HINDSIGHT

Newsletter of the
Optometric Historical Society
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Optometric Historical Society meeting:

The Optometric Historical Society will be holding its annual meeting at the American Academy of Optometry meeting on Friday, December 8, 2000, from 6:00 to 7:00 pm in the Europe 8-Dolphin meeting room. Dr. Arol Augsburger, Dean of the University of Alabama Birmingham School of Optometry, will talk about the "Evolution and Early Development of the Celebrity Eyewear Collection." Dr. Augsburger started this collection at The Ohio State University when he was a faculty member there. A short business meeting will follow.

Book review: A History of Color:

Robert A. Crone. A History of Color: The Evolution of Theories of Lights and Color. Documenta Ophthalmologica 1999; 96 (1-3): 1-282. Dordrecht, The Netherlands: Kluwer Academic Publishers, 1999. 252 pages of text plus 30 pages of bibliographical notes, references, and index.

In the words of the author, "this book gives a survey of color theories between 500 BC and 2000 AD. Naturally it cannot provide more than a broad outline." (p. 1) Believing that color theory history is best understood in the context of the development of the underlying sciences, Crone also discusses theories of light and vision and studies on the structure and function of the eye. This book is an adaptation of the author's *Licht-Kleur-Ruimte* (Light-Color-Space) which was published in Dutch in1992. The text of this book is organized as follows:

Chapter XIII. The twentieth century (pages 191-246)
Appendix and synopsis; What is color? (pages 247-252)

Crone identifies Empedocles (490-435 BC) as the first Greek philosopher to write on color. Empedocles believed that there were four elements - fire, water, air, and earth. Similarly he believed that there were four colors - black, white, red, and yellowish green. Empedocles thought that the eyes sent out fire which then interacted with something which moved in the direction of the eyes from the object being viewed. The resulting interaction produced color.

The theories of Democritus (460-370 BC) were preserved in the writings of his follower Epicurus (341-270 BC) and of the Roman Titus Lucretius Carus (95-52 BC). In the Democritus theory of vision, images of objects in the visual field came to the eye as *eidola*, " a sort of minimalized flying outer skins of obejcts." (p. 6) Democritus did not believe in the four elements of Empedocles. Rather everything is composed of minute indivisible seeds or atoms. Democritus accepted Empedocles' four colors, but he thought the four colors - black, white, red, and yellowish green - were associated with four different atoms.

Democritus appears to be the first to suggest that sensory knowledge was "second quality" knowledge or an interpretation of objects - colors are not present in the objects themselves, but rather color atoms from an object become color when they act on the atoms of the person viewing the object. Carried to its extreme, this idea was adopted by Plato (428-347 BC) to suggest that sensory experience is illusory while everlasting truth is present in mathematics and ideas.

Aristotle (384-322 BC) viewed white and black as the extreme qualities of light and darkness. He thought of other colors as intermediary qualities, mixtures of light and darkness. Aristotle believed that the transparent media of the eye are actualized by light to allow colors to affect the eye. Aristotle had a significant influence on scientific thought. His approach was more in terms of forms and qualities as opposed to the more abstract mathematical approach of Plato.

The Greek astronomer Claudius Ptolemy (c. 150 AD) wrote a book on optics. He continued the work in geometrical optics of Euclid (c. 300 BC), who sketched image formation by light rays. Ptolemy studied reflection and refraction, as well as various aspects of vision, such as binocularity and color. Crone credits Ptolemy as being "...the first to describe how colors can be mixed, not only on the artist's palette but also 'optically' in the eye. Ptolemy painted colors on a wheel - probably a potter's wheel - which he rotated rapidly....It was also possible to mix individual colors 'optically' in another way: by looking at them at a distance." (p. 14)

The Arab scholar Ibn al-Haytham (Alhazen) (c. 1000 AD) is notable for his arguments against extramission theories of vision. Included in his extensive writings on optics and vision is some work on color. Like Ptolemy, he studied color mixing by rotating a wheel with sectors of different colors. Crone credits Alhazen as being the first to describe colored shadows.

The author identifies Robert Grosseteste (1168-1253), the first Chancellor of Oxford University, as being a "transitional figure" in optics. With regard to color, Grosseteste "examined the colors which occur on refraction in prisms and in glass globes filled with water. He thought that the colors produced were caused by differential refraction and by different degrees of darkness, colors being produced by weakening of white light." (pp. 29-30)

In about 1304, Theodoric of Freiberg (c. 1250-1310) wrote about the formation of rainbows by refractions and reflections in rain drops. The Arab Kamal al-Din al-Farisi (died c. 1320) wrote an independent correct optical description of the formation of rainbows at about the same time. Theodoric, Witelo (Vitellio) (1220-1270), and Roger Bacon (1214-1292) elaborated on the optics work of Alhazen. Witelo suggested that the colors produced by a prism were formed by differential refraction, but then he also talked about Aristotle's theory of colors being produced by the mixing of light and darkness, in the case of a prism due to opacities in the prism.

Crone notes that there were no significant advances in color science during the Renaissance. I found his mention of "lens-grinders" in his discussion of the changes in natural science during the Renaissance to be interesting:

"The Renaissance, the transitional period between the Middle Ages and the new era, is the period in which natural science...begins to loosen its bands with the church and Aristotelian Scholasticism. There are various reasons for this change. In the first place, the rise of a new class of non-ecclesiastical professionals, usually non-academic, full of self-confidence and unhampered by rigid traditions. They are architects, lens-grinders, artists, cartographers. A representative of this group is the Florentine artist and technician Leonardo Da Vinci. A seond circumstance which contributes to the secularization of science is the invention of printing, which made the rapid of new ideas possible. In addition, there is the rise of humanism, closely connected with the fall of the East-Roman Empire. Byzantine scholars came to Italy and bring with them the works of ancient authors; Plato's work and his high regard for mathematics are found fascinating." (p. 35)

A continuing question over the years was the number of primary colors as well as whether there were "types" of colors. Leonardo da Vinci (1452-1519) identified six simple colors - white, yellow, green, blue, red, and black - although he did note that some philosophers did not consider white and black to be colors, white being the origin of all colors and black being the absence of colors. Aguilonius (1567-1617), in a noted book on optics illustrated by his friend Peter Paul Rubens, suggested that there were three types of colors: (1) true colors - the colors of colored objects, (2) apparent colors - for example, the colors of the rainbow and peacock's feathers, and (3) intentional colors - "invisible colors in light, which only become visible when light falls on an object. Thus a ray of sunlight, filtered through blue stained glass in a cathedral, can by means of an invisible ray throw a patch of blue light on a bishop's grave." (p. 38)

The development of color vision theory was hampered somewhat by the lack of a correct theory of vision. The physician Galen (130-200 AD) thought that it was the crystalline lens that was the light sensitive element in the eye. Crone suggested that the development of spectacle lenses and the camera obscura had important effects on optics in the Renaissance. Leonardo da Vinci likened the eye to the camera obscura, and suggested that the crystalline lens must have an optical function (like a spectacle lens), that of making the ocular image upright. It was thought that if the ocular image was not upright we would see everything upside down. Leonardo thought that the crystalline lens formed an upright image on the optic nerve head, which he thought to be the sensitive part of the eye.

Crone portrays Johannes Kepler (1571-1630) as "...one of the most important initiators of a movement which disposed of the whole range of medieval science...the scientific revolution." (p. 49) Kepler's work on vision followed from his astronomy studies. Kepler showed that the retinal image was indeed upside down. Kepler then asked whether we see with the eyes or with the brain, the latter possibility then showing that an upside down ocular image could still result in properly oriented vision. Crone suggests that Kepler helped set up future advances in color vision in that he "indicated the organ in which color takes place." (p. 47)

A discovery with important implications for color science was the discovery of diffraction by Francesco Maria Grimaldi (1628-1663). It was described in his book on light, color, and rainbow which was published posthumously in 1665. As a result of his discovery of diffraction, "Grimaldi asks himself whether light consists of waves; he compares the light which can bend round an obstacle with the movement of waves in water: there too a movement can continue round an obstacle. Grimaldi thinks that colors are different sorts of light waves...Grimaldi's discovery that colors can arise from light without the intervention of any device such as a prism *(sine mutatione medii)*, is essential to the theory of color. Color is property, or at least a modification of light itself. The distinction between true and false colors is therefore, according to Grimaldi, unnecessary." (pp. 60-61)

Robert Hooke (1635-1703) described studies of colors produced in thin layers and, like Grimaldi, suggested a sort of wave theory of light. Hooke thought that red and blue were the two primary colors. Hooke introduced the concept of wave fronts, which was elaborated by Christiaan Huygens (1629-1695). In 1664, Robert Boyle (1627-1691) called red, yellow, and blue the primary colors, anticipating the trichromatic theory.

Experiments by Isaac Newton (1642-1727) showed that color resulted from properties of light itself rather than a property of objects or a modification of light by a device such as a prism. He split white light into the spectrum of colors with a prism and then recombined the spectrum into white light with another prism. He also discovered that red and yellow combined to make an orange that could not be distinguished from monochromatic orange. Newton proposed that light was composed of particles conducted by vibrations in the ether.

In the seventeenth and eighteenth centuries there were attempts to classify colors. This was important to persons such as painters, engravers, cartographers, entomologists, and printers. Crone credits Richard Waller (1686), Secretary of the Royal Society, as being one of the first to make a practical scheme of color naming, starting with three simple colors - red, yellow, and blue.

The German mathematician and astronomer Johann Heinrich Lambert (1728-1777) found that if red, yellow, and blue were mixed in the right proportions the result was black. He also noted that nothing was seen if one tried to look through a red, a yellow, and a blue filter, all at the same time. Crone notes that Lambert was thus the discoverer of the principle of subtractive color mixing, which is usually attributed to Helmholtz.

In a paper published in 1786 in French, George Palmer (1740-1795) suggested that colorblindness originates through loss of retinal elements sensitive to color. Crone gives Thomas Young (1773-1829) the credit for being the first to recognize "that it was not light, but the retina, that was trichromatic." Young proposed the wave theory of light, and offered his double slit interference experiment as evidence. Newton had argued against a wave theory of light by suggesting that it was incompatible with rectilinear propagation of light. Augustin Jean Fresnel (1788-1827) showed mathematically that rectilinear propagation could occur with waves because secondary waves would cancel each other out.

It appears that the first published account of defective color vision was that of two brothers published in 1777 by Joseph Huddart. In 1778, John Dalton (1766-1844) published the first scientific description of defective color vision when he wrote about his own color anomaly.

Crone credits Hermann von Helmholtz (1821-1894) as being the first "to perform flawless experiments on the mixing of spectral colors." (p. 138) He was thus able to distinguish additive color mixing from subtractive color mixing. James Clerk Maxwell (1831-1879) founded colorimetry when he assembled an apparatus for making color comparisons with spectral colors. He found that a color blind individual showed dichromatism rather than trichromatism. Experiments by Helmholtz and Maxwell were important in confirming Young's trichromatic theory.

Ewald Hering (1834-1918), who succeeded Purkinje as professor of physiology at Prague, suggested a four color opponent theory in which the principal colors were red, yellow, green, and blue. The Young-Maxwell-Helmholtz trichromatic theory and the Hering opponent colors theory both described some color phenomena well, so it became clear that color vision was more complicated than either theory alone would suggest. In 1889 Hering stated that "...the opponent-colors theory and the Young-Helmholtz three color theory could with some modification very well exist side by side if one strictly distinguished between the *process of excitation and the process of sensation,* and used the three-color theory for the former and my theory for the latter." (p. 172) Johannes von Kries (1853-1928) was correct in his zone theory (1882) in that the trichromatic system was chemical at the retina, while the opponent system was due to a neural recoding system.

Studies on the anatomy and physiology of the visual system conducted in the seventeenth through the nineteenth centuries were important in the development of color theory. Such discoveries in this time period included the different functions of rods and cones, neural structure of the retina, anatomy of visual pathways, visual pigments, the Purkinje shift, and dark adpatation.

The longest chapter in the book is on color science in the twentieth century. It starts with quantum theory. The chapter talks about further development of color theory and discoveries made possible by increased sophistication in experimental methods, such as electron microscopy, retinal densitometry, and electrophysiological recording. The book concludes with a short and sketchy "appendix and synopsis" which briefly summarizes the history of color theory and makes some closing remarks.

This book, published as a special issue of the journal *Documenta Ophthalmologica,* provides an interesting history of our understanding of color. The author does a good job showing how new developments in thought on color were influenced by previous color theory and how the development of color science was dependent upon knowledge of the nature of light and of the structure and function of the eye and visual system. The book is recommended to persons interested in the history of vision science.

D.A.G.

<u>Changes in optometry in the twentieth century</u>:

We are all well aware that what could readily be recognized as optometry has been practiced for several centuries. Non-medical practitioners which have gone by different names over the years have been prescribing lenses to improve vision for hundreds of years. The history of optometry is a long and proud one extending back for centuries before the first American state licensure laws were passed early in the twentieth century and before the use of the term optometrist became common at about the same time.

As with many professions and many areas of science, the twentieth century was a time of rapid change and significant development. In a guest editorial in the journal Optometry and Vision Science (volume 77, number 4, April, 2000, pages 165-167), Alden N. Haffner outlined the major twentieth century changes in optometry.

The first state optometry licensure law was passed in Minnesota in 1901. By 1924, all 48 states and the District of Columbia had laws which regulated optometry licensure and scope of practice. Haffner noted that "the scope of professional responsibility, as defined at the beginning of the century in Minnesota, was not significantly altered for the first seven decades after its establishment."

Haffner suggest that "the major progenitor of change" in optometry in the twentieth century was "the establishment and enhancement of the structured system of formal professional and scientific education of the optometrist." One of the most obvious byproducts has been the uniformity of the terminal academic degree. By the 1960s, all optometry schools awarded the O.D. degree at the successful completion of the professional program.

Haffner identifies three phases of change in the profession associated with the incorporation of pharmaceutical agents into the scope of practice: (1) introduction of diagnostic pharmaceutical agents (DPAs) into the scope of practice, (2) introduction of therapeutic pharmaceutical agents (TPAs) into the scope of practice, and (3) cultural and behavioral changes in the profession. In Haffner's words, "I join with my colleagues in sociology to assert that the third phase, currently well underway, is the institutionalization of the culture, habits, practice models, and professional environment of optometry resulting from both DPA authority and TPA authority. The third change probably will proceed for yet another generation, although it can already be measured in social and behavioral terms. Indeed, its fundamental importance should not be diminished. Moreover, a body of understanding, reflected in the optometric literature, remains to be constructed."

Other changes in optometry in the twentieth century noted in the editorial are: upsurge of optometric publications, both books and journals; increase in vision science research; limited use of surgical procedures; new technology; public health efforts in optometry; and development of institutional optometry, such as in the Department of Veterans Affairs, the military, and the Indian Health Service.

D.A.G.

Ocular Heritage Society meeting:

Optometric Historical Society member Jerry Abrams, who is also president of the Ocular Heritage Society, announces that the 2001 annual meeting of the Ocular Heritage Society will be held April 2-11 in Italy. The major cities to be visited are Venice, Treviso, and Florence. Some of the highlights of the trip are stops at the Luxottica Museum and Factory at Agordo, the Safilo Museum in Padua, The University of Padua, and Florence's Museum of the History of Science, which includes a special section devoted to Galileo.

A few spaces are still available for the trip. To reserve a space, send a $50.00 non-refundable check made out to the Ocular Heritage Society to: Val Tull, Treasurer, Ocular Heritage Society, 467 W. Market Street, York, PA 17404, USA. For questions, Contact J. J. Abrams at 317-241-8315 (telephone) or 317-241-2385 (fax).

Optometrist makes eyeglasses worn in *The Patriot*:

The Tuesday, July 25, 2000, issue of the *Indianapolis Star* newspaper features an article about Shelbyville, Indiana optometrist Ronald McDaniel. About ten years ago, McDaniel started the hobby of hand making spectacles of the type worn in early America. The tedious work required to complete one pair of spectacles takes about 12 to 15 hours, using small hand tools.

Through Revolutionary War re-enactors, McDaniel's hobby came to the attention of the property masters for the movie *The Patriot,* about the involvement of an American family in the Revolutionary War. McDaniel was recommended due to the authenticity of his work. The star of the movie Mel Gibson can be seen wearing the spectacles to read letters.

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