Hist. Ophthal. intern. 2, 323 – 336 (1982)

FOUNDATIONS OF MODERN OCULAR VEGETATIVE PHYSIOLOGY II. OCULAR BIOCHEMISTRY

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Introduction

In 1934, in a preface to his *Biochemistry of the Eye*, A. C. KRAUSE, stated that „until forty years ago, ocular chemistry was nothing more than a series of observations and experiments which frequently had no obvious connection with one another".

KRAUSE, of course, was only partly justified in making his remark. The „magical" date (1894) doubtlessly referred to the classical investigations of Mörner. Earlier workers had played a highly important role, and if we consider their investigations in the period during which their chemical analyses were conducted, they must surely appear no less impressive than do the later, modern researches in this field.

The works of SIR CLIFTON WINTRINGHAM (1710 – 1794), RICHARD CHENEVIX (1774 – 1830), ANTOINE FOURCROY (1755 – 1809) and NICOLAS VAUQUELIN (1763 – 1829), are now forgotten. Virtually the sole survivor of this early „pre-modern" period is JACOB BERZELIUS (1779 – 1848). Even then, when reviewing the history of the subject, the information perpetuated in modern books concerning his analytical results is invariably derived from second or third source, his original contributions having been completely neglected.

Ocular chemistry formed part of the rapidly growing interest in the whole field of „*animal chemistry*". This is particularly evident in England, where, by 1812, SIR EVERARD HOME (1756 – 1832) had formed the *Animal Chemistry Society*[1]. The Society included among its eminent active members, CHARLES HATCHETT, SIR HUMPHRY DAVY, MR. BRODIE, WILLIAN CLIFT (Curator of the Hunterian Museum) and Professor BRANDE (the Secretary, who, incidentally, made a chemical analysis of the tears)[2]. At a later time, SIR JOSEPH BANKS (President of the Royal Society) and CAVENDISH also became members.

The purpose of the present discussion is to draw attention to some early contributions to the field of ocular chemistry, with particular reference to analyses made during the eighteenth and early nineteenth centuries. Perhaps in no other aspect of the diverse facets of physiological optics is it so imperative to bear in mind that the contributors were attempting to answer particularly complex problems in physiological optics at a time when the subject could hardly be said to have emerged as a science. The work to be discussed below follows two themes, namely, organic chemistry and physics.

Throughout the period from 1790 to 1830, there had been an increasing interest shown in the physiological mechanism of the eye, with particular reference to the crystalline lens. Special attention, as we have seen, was devoted to the role played by the lens in the mechanism of accommodation. Practical considerations, such as the onset and progression of presbyopia and the formation of cataract, doubtlessly stimulated further interest in the chemical constituents of the lens. Other perhaps less obvious factors, such as the explanation of the eye's aberrations (spherical and chromatic) together with anomalies considered to be directly related to the aqueous and vitreous humours, provided further interest in the composition of the ocular media. Whereas in the past there had been scanty and vague notions concerning the chemistry of the humours of the eye, detailed knowledge of ocular chemistry had now become of prime importance.

FOURCROY, in the latter part of the eighteenth century, was undoubtedly right when stating that the reason for the previous neglect in chemical analysis of animal fluids was, due to the unpleasantness of the work, in addition to the difficulties encountered in the analyses, e.g. alteration of animal substances by the action of heat or reagents (SMEATON, 1962). Attitudes were now to change, and detailed accounts, such as those of FOURCROY, VAUQUELIN, BERZELIUS and others, became standard texts all over Europe, with their corresponding influence and sti-

[1] The society flourished for thirteen years, until in 1825, with the President's resignation, the society became dissolved.

[2] BRANDE found them to contain small portions of albumen combined with soda, murate of soda, and water, and also a small portion of other salts. He estimated that the lens contained more than half its weight of water, the remainder being „an albuminous substance with traces of murates" (BRANDE, 1821).

mulus to further work in the ,,new'' field of animal chemistry. It was, however, BERZELIUS' typically detailed but concise results which were to dominate and remain the main source for almost a century. The extensive researches of FOURCROY, VAUQUELIN and BERZELIUS, embraced the whole field of animal chemistry, with only partial emphasis on the eye. The more restrictive studies of RICHARD CHENEVIX and NICOLAS were confined specifically to the eye and the ocular media.

That the work of these men was not merely a series of ,,*observations and experiments with no obvious connection*'' will surely become evident from the discussion to follow.

Sir Clifton Wintringham

In order to fully appreciate the significance of what might be called a new interest in the chemistry of the eye during the approximate period from 1790 to 1830, it is necessary to go back to 1740 and consider the singular researches of SIR CLIFTON WINTRINGHAM[3]. His contribution to physiological optics, although hitherto neglected, is of particular interest, for with the exception of occasional brief references in a now equally forgotten work, WINTRINGHAM appears to have been generally overlooked. In VON HELMHOLTZ's extensive bibliography, contained in his *Treatise on Physiological Optics*, WINTRINGHAM is listed once only[4], with no accompanying discussion of his work in the main text.

WINTRINGHAM's experimental work on the chemistry of the eye accounts for almost the whole of the second half of his *Experimental Inquiry on Some Parts of the Animal Structure* (1740). Dr. JAMES JURIN (1684 – 1750), only two years earlier had published his important ,,*Essay Upon Distinct and Indistinct Vision*'' in ROBERT SMITH's *Opticks* (1738). While agreeing with many of the opinions expounded in JURIN's thesis, WINTRINGHAM expressed at the outset of his work that his specific intention was to experiment upon and discuss aspects of visual optics not touched upon by JURIN. As the progress of physiological optics in Britain during almost the whole of the eighteenth century has been essentially linked with the works of JURIN and WILLIAM PORTERFIELD (1696 – 1771), Wintringham's work is particularly worthy of attention. His experiments are important as they represent some of the earliest (in some cases the first) quantitative experiments on the ocular media and tissues. His researches included the investigation of the specific gravities of the crystalline lens, capsule, and vitreous, and in addition, va-

[3] SIR CLIFTON WINTRINGHAM, Bart. (1710 – 1794), educated at Trinity College, Cambridge; M.B. 1734; M.D. 1749; F.R.S., 1742; Fellow of the College of Physicians, 1763; Physician in Ordinary to George II (Dictionary of National Biography; MUNK, 1878).

[4] (Reprint, 1962, vol. 1, p. 14) CHENEVIX fares worse, with no mention at all.

Table I:

WINTRINGHAM's calculations of the specific gravity of the crystalline lens and capsule (ox eye). Note: Column 2 gives a conversion to grains of WINTRINGHAM's values in column 1 (expressed as pennyweight, grains and mites).
Calculations by the author (column 4), based on Wintringham's values, gave somewhat different results in two cases, but agreed with WINTRINGHAM with respect to the capsule. WINTRINGHAM's results are essentially confirmed by the author in that the specific gravity of the cortical layers of the lens is low, as compared to the central firm nucleus.

	1 weight (P4, gr., m.)	2 conversion (gr)	3 specific gravity with respect to water (WINTRINGHAM)	4 Specific gravity (LEVENE)
crys. lens, without capsule, in air	2 P't, 20 gr., 20m.	70		
ditto, counterpoised in water	6gr., 56m.	8.8	1106 : 1000	1144
crys. lens, with external part removed, nucleus, in air	1 P't, 2gr.2m.	26.1		
ditto, counterpoised in water	3gr.36m.	4.8	1148 : 1000	1226
capsule, in air	Ogr.90m.	4.5		
ditto, counterpoised in water	Ogr.4m.	.2	1046 : 1000	1046

lues for the thickness of the cornea, capsule and retina (the first recorded measurements of the capsule and retina in the literature[5].

WINTRINGHAM's calculations are shown in Table I. The weights (troy) have been converted to grams. From an analysis of his results, WINTRINGHAM was able to deduce that the crystalline lens was of higher density than the capsule (or aqueous humour). An inspection of his experiments enables us to trace the systematic procedure adopted throughout his work on physiological optics. Having ascertained the specific gravity of the crystalline lens (including the capsule and nucleus), he proceeded to discuss the practical significance of his findings. He first compared the crystalline lens with a glass lens, and also dealt with the functional usefulness of a nonchemically consistent lens, the density of which was a variable.

[5] S. POLYAK's (1941) monumental work on the subject, has overlooked WINTRINGHAM's researches entirely. HELMHOLTZ's (1924) has compiled a number of measurements for the thickness of the retina from several authors, the earliest one being that of C. F. KRAUSE (1842).

Having compared the specific gravities of the vitreous and lens (he found the density of the lens superior to that of the vitreous in the ratio 10:9), his next step was to relate the densities and refractive powers of the media. By using the method of Newtonian fluxions (calculus) and SNELL's Law for calculations of the sine relationship of incident and refracted rays passing from the aqueous to the crystalline lens, WINTRINGHAM found the proportions to be very nearly 21:20.

Assuming that the ,,*difference between the cornea and capsule in point of density could not exceed the 1/1021 part*'', WINTRINGHAM proceeded to show that the pressure required to burst the capsule was equal to 1.08 atmospheres, and further, that the cornea ,,*bore the pressure of 7.7 atmospheres without breaking, but not without suffering such a stream of air to pass thro' its Pores as prevented its rupture*'' (WINTRINGHAM, 1740, cf. p. 252).

With a view to testing the ,,strength'' of the cornea and capsule, Wintringham calculated the area of the cornea, and found that ,,*the weight incumbent on this area from 7.7 atmospheres was equivalent to 148 pounds...*'' (l.c., cf. p. 254). As the lens capsule broke with a pressure of 1.08 atmospheres, WINTRINGHAM concluded that had its area been equal to that of the cornea, the weight incumbent on it at the time of breaking would have been, equal to 20 pennyweight (480 grams). From his results, he concluded that the strength of the cornea was ,,*superior to a portion of the same area of the capsule in the proportion of 7129 to 1000 nearly*'' (l.c., cf. p. 254). But although the cornea was shown to be ,,*stronger*'' than the capsule, WINTRINGHAM observed that their densities and refractive powers ,,*were very nearly equal as are also those of the humours immediately surrounding the crystalline a consequence of which enables the incident rays to pass without any variation*'' (l.c., cf. p. 254). WINTRINGHAM's results, concerning the strength and elasticity of the capsule, would appear to be the first estimates in the literature.

It should be appreciated that the temperature was not recorded in any of his experiments, and with reference to the thickness of the cornea, capsule, and retina, WINTRINGHAM gave no indication as to the particular section examined. His experimental approach provided a complementary link with the more generally clinical and theoretical approaches of PORTERFIELD (1737, 1759) and JURIN, respectively. Especially significant was their interest in demonstrating the effects of mathematical and experimental physics upon medicine, with particular reference to the eye. WINTRINGHAM's work indicated how physiological processes could be treated in terms of physical measurement and physical laws, typifying the group of iatromathematicians who flourished during the eighteenth century.

Richard Chenevix

During this period too, it was becoming more generally appreciated that the chemistry of living organisms could be analyzed in much the same way as natural substances. Typifying this concept is the work of RICHARD CHENEVIX[6]. Sixty years after WINTRINGHAM's investigations, CHENEVIX (1803, p. 195 – 199) presented before the Royal Society, a paper entitled ,,*Observations on the Chemical Nature of the Humours of the Eye*''. Just as the quantitative work of WINTRINGHAM had been novel to physics, so we may regard CHENEVIX's quantitative chemical analyses of the ocular media the first to appear in the English literature.

Table II:
The specific gravity[7] and chemical composition of the ocular humours (CHENEVIX, 1803, p. 199)[8]

	Aqueous	Aqueous modern Values	Vitreous	Crys. Lens (total)	Crys. Lens (Centre)
SHEEP	10090	1.009	10090	11000	
OX	10088[9]	1.0038 to 1.0077	10088[10]	10765	11940
HUMAN	10053	1.002 to 1.012	10053	10790	
Chemical constituents in sheep, ox, and human eye[11]	water albumen gelatine sodium chloride		same as aqueous	small proportions of albumen and gelatine, but a larger proportion of water than in aqueous and vitreous	

[6] CHENEVIX (F.R.S., 1801), a chemist, mineralogist and minor playwright was born in Dublin of Huguenot extraction. He contributed many papers to the *Annales de Chimie*, and the Royal Society's *Philosophical Transactions*. For his contributions to chemistry and mineralogy he was awarded the Royal Society's *Copley Medal* (1803).
R. P. PARTINGTON (1961) gives a brief but good summary of CHENEVIX's chemical works, including a biographical account of this ,,character''.

[7] CHENEVIX appears to have been the first to recognize the significance of recording the temperature in this type of experiment. The value he records in 60 degrees F. A. C. KRAUSE (1934, p. 107) incorrectly states that the temperature was ,,not given''.

[8] Not 1832, the date given by KRAUSE (1934, p. 161).

[9] Cited inaccurately as 1.0038 in A. C. KRAUSE (1934, p. 107), cf. BERZELIUS (1812)

[10] Cited inaccurately as 1.0053, (KRAUSE, 1934, p. 161). The value 1.0053 is the specific gravity given by CHENEVIX for the human eye.

[11] CHENEVIX mentions that he was unable to detect any phosphate in the humours. This was contrary to FOURCROY's findings.

The specific gravities and chemical composition of the ocular media as found by CHENEVIX have been arranged in Table II. In the column immediately following the values for the aqueous appear present-century mean values, based on STEINDORFF and DUKE-ELDER (1968), on researches in 1909 and 1927, respectively. CHENEVIX seems to have adopted the same technique as WINTRINGHAM, in first „*paring away*" all the external parts of the lens, and then finding the specific gravity of the central part (nucleus) of the lens. Whereas the value that Wintringham obtained for the weight of the whole lens was approximately 68 grains, the nucleus weighing approximately 26 grains, the weight found by CHENEVIX for the whole lens was 30 grains, the central zone that he used weighing only 6 grains. From the marked differences found in the specific gravities of the external and central areas of the lens, CHENEVIX (1803, p. 199) confirmed much the same as WINTRINGHAM's earlier conclusions that „*the density increases gradually from circumference to the centre*". What appeared especially significant to CHENEVIX was the considerable difference in the specific gravity of the aqueous or vitreous, and that of the crystalline lens (the latter being considerably higher in the human eye than in that of sheep, and less in the eye of the ox). He reasoned that the densities of the aqueous and vitreous humours, and that of the lens, were in the inverse ratio as the diameter of the eye (from the cornea to optic nerve), suggesting that if this was in fact a universal law in nature, then it was „*in some degree designed for the purpose of promoting distinct vision*" (l.c., cf. p. 199). This is of particular interest in being an early example of correlation of changes.

Upon considering the composition of the lens („*animal matter of the most perishable kind*"), CHENEVIX thought it hardly surprising that it should be so subject to pathological disorders. That he had the condition of cataract in mind is evident from his conclusion that if an analysis were made of the frequency of cataract associated with „*gouty habits*", some conclusions might be drawn as to „*the influence of phosphoric acid ... as a cause of the anomaly, by common effects of acids in coagulating albumen*" (l.c., cf. p. 199). It was by considering the coagulation of albumen that was manifest in the dead eye and relating it in terms of the living eye that enabled CHENEVIX to account for the formation of cataract. It would appear then that the possible applications in medicine may have been the stimulus to the quantitative approach adopted by CHENEVIX.

There is an interesting comparison between CHENEVIX's researches and the earlier work of WINTRINGHAM. The latter had been primarily concerned with examining the ocular media with a view to explaining the superior qualities of the physiological processes of distant vision over a „*machine*" (the camera obscura). CHENEVIX, however, provided an analysis of not only the physiological basis of distinct vision, but also the related causation and formation of pathological changes. It would appear that CHENEVIX also studied the eyes of birds, for although he made no mention of it in his Royal Society paper, yet according to DAVY writing in the *Journal of the Royal Institution* (l, p. 297). CHENEVIX found the humours of birds to have the same composition as those of other animals. CHENEVIX further found the specific gravity of the vitreous in animals to be greater than the specific gravity of the crystalline lens.

Shortly after the appearance of CHENEVIX's paper, PIERRE FRANCOIS NICOLAS, Professor of Chemistry at Grenoble, communicated a paper to the *Annales de Chimie* devoted entirely to the chemical analysis of the ocular humours, with specific reference to the cause of cataract. His experiments, illustrating how physico-chemical methods were being applied to ocular research, were conducted on sheep, ox and human eyes.

While his analysis of the aqueous showed it to have a similar composition to that found by CHENEVIX, NICOLAS (1805, p. 311) found that the aqueous in solution possessed little sodium chloride and a small quantity of lime phosphate. NICOLAS considered that cataract was in fact due to too great a quantity of lime phosphate infiltrating the crystalline lens. Whereas FOURCROY had reported the presence of phosphate in the eye, NICOLAS (1805, p. 311), like CHENEVIX, was unable to confirm this. He considered the outer region of the crystalline lens to be composed of albumen and gelatin, the middle zone to contain less gelatin and more albumen, while in the nucleus, he found „*scarcely a speck of gelatin*''. Lime phosphate was found in all parts of the lens, being more abundant in the nucleus, with lesser quantities going towards the outer layers. NICOLAS concluded that these differences in density throughout the lens could account for the effect of achromatism in the eye.

Jöns Jacobus Berzelius

When referring to BERZELIUS' contribution to ocular chemistry, the literature (cf. DUKE-ELDER and GLOSTER, 1968, p. 135 – 140; KRAUSE, 1934, p. 147) invariably cites his *Treatise* (1833, vol. 7). However, the majority of his analyses of the ocular humours were conducted as early as 1810, and had in fact been translated into English by 1813. From his results (see Tables III and IV) we may immediately see the great advance on earlier researches. This is evident from his inclusion of the specific quantities of each chemical found in the particular organ examined. BERZELIUS, whose account of the ocular humours formed part of a much larger work on all aspects of animal chemistry, showed a prime interest in the lens. His comments are particularly illuminating, as they throw light on the tremendous argument concerning the anatomical structure of the crystalline lens. They provide an example of how chemical analysis could be used to predict anatomical structure; he is, therefore, essentially a forerunner of histochemistry. It will be remembered that the lens had been considered to be a muscle. Nor was experimental consolidation lacking, particularly as REIL (cited in YOUNG, 1813, p. 522), just a few years before the end of the nineteenth century, had become convinced of its muscular structure as a result of treating it with nitric acid. BERZELIUS (1812, p. 253), on the

Table III

Chemical composition of Aqueous and Vitreous (BERZELIUS, 1812).

Composition	Aqueous	Vitreous
Water	98.10	98.40
Albumen	a trace	0.16
Muriates and lactates	1.15	1.42
Soda with animal matter soluble only in water	0.75	0.02
Total	100	100

Table IV:

Chemical composition of the crystalline lens. (BERZELIUS, 1812).

Composition	Crys. Lens
Water	58.0
Peculiar matter, coagulable, albuminous	35.9
Muriates, lactates, and animal matter, all soluble in alcohol	2.4
Animal matter, soluble only in water, with some phosphates	1.3
Portions of the remaining insoluble cellular membrane	2.4
Total	100

basis of his analyses, however considered that its solubility in water was sufficient proof that it was not a muscle. This, added to the fact of the increasing density of the lens towards its center, indicated positive evidence to BERZELIUS of its cellular, rather than muscular, nature, ,,*the cells being filled with a pellucid matter of different degrees of concentration...*''. Despite BERZELIUS' highly significant evidence, THOMAS YOUNG remained unconvinced, still believing, certainly until 1823, that the lens was most probably of a muscular nature.

BERZELIUS (1812, p. 253 – 255) had noted that the lens when, coagulated as a result of boiling, appeared to exhibit all the chemical properties (except for the colour) of the colouring matter of blood. When burnt, the remaining ash contained a small quantity of iron, and ,,*the liquor in which the coagulum formed reddens litmus, has a smell of humours of the muscles, and like them contains free lactic acid*'' and with respect to the presence of gelatine and albumen in the lens, he considered the opinions of CHENEVIX and FOURCROY to be erroneous.

BERZELIUS further investigated the properties of the sclera, choroid, cornea and iris and had no difficulty in recognizing in the latter its muscular properties. In contrast with his experiments with birds, he considered it highly probable that the iris in man was composed of involuntary muscle. BERZELIUS was fortunate in having, soon after its publication, two English translations of his *View of the Progress and Present State of Animal Chemistry*[12]. *YOUNG, in 1812, was preparing an abridged version of Berzelius' book, and he is acknowledged to have given a considerable amount of advice to GUSTAVUS BRUNNMARK for another English translation, which appeared in 1813. YOUNG indirectly played an important role in promoting Berzelius' work by the inclusion of an English translation at the end of his Introduction to Medical Literature* (1813), a second edition of which appeared ten years later.

By 1832, BERZELIUS' account of the ocular media had been augmented to include analyses of the retina (92.9 parts water, 6.25 albumen, 0.85 fats), presumably the first in the literature, and the optic nerve (70.36 water, 22.04 albumen, 4.4 fats). He also presented for comparison, the researches of CHENEVIX, GMELIN and FOURCROY, and he particularly cited LASSAIGNE's analysis of the vitreous of a blind horse, in which he had found the specific gravity to be 1059. Yellow colored matter (,,*resembling bile*'') was also reported, in addition to 8 % albumen and salt. (BERZELIUS, 1833, p. 451). At an earlier time, LASSAIGNE[13] had investigated

[12] From an inspection of his correspondence, BERZELIUS seems to have been greatly concerned to have an English translation, although at first, there was very little enthusiasm to have it translated. Despite this, two translations appeared within three years (cf. BERZELIUS, 1912/41).

[13] LASSAIGNE's analysis of the lens of a horse (cf. RICHE, 1870) showed it to contain coagulated albuminous matter, 29.3.; lime phosphate, 51.4; carbonate, 1.6; part soluble in water 17.17 (total 100).

the chemistry of the choroid, and had observed that there were similarities with the medullary substance of the brain, with the exception that the choroid contained a trace of fat.

The important work of LEOPOLD GMELIN (1788 – 1853) was also cited by MONRO (1825) who discussed one of GMELIN's most detailed analytical accounts of the coroidal pigment from the eyes of no fewer than 500 oxen and calves. GMELIN's final analysis indicated the presence of soda, lime, iron, oxide, muriatic acid, and also probably phorphoric and carbonic acid. (MONRO, 1825, p. 39). His experiments included the analysis of the choroidal pigment's solubility in water, alcohol, and lime water. He also gave the results of an experiment in which he had subjected the pigment to heat.

We should not conclude this discussion without at least citing the enormous contributions of ANTOINE FRANCOIS DE FOURCROY (1804)[14] and NICOLAS VAUQUELIN (1805)[15]. Their works are particularly important (especially their analyses of the tears), as they provided some of the first applications of quantitative analysis to organic chemistry and to physiology and medicine in general.

In a recent study, SMEATON (1962) has pointed out that one of FOURCROY's principal concerns was to show how an analysis of the body's fluids in physiological and pathological conditions might lead to an understanding of the nature of some diseases and, in turn, to the development of methods of treatment. We have shown in the preceding discussion that precisely these considerations motivated earlier workers. As the methods of chemical analysis improved, their work became neglected and obsolete; the writings of BERZELIUS particularly, and perhaps a little unfairly, remained the only standard source for three quarters of a century.

Summary

An account is given of the historical development of theoretical and practical methods of chemical analysis of the ocular media. Attention is drawn to the significance of the crystalline lens, the practical implications of the progression of presbyopia, the formation of cataract, and explanations for the eye's chromatic and spherical aberrations. Particular reference is made to the hitherto neglected contributions of Sir Clifton Wintringham, including his quantitative values of the ocular media and tissues, lens, thickness of the cornea, capsule and retina. Several of these are the first published contributions in the history of physiological optics.

[14] Professor of Chemistry at the Jardin du Roi.

[15] FOURCROY's co-worker and successor as Professor at the Jardin du Roi (cf. SMEATON, 1962; PARTINGTON, 1961).

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LEVENE, J. R. – Die Grundlagen der modernen vegetativen Physiologie des Auges: II. Biochemie des Auges.

Zusammenfassung

Der Artikel enthält eine Darstellung der historischen Entwicklung theoretischer und praktischer Methoden der chemischen Analyse der brechenden Medien des Auges. Dabei wird besonders auf die Bedeutung von Untersuchungen an der Augenlinse hingewiesen sowie auf deren Bedeutung für das Fortschreiten der Presbyopie, die Entstehung der Katarakt und die Erklärung der chromatischen und sphärischen Aberration. Besondere Berücksichtigung findet das bisher vernachlässigte Werk von Sir Clifton Wintringham einschließlich seiner quantitativen Untersuchungen der Medien und Gewebe des Auges, insbes. der Linse, sowie seiner Dickenmessungen an Cornea Linsenkapsel und Netzhaut. Manche seiner Arbeiten enthalten Erstbeschreibungen aus dem Bereich der physiologischen Optik.

LEVENE, J. R. – Fondements de la physiologie vegetative oculaire moderne: II. – Biochemie oculaire

Resumé

L'auteur rapporte l'histoire des méthodes théoriques et pratiques utilisées pour l'analyse chimique des milieux oculaires. Il attire l'attention sur la signification du cristallin, les implications pratiques de la progression de la presbyopie, la formation de la cataracte, et les aberrations chromatiques et sphériques. Il rappelle tout particulièrement les contributions oubliées jusqu'à nos jours de Sir Clifton Wintringham, qui comprennent les valeurs quantitatives des milieux et des tissus oculaires, du cristallin, de l'épaisseur de la cornée, de la capsule cristallinienne, et de la rétine. Quelques unes de ces contributions donnent les premières mesures publiées dans l'histoire de l'optique physiologique.

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Resumen

El autor relata la historia de los métodos teóricos y prácticos utilizados para el análisis quimico de los medios oculares. Llama la atención sobre la significación del cristalino, las implicaciones prácticas de la progresión de la presbiopia, la formación de la catarata, y las aberraciones cromáticas y esféricas. Recuerda especialmente las olvidadas contribuciones hasta nuestros dias, de Sir Clifton Wintringham, que comprenden los valores cuantitativos de los medios y de los tejidos oculares, del cristalino, el espesor de la córnea, de la cápsula del cristalino y de la retina. Algunas de estas contribuciones dan las primeras medidas publicadas en la historia de la óptica fisiológica.

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