positions the *cristalleidos* in the centre of the eye, whereas the crystalline lens is located more anteriorly [Leffler et al., 2016]). Anteriorly of the *cristalleidos* is the *euagaidos* and the two are separated by a thin membrane called *tela arachnoidea*. Anteriorly the *euagaidos* is covered by the *uvea*. The frontal outside of the eye is formed by the *cornea* (which is the continuation of the *scliros* as described above). The sides of the eye are wrapped together with the extraocular muscles by the white *coniunctiva*, which tightens the eye to the orbital bones.

To understand what Constantinus writes on the function of the eye and its parts, it helps to read discourse 4, chapter 11 “de virtute visus” (Africanus, circa 1080d). Here Constantinus describes the concept that eyesight is realized by the *spiritus visibilis* which arises in the ventricles of the brain and travels through the hollow optic nerves to the *cristalleidos*. By effusing this *spiritus visibilis*, the *cristalleidos* makes contact with the object that is seen and subsequently changes itself in the objects colour, after which the conceptualized consciousness in the brains ventricles perceives this colour and intrinsically the form of the object (Ierodiakonou, 2014; Russell, 1994).

With this background information we can distill that Constantinus explains that the *spiritus visibilis* travels from the ventricles of the brain through the hollow optic nerves via the *rete* (which is a prolongation of the optic nerve) to the *cristalleidos* and then through the *euagaidos* and the perforation (or pupil) in the *uvea* through the *cornea* to make contact with the visualized object (Jordan, 1990; Reeves and Taylor, 2004; Salmón, 1996). Subsequently the clear *cristalleidos* adapts to the colour which is perceived by the effused *spiritus visibilis*.

Constantinus meticulously explicates the efficiency of the eye handling the *spiritus visibilis*: the spherical lens is somewhat flattened to maximize the passage of *spiritus visibilis*, the *cornea* prevents leakage of *spiritus visibilis*, the dark colour of the *uvea* facilitates storage of the *spiritus visibilis* within the eyeball and in case of bright light the palpebral aperture is decreased (de Koning, 1903).

Table. Etymological origins for ocular anatomical names as used by Constantinus Africanus in the *Pantegni*, book 3 chapter 13 (Africanus, circa 1080c).

Name by Constantinus Africanus	Constantinus' etymological explanation	Greek word as used by Galen in <i>De usu partium</i>	Rendering in the contemporary anatomical equivalent
Gelaidon		τὸ ὑαλοειδὲς ὑγρόν [@]	vitreous body
Humor vitreus (synonym for gelaidon)	sicut uutri liquor	τὸ ὑαλοειδὲς ὑγρόν [§]	vitreous body
Cristalleidos	lucens sicut cristallus hic humor graece uocatur cristalleidos	τὸ κρυσταλλοειδὲς ὑγρόν [@]	crystalline lens
Euagaidos		τὸ ὠροειδὲς ὑγρόν [@]	aqueous humour
Albugineus (synonym for euagaidos)	albus oui albugini assimilator	τὸ ὠροειδὲς ὑγρόν [§]	aqueous humour
Rete	ex retis tantum similitudinem [#]	ὁ ἀμφιβληστροειδῆς χιτῶν [§]	retina
Secundina	sicut et mater pia unde processit est uocata [*]	ὁ χοριοειδῆς χιτῶν [§]	choroid
Scliros		ὁ σκληρὸς χιτῶν [@]	sclera
Dura (synonym for scliros)		ὁ σκληρὸς χιτῶν [§]	sclera
Tela arachnoidea	quia ipsi est simillima	ὁ ἀραχνοειδῆς χιτῶν ^{@,%}	anterior lens capsule
Uvea	cuius forma est uue medietas	ὁ ὀραγοειδῆς χιτῶν [§]	iris
Cornea	cornu albo et subtili simillima	ὁ κερατοειδῆς χιτῶν [§]	cornea
Coniunctiva		ὁ περιόστιος ὑμῆν [§]	conjunctiva
Yreus ⁺	quia in colorum diuersitate ei assimilatur, et incircuitionibus	ἡ ἴρις	conceptualized region near the ciliary body

[@] The term used by Constantinus is derived from the Greek word used by Galen (Baader, 1967).

[§] The term used by Constantinus is not derived from the Greek word used by Galen (Baader, 1967).

[#] For a comprehensive study on the etymology of the word *rete* see de Jong (2014).

^{*} *Secundina* is another name for *pia mater* (Baader, 1967).

⁺ *Yreus* is not so much an ocular component but a location (*locus*).

[%] *Tela arachnoidea* is derived from ὁ ἀραχνοειδῆς χιτῶν, which is used by Galen in his *Methodus medendi* (Baader, 1967).

Constantinus also addresses the blood supply. The ocular blood vessels stem from the cerebral *pia mater's* vessels, enter the eye in the *secundina* and continue in the *uuea* and in the *rete*. Constantinus distinguishes arteries and veins, which are required for

supplying the ocular parts with respectively natural warmth and nutrition. The clear cornea is lacking blood vessels but is nourished by the *uvea* veins. The *humor vitreus* transforms the blood from the *rete* vessels in a clear fluid to supply the transparent non-vascularized *cristalleidos*.

A lot of attention goes to the vulnerability of the most precious part of the eye: the *cristalleidos*. It is not spherical all-around preventing it to be unstably attached and anteriorly it is covered by the *euagaidos* which prevents its dehydration (and protects the *cornea* against the hard *cristalleidos*). Finally, the *cristalleidos* is protected by the *cornea* from trauma.

Introducing the anatomical names of the ocular components, Constantinus also supplies us with the etymological information wherever it is applicable. In this context the analysis by Baader (1967) is of much interest: he discusses elaborately which of the names are derived from the Greek terms that are already used by Galen. In the table we depict the etymological explanations by Constantinus, add the Greek terms as used by Galen and render the anatomical names into a modern anatomical equivalent.

One sentence about the tunic which has been called *uvea* forms an enigma; what was meant by “Est et uillosa, ut aquam ad oculos descendentem combibat.”? Haly Abbas mentions couching/cataract operation in this context (Majūsī, 1903; Russell, 1994), but the couching is not mentioned by Constantinus in this chapter. Haly Abbas’ text is later also translated from Arabic to Latin by Stephanus Antiochenus (Majūsī, 1492). Stephanus writes here: “Facti que sunt in ea ab interioribus villuli: quibus aqua que ad oculos veit suspendit.” It appears that Constantinus (and Stephanus) describe(s) a physiological phenomenon, which might be hampered in the pathological condition of *cataracta* (Africanus, circa 1080a and circa 1080b; Fischer, 2000; McVaugh, 2001).

We compared our translation with the interpretation of Haly Abbas’ corresponding text by de Koning (Majūsī, 1903) and by Russell (1994). With respect to the content and the outlay, the description of Constantinus is almost exactly the same as what de Koning (Majūsī, 1903) and Russell (1994) distilled from the text by Haly Abbas. Constantinus specifically did not add any content or add new insights.

In conclusion, Constantinus bequeathed a compact but comprehensive account of the anatomy of the eye, which can be rendered into a contemporary representation with use of the historical context.

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