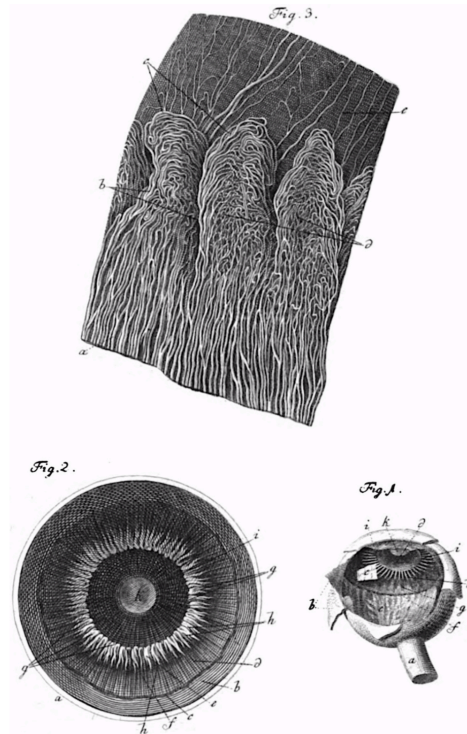


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The History of Ophthalmology
THE MONOGRAPHS
Volume 16



EYE REPRESENTATION AND OCULAR
TERMINOLOGY FROM ANTIQUITY
TO HELMHOLTZ

DOMINIQUE RAYNAUD



ISBN 978-90-6299-468-7

Wayenborgh Publications
P.O. Box 20538
1001 NM Amsterdam, The Netherlands
www.history-ophthalmology.com

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Wayenborgh Publications is an imprint of Kugler Publications, P.O. Box 20538, 1001 NM Amsterdam, The Netherlands

TABLE OF CONTENTS

INTRODUCTION	xi
1. Background	xi
2. Aim of this Book	xiv
3. Caveats	xv
4. Acknowledgements	xvi
SECTION 1: EYE DIAGRAMS FROM ANTIQUITY TO HELMHOLTZ	1
1. Antiquity: from Ebers Papyrus to Philoponus	3
2. Arabic World: Ḥunayn to Taqī al-Dīn	17
3. The Latin Middle Ages: John of Seville to Ryff	47
4. Early Modern Europe: Vesalius to Schott	81
5. Classicism: Descartes to Porras	135
6. The Enlightenment: Hovius to Adams	201
7. Nineteenth Century: Pellier de Quengsy to Helmholtz	291
SECTION 2. CLASSIFICATION OF DIAGRAMS	443
1. History	443
2. Character Identification and Coding	444
3. Matrix of Characters	446
4. Hierarchical Clustering Analysis	452
SECTION 3. TABULAR OVERVIEW OF EYE TERMINOLOGY	475
SECTION 4. BIBLIOGRAPHY	527
1. Commentaries	527
2. Primary Sources	536
SECTION 5. APPENDIXES	559
Index of Concepts	561
Index of Languages	607
Index of Manuscripts	617
Photographic Credits	621
SECTION 6. HOW TO USE THIS BOOK	625
1. Writing Conventions	625
2. Exploration of the Data	627

Introduction

This book is a follow-up to the research on ocular representation initiated by Ludwig Choulant (University of Dresden) and Hugo Magnus (University of Breslau) at the end of the 19th and beginning of the 20th century. The purpose of this book is to provide all those who need information on how the eye was conceived in a given historical context, with clear and precise iconographic and lexicographic data.

Because of the slightest disciplinary partitioning that prevailed until the 19th century – remember that physicists Huygens and Newton both studied the anatomy of the eye – this work is likely to be of interest to a wide-ranging audience: science historians (geometric and physical optics), medical historians (ocular anatomy, ophthalmology), art historians (drawing, painting, sculpture, architecture) and social scientists interested in vision (e.g. psychology and anthropology of visual perception).

1. Background

In his pioneering booklet, *Historische Tafeln zur Anatomie des Auges. Ein Beitrag zur Geschichte der anatomischen Abbildungen des Auges*, Hugo Magnus (1877) turned his attention to the representation of the eye. He reproduced eleven diagrams of the eye with their captions (i.e. Peyligk, Maurolico, Ryff, Alhacen-Risner, Vesalius, Bartisch, Della Porta, Spigel, Scheiner, Molinetti, Soemmering).

Twenty four years later, in his book *Die Augenheilkunde der Alten*, Hugo Magnus (1901) extended his previous research by recreating, based on textual data, the figures of the eye by Democritus, Hippocrates, Aristotle, Celsus, Rufus and Galen. Magnus's figures have often been copied, without always correcting the errors they contain. In particular, we note that:

1/ In Figure 1 (Democritus) the outer membrane of the eye is divided into *χιτῶν λεπτότατος* (*cornea*) and *χιτῶν πυκνότατος* (*sclera*) whereas Democritus identifies one single external membrane as opposed to one single internal membrane. In addition, Democritus always uses *φλέβες* in the plural, which prevent us from identifying them with the optic nerve (ed. Mullach 1860, p. 359).

2/ In Figure 2, seven out of the nine terms attributed by Magnus to Hippocrates and Aristotle are lacking from Hippocrates's *De visu*, which has only *ὄψις* and *στεφάνη* (ed. Sichel 1861, pp. 156–8).

3/ Four terms are missing, or overinterpreted from Aristotle's treatises (Lloyd 1978, pp. 220–1).

4/ In Figure 3 (Celsus), Magnus does not mention the existence of the pupil, whereas the *pupilla* is explicitly written in *De oculorum vitiis* (cap. 7, sect. 13, ed. Daremberg 1859, pp. 279).

5/ In Figure 4 (Rufus Ephesius) the author is credited with the knowledge of the conjunctiva, the sclera and the optic nerve, whereas the conjunctiva is not referred to in the text, the sclera is not distinguished from the cornea and the optic nerve is called *πόρος*, both in *De corporis humani appellationibus* and in the anonymous anatomy that is attributed to him (ed. Daremberg 1879, pp. 154 and 170).

6/ In Figure 5 (Galen), Magnus thinks it possible to infer the presence of the hyaloid tunic from the words ἐπιπεφυκῶς χιτῶν ἀδηλός, whereas a passage of Galen's *De usu partium* denies its existence (ed. Helmreich 1909, p. 75; ed. Daremberg, 1854, p. 624).

7/ Again in Galen's eye anatomy, Magnus omits the uvea, whereas ῥαγοειδής is explicitly mentioned in *De usu partium* (ed. Helmreich 1909, p. 69; ed. Daremberg 1854, p. 620).

These small inaccuracies suggested undertaking a revision of Magnus's eye figures, especially since they are often reproduced by contemporary authors.

By 1852, Ludwig Choulant published *Geschichte und Bibliographie der anatomischen Abbildung nach ihrer Beziehung auf anatomische Wissenschaft und bildende Kunst*. A substantially revised version appeared in English under the title *History and Bibliography of Anatomic Illustration* (Choulant 1920). The section entitled "The Schematic Drawing of the Eye in its Historic Development" (Choulant 1920, pp. 75–80) provides six figures of the eye from then little known manuscripts (London: British Library, Sloane MSS 420 et 981; Leipzig: Universitätsbibliothek, MS 1183; Paris: BnF, MS Arabe 3008; Istanbul: Süleymaniye Kütüphanesi, Yeni Camii, MS 924).

A few years later, Adam Bednarski (1929, 1931) applied the same objective to the three major perspectivists from the Middle Ages. Bednarski reproduced and commented on fourteen handwritten figures of the eye illustrating the treatises of Roger Bacon, John Pecham and Witelo.

In 1941, Stephen L. Polyak published *The Retina*, a reference book whose Part II: "Historical Survey of Investigations of the Faculty of Vision, of the Law of Optics, and of the Structure of the Eye" (Polyak 1941, pp. 95–141) deals in detail with anatomical and physiological conceptions of the eye during Antiquity, the Arab and Latin Middle Ages, and the Renaissance. This part is illustrated by twenty-two figures from thirteen authors (i.e. Ḥunayn, Ibn al-Haytham, al-Fārisī, Alhacen, Bacon, Pecham, Witelo, Da Vinci, Vesalius, Acquapendente, Scheiner, Descartes, Kircher). The captions accompanying the handwritten figures have been scrupulously translated from Greek, Arabic and Latin. For representative works, the textual descriptions of the eye are fully transcribed. Thus, Ibn al-Haytham's diagram of the optical pathways (*Kitāb al-manāẓir*, Istanbul: Süleymaniye Kütüphanesi, MS Fātiḥ 3312, fol. 81v) is confronted with the captions found on the figure, with the Arabic text of *Optics* translated by Max Meyerhof, and with the Latin text provided by Risner's edition (Polyak 1941, pp. 108–11; Fig. 8). With the help of his talent as a neuroanatomist, rigor and historical erudition, Polyak produced a short work – less than 50 pages – yet remarkable for its content. The translation and comment conducted jointly by Stephen Polyak and Max Meyerhof on the anatomical part of Ibn al-Haytham's *Optics* compare favourably with that, otherwise excellent, established by Abdelhamid I. Sabra (1989, vol. 1, pp. 55–7). It should be noted that Sabra does not mention that the word *thaqb* (hole) also designates the *foramen opticum*, that *khaml* (fringes) refers to the ciliary processes, that conjunctiva and sclera (or fascia bulbi?) are intermingled, and that Ibn al-Haytham uses on occasion the word *tabāqa* (layer, tunic) to describe the humours of the eye.

In 1998, Nicholas J. Wade published *A Natural History of Vision*. Reissued in 2000, his book highlights the milestones in the history of ocular anatomy and physiology, relying on a wide range of texts, quoted verbatim, and anatomical figures. For antiquity, Wade repeats the figures of Magnus (Democritus, Aristotle, Celsus, Rufus, Galen) and completes them by diagrams from twenty-seven other works (namely Ḥunayn, Ibn al-Haytham, Reisch, Da Vinci, Vesalius, Platter, Fabricius, Aguilonius, Scheiner, Descartes, Kircher, Rohault, Leclerc, Briggs, Molyneux, Newton, Mariotte, Smith, Taylor, Le Cat, Porterfield, Soemmering, Young, Bell, Mackenzie, Müller, and Brewster). The figures sometimes illustrate the anatomy of the eye, sometimes the treatment of particular problems such as: Color, Motion, Binocularity, Space and Illusion. On the whole, the author uses original illustrations except for the period of antiquity, pp. 69–73, for which the figures of Hugo Magnus (1901) are used. Suffice it to remember the shortcomings of these reconstructions.

In 2004, Michael L. Robinson and Franck J. Lovicu published *Development of the Ocular Lens* in which the reader will find seven classical illustrations of the eye (Hippocrates, Celsus, Rufus, Galen, Vesalius, Platter, Scheiner). For antiquity, the figures are again those of Magnus, taken from the book of Wade (1998). They are adopted without discussion.

The same year, in 2004, Reeves and Taylor also published seven well-known diagrams of the eye, chosen from different sources (Ḥunayn, Ibn al-Haytham, al-Fārisī, Risner, Gemma Frisius, Descartes, Scheiner).

In 2010, in the section “Anatomical Illustrations of the Organ of Vision” of Volume IV of *Science and Technology in Islam*, Fuat Sezgin reproduced sixteen representations of the eye, half of which were taken from Arab authors, the other being taken to their Latin commentators. Although short, this 12-page text is erudite and accurate.

In 2012, a 68-page self-published book, entitled *The Eye: Atlas of Anatomical History*, was released by Héctor Barajas. It repeats with no comment some of the most famous illustrations of the eye found in ancient books on the history of ophthalmology.

A year later, in 2013, Frank J. Goes edited *The Eye in History*, an encyclopedic project bringing together about fifty authors. The chapter on the history of ocular anatomy provides seven diagrams of the eye. This chapter contains several errors. First, the attribution of figures is not always accurate:

1/ The figure attributed to Roger Bacon (Goes 2013, p. 96) is actually that of Leonardo da Vinci (Milan: Veneranda Biblioteca Ambrosiana, *Codex Atlanticus*, fol. 921r, ed. Hoepli 337ra).

There are also a number of inaccuracies in the text. Thus p. 79 reads:

2/ “Euclid... studied the properties of light” whereas his optics, which is actually a theory of sight, does not contain a single line about light (physical optics);

3/ “He questioned that sight is the result of a beam from the eye, for he asks how one sees the stars immediately” whereas Euclid is known to have adopted the thesis of extramission, Postulate 1: “The ray issues from the eye in straight lines” (Theisen 1979, p. 62; Kheirandish 1989, p. 2). Next, the impossibility of seeing distant stars is anything but a Euclidean argument: it is a common objection, running from Aristotle (*De sensu et sensato*, 438a25–438b2) to Pecham (*Perspectiva communis*, I, 45);

4/ It is said that Risner published Ibn al-Haytham’s *Kitāb al-manāẓir* along with “his book dealing with the colors of sunset”, which is false in two respects. The two texts are not by the same author: *De crepusculis et nubium ascensionibus* was authored by the Andalusian astronomer Ibn Mu’ādh al-Jayyānī (Sabra 1967). The text does not deal with the colors of sunset: rather it is an attempt to determine the height of the Earth’s atmosphere (Goldstein 1977; Smith 1992);

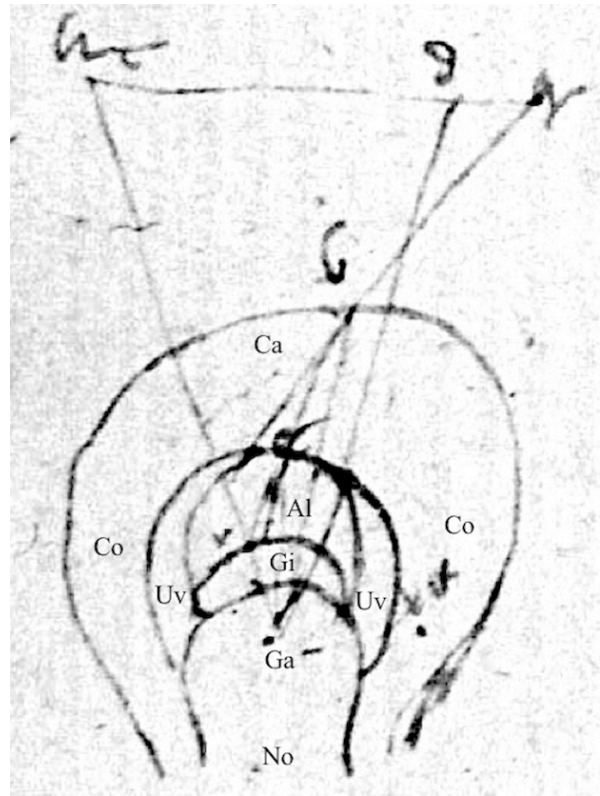
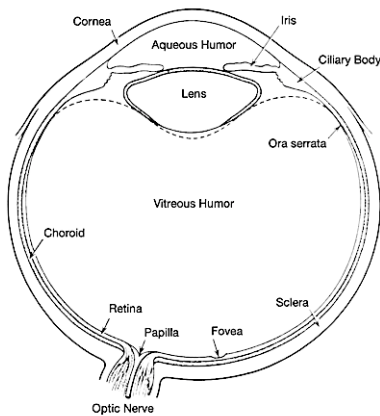
5/ “Ibn al-Haytham went on to discover the laws of refraction”, whereas Ibn al-Haytham, notwithstanding his great mastery of optics, is not credited with this breakthrough: the relationship of sines, rather than the *law* of sines, was used to his predecessor Ibn Sahl (Rashed 1990);

6/ “Ibn al-Haytham... stated that only one ray from each point, which strikes the eye perpendicularly, can be seen”, whereas Ibn al-Haytham explains, in Book VII, cap. 6, 17, that vision is effected by bringing to the center of the lens refracted rays by the different envelopes of the eye: “all that is perceived by the eye is perceived by refraction” (for the Latin version, see Alhacen, ed. Smith 2010, p. 106; ed. Pietquin 2010, p. 252).

Such inaccuracies again suggested that there was a need to complete and correct the description of the figures of the eye found in contemporary literature, so as to have a collection of reliable documents on the subject.

The gradual change of descriptive scale induced by the combined use of the microscope, chemical reagents and photography at the end of the 19th century provided, in some way, a natural stopping point for this investigation on ocular anatomy. Therefore, we decided not to go beyond Hermann von Helmholtz’s reference work, *Physiologischen Optik* (1867).

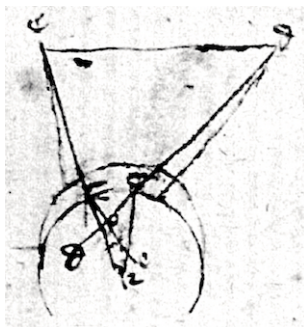
Section 1
Eye Diagrams from Antiquity
to Helmholtz



Key to Symbols

- Ca Cornea
- Uv Uvea
- Co Consolidativa [i.e. sclerotica vel fascia bulbi?]
- Gi Humor glacialis interior [crystallinus]
- Ga Humor glacialis anterior [vitreus]
- No Nervus opticus

Note. As Langenstein’s *Perspectiva* is a comment of Pecham’s optics, the eye terminology can be extended with terms taken from *Perspectiva communis*, i.e. **Al** Humor albugineus, **Co** Consolidativa, **Uv** Uvea, and **No** Nervus opticus. The vitreous body, called *glacialis exterior* by Pecham, now becomes the *glacialis anterior*. We may wonder whether it could be a residuum of the extramission theory. Note also that in Langenstein’s work, glacialis anterior **Ge** and nervus opticus **No** are merged. The same folio has another diagram studying the projection of rays onto the center of the crystalline, then the seat of vision: “*radii... sunt oblique super corneam, ergo non penetrabunt irrefracte*”. The crystalline (*glacialis*) is spherical and the cornea is eccentric on the crystalline.



References

H. de Langenstein, *Questiones super perspectivam*, Florence: BNCF, Conv. Soppr. J.X.19, fol. 72v. *Præclarissimum mathematicarum opus...* Valencia, 1503, fols. 47r–65v.

Index of Concepts

This Index lists all native concepts of ocular anatomy encountered in our sample. They are classified by determiners, in priority by spatial determiners (*Hyaloideus canalis*: search for *hyaloideus* not *canalis*, because this duct is actually a part of the Hyaloid), then by determiners of other kinds (*Centralis arteria*: search for *centralis*, neither *arteria*, which is not a spatial locator, nor *retinæ*, for this artery, which supplies blood to the retina is located in the Optic Nerve, not in the Retina). In general, terms like *humor*, *liquor*, *membrana*, *tunica* are included in the Index only to refer to other entries. Concepts drawn from foreign languages are transliterated. Alphabetical order ignores the article and the initial ‘*ayn*’ in Arabic. Rare anatomical terms are followed by an abbreviation indicating the language in which they are written: Arabic Ar., Catalan Cat., Danish Dan., Dutch Dut., Farsi Far., Greek Gr., Hebrew Heb., Polish Pol., Portuguese Port., Russian Rus., Spanish Sp., Turkish Tur. Terms in the main scientific languages (Latin, English, German, French, Italian) come with no indication of language, except to avoid ambiguity. Names marked with an asterisk* refer to the Overview of Eye Terminology, appearing immediately before the Bibliography.

Aabning, Dan. (Pupil) – 1806 Herholdt.

Aarehinden, Dan. (Choroid) – 1861 Holten.

Aarehindens Siv-Plade, Dan. (Lamina Cribrosa) – 1806 Herholdt.

Abductor (Lateral Rectus Muscle) – 1615 Schalling. 1737 Porterfield. 1865 Pitha.

Achterste oogkamer (Posterior Chamber of the Eye) – 1853 Cramer.

Acinosa tunica (Uvea) – 1583 Bartisch.

Acqueo, umore (Aqueous Humor) – 1583 Danti. 1749 Della Torre.

Acquoso, umore (Aqueous Humor) – 1794 Poli.

Acuoso, humor (Aqueous Humor) – 1834 Rodríguez.

Adductor (Medial Rectus Muscle) – 1615 Schalling. 1737 Porterfield. 1865 Pitha.

Aderhaut, Ader-Haut, Ader-Häutlein (Choroid) – 1740 Teuber. 1752 Heuermann. 1783 Karsten. 1788 Mayer. 1805 Fischer. 1832 Eble. 1832 Arnold. 1832 Krause. 1833 Krause. 1837 Berres. 1841 Bock. 1854 Vogt. 1856 Stolle. 1862 Steffan. 1862 Pilz. 1865 Pitha. 1867 Helmholtz.

Aderhaut, Muttergefäße der (Main Arteries of the Choroid) – 1837 Berres.

Aderhaut, Spannmuskel der (Brücke’s Muscle) – 1856 Stolle. 1862 Steffan. 1865 Pitha.

Adhærens tunica (conjunctiva, the anterior outer tunic of the Eye, distinct from the Sclera) – 1543 Vesalius. 1545 Geminus. 1611 Guidi. 1632 Plemp*.

Adhærens tunica (conjunctiva, the outer tunic of the Eye, including the Sclera, along with the expansion of the Oculomotor Muscles Tendons, if not the Muscles themselves) – 1040 Alhacen^E (1572 Risner). 1274 Witelo^E (1572 Risner). 1559 Colombo*. 1585 Guillemeau*. 1659 Izquierdo.

Adnata tunica (conjunctiva, the anterior outer tunic of the Eye) – 1552 Eustachi. 1559 Colombo*. 1561 Paré. 1569 Gemma Frisius. 1583 Platter. 1585 Guillemeau*. 1591 Varolio. 1604 Kepler. 1605 Bauhin. 1612 Horst. 1615 Crooke. 1627 Casseri. 1632 Plemp*. 1641 Bartholin. 1645 Spiegel. 1651 Bartholin. 1654 Saint-Joseph.

1665 Guarini. 1672 Diemerbroeck. 1678 Bourdon. 1679 Browne. 1685 Bidloo. 1692 Chauvin. 1696 Tolomei. 1698 Wagner. 1700 Pourchot. 1700 Christie's. 1716 Porras. 1735 Scheuchzer. 1735 Krieger. 1737 Porterfield. 1738 Winckler. 1740 Teuber. 1744 Kulmus. 1746 Boerhaave. 1747 Ferrari. 1748 Fortunato. 1749 Della Torre. 1752 Heuermann. 1781 Edlen von Kurzböck. 1833 Krause.

Adnata tunica (conjunctiva, the outer tunic of the Eye, distinct from the Sclera, possibly including the expansion of Oculomotor Muscles Tendons, if not the Muscles themselves) – 1539 pseudo-Fuchs. 1541 Ryff. 1583 Bartisch. 1641 Młodzianowski. 1659 Izquierdo. 1675 Traber. 1741 Berrettini.

Adnata tunica (conjunctiva, the anterior part of the Sclera less the Cornea) – 1618 Fludd. 1641 Lubertus Erbenius. 1721 s' Gravesande. 1775 Thysbaert.

Adnata tunica (conjunctiva, the posterior outer tunic of the Eye, Sclera, Fascia Bulbi, and possibly the Fat filling the Eye Socket) – 1663 Heinlin. 1685 Zahn.

Afīfāfiqūs, Ar. (the anterior outer tunic of the Eye, Conjunctiva; transliterated from the Gr. επιπεφυκώς) – 857 Ibn Māsawayh* (1915 Prüfer-Meyerhof).

Agnata tunica (the anterior outer tunic of the Eye, Conjunctiva) – 1559 Colombo*. 1632 Plemph*.

Agnata tunica (the anterior part of the Sclera less the Cornea) – 1600 Fabricius. 1641 Lubertus Erbenius.

Aisthētikos neuron, Gr. (Optic Nerve) – 395 Orbasius* (1858 Bussemaker).

'Akhvishit, Heb. (Arachnoid; lit. spider) – 1162 Ibn Rushd* (Munich MS hebr. 29). 1374 Menaḥem ben Zerah* (1567 Sabbioneta). 1380 Samuel Ibn Zarza* (1559 Mantua). 1444 Sim'on ben Zemaḥ Duran* (1762 Livorno). 1587 Gedaliah Ibn Yaḥya*.

Alba tunica (the opaque outer tunic of the Eye, Sclera) – 1543 Vesalius. 1545 Geminus. 1585 Guillemeau*. 1679 Browne. 1692 Chauvin.

Alba tunica (the anterior part of the Sclera less the Cornea) – 50 Celsus^R. 1604 Kepler.

Alba tunica (the opaque outer tunic of the Eye, Sclera, Fascia Bulbi, possibly including the Fat filling the Eye Socket) – 1421 Kraków (Jagiellońska MS 552). 1538 Fuchs. 1554 Maurolico. 1591 Varolio. 1659 Izquierdo.

Albamentum (Humor Aqueous) – 1539 pseudo-Fuchs. 1541 Ryff.

Albedo oculi (Sclera) – 1162 Ibn Rushd* (1482 Rubeis).

Albidus annulus (Ora Serrata) – 1830 Mackenzie. 1843 Lawrence.

Albigineus! humor (An undetermined area comprised between the Vitreous and the Retina) – 1279 Pecham¹ (14th MS Oxford).

Albuginea! humor (Humor aqueous) – 1279 Pecham² (14th MS Paris).

Albuginea membrana (the compound of the Conjunctiva and Sclera) – 1737 Porterfield.

Albuginea membrana (the opaque outer tunic of the Eye, Conjunctiva, distinct from the Sclera) – 1744 Kulmus. 1752 Heuermann. 1781 Edlen von Kurzböck. 1797 Nicholson. 1809 Bell.

Albuginea membrana (the opaque outer tunic of the Eye, Sclera, along with the expansion of the Oculomotor Muscles Tendons) – 1833 Tuson.

Albuginea membrana (Sclera) – 1833 Krause. 1838 Wilson. 1841 Grant. 1865 Pitha. 1867 Helmholtz.

Albuginée (the posterior outer tunic of the Eye, Sclera, possibly including the Fascia Bulbi, Muscles and Fat filling the Eye Socket) – 1789 Pellier de Quengsy.

Albugineo humore (Aqueous Humor) – 1040 Alhacen³ (14th MS Vatican). 1455 Ghiberti. 1567 Bartoli*.

Albugineus humor (Aqueous Humor) – 903 al-Rāzī (14th MS Vatican). 903 al-Rāzī* (1500 Hertzog). 1010 Ibn 'Īsā* (1500 Locatelli). 1025 Ibn Sīnā¹ (14th MS Laon). 1025 Ibn Sīnā² (1479 marg.). 1025 Ibn Sīnā^{E1} (1498 Treschel). 1025 Ibn Sīnā^{E2} (1544 Alpago). 1040 Alhacen² (13th MS Paris). 1159 al-Quwaṭī. 1128 John of Seville. 1150 Graffeuus* (1897 Albertotti). 1180 Zacharias. 1230 Gilbertus Anglicus* (1510 Portonariis). 1267 Bacon¹ (13th MS London). 1267 Bacon² (14th MS Prague). 1267 Bacon^E (1614 Combach). 1270 Albertus Magnus* (1916 Stadler). 1270 Saliceto. 1274 Witelo¹ (15th MS Paris). 1274 Witelo^E (1572 Risner). 1277 Petrus Hispanus* (1908 Pansier). 1279 Pecham^{E1} (1504 Leipzig). 1279 Pecham^{E2} (1542 Hartmann). 1303 Pietro d'Abano* (1496 Giunta). 1305 Bernard de Gordon* (1491 Lambillionis). 1316 Mondino* (1494 Georgium). 1340 Leipzig (MS 1183). 1363 Chauliac* (1498 Locatelli). 1375 Langenstein. 15th Escorial (MS f. III 6). 1421 Kraków (Jagiellońska MS 552). 1491 Ketham*. 1503 Reisch. 1512 Brunschwig*. 1521 De Melo. 1521 Carpi*. 1538 Fuchs. 1539 pseudo-Fuchs. 1541 Ryff. 1554 Maurolico. 1583 Bartisch. 1615 Schalling. 1618 Fludd. 1634 Hérigone. 1659 Izquierdo. 1661 Schott. 1675 Traber. 1679 Verle. 1685 Zahn. 1692 Chauvin.