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INTER-SOCIETY COLOR COUNCIL

NEWS LETTER NO. 48

JULY 1943

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Charles Bittinger, Editor for Art
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ISCC EXECUTIVE COMMITTEE MEETING

A brief business session of the Executive Committee was held in New York City on June 22. The following nominating committee, appointed by the Chairman, was approved: Forrest L. Dimmick, chairman, Carl E. Foss and R. C. Gibbs. Preliminary plans were laid for the 1944 annual meeting. The Executive Committee noted with approval that Dr. Le Grand Hardy's subcommittee has enlarged its activities to include a consideration of other tests than those for which the subcommittee was originally formed. The Executive Committee went on record as encouraging the subcommittee to make, through its parent Color Aptitude Test Committee, such recommendations for approval of tests as they may see fit. The committee has been gathering information for some time on a battery of tests. They are particularly interested in the Farnsworth developments, and in the more recent Rand development that has come out of committee work being carried on at the Ophthalmological Institute under Dr. Hardy's direction.

COMMUNICATIONS TO THE EDITOR

May we ask our readers who have occasion to communicate with the editor to note the change of address given in the heading above. This change will become effective about August 1, 1943.

NEW MEMBERS

We are glad to welcome as individual members: Wayne Shirley, Library of Pratt Institute, Brooklyn, N. Y. and Fred G. Clark, Bakelite Corporation, Bound Brook, N. J. Mr. Clark is a chemist working with plastics. He is interested in color specification, both Munsell and spectrophotometric.

WASHINGTON AND BALTIMORE COLORISTS MEET

The third meeting of the Washington and Baltimore Colorists during the 1942-43 season was held at the Arts Club on June 7, 1943. Following dinner, which was served in the garden, the group adjourned to the Gallery to discuss in an informal Round Table - Information Please type of program the subject of material color standards. Experts for the occasion were W. N. Harrison, chief of the Enamelled Metals Section of the National Bureau of Standards; Walter C. Granville of the Research Laboratories of Interchemical Corporation; Blanche R. Bellamy, manager of the Munsell Color Company; and Francis Scofield of the National Paint, Varnish and Lacquer Association Research Laboratory. Dr. D. B. Judd, as master of ceremonies, presented a series of questions particularly aimed to discover some of the limitations that need to be considered in procuring or using the several types of material standards under discussion. The group had hoped to have Mrs. Margaret Hayden Rorke with them to discuss textile standards, but a conflict in meeting dates made this impossible. There were several guests present, among them Mr. W. O'D. Pierce and Dr. Helen Pallister (Mrs. Pierce). Mr. Pierce, as most of our readers will know, is the author of the book, The Selection of Colour Workers, published in England in 1934 when Mr. Pierce was on the staff of the British National Institute of Industrial Psychology.

COLOR BLINDNESS AND THE DETECTION OF CAMOUFLAGE

There has been much in the public press during the past year or two about color blindness. One story has it that color-blinds have been successful in detecting camouflaged positions. No one has been able to find that color-blinds are being used for such purpose, but Dr. Judd, in answer to many questions, last fall before the Washington Academy of Sciences and before the local Colorists group gave a report dealing with the possibilities. A statement based on these reports appeared on page 544 of SCIENCE for June 18, 1943. Anyone interested to know whether the camouflage-detection reports can be believed can find in Dr. Judd's report information regarding the facts that should be taken into consideration in making a judgment on the question.

VITAMIN-A AND COLOR VISION

From Louisiana State University comes a report by J. H. Elder (SCIENCE, June 18, 1943) that is at complete variance with reports by Dunlap and Loken. The Elder report is in closer agreement with the report by Dr. Dimmick in News Letter No. 43 (Sept. 1942). The studies made at Louisiana started with a test of 16 students with defective color vision, most of whom had failed to pass tests of the Army Air Corps but were anxious to do so. Doses of 25,000 units daily for 8 weeks or more were given to these subjects; one subject took 250,000 units daily on prescription of a local physician. Fourteen of the sixteen cases, including the one with massive dosage, failed to show improvement. But because two subjects subsequently passed the Air Corps tests, (the original defect being slight in these cases) more extensive observations were made in order to check the possibility that some benefit could be derived from vitamin-A by a few individuals. Group tests of 897 R.O.T.C. freshmen cadets showed 65 with various degrees of weakness in color sensitivity. Individual tests were then given to 58 subjects who began taking 50,000 units of vitamin-A on alternate days for an eight-week period. No significant improvement in color sensitivity was found in any of the 41 individuals who finished the eight-week period of treatment.

The report refers to Murray's warning (SCIENCE 96, Nov. 13, 1942) against the unfortunate consequences which could follow acceptance of vitamin cures for color deficiency, and goes on to say that while the present study does not entirely dispose of the possibility that a few men, perhaps with minor defects, may improve slightly, the number who could use vitamin-A for this purpose is so small as to be negligible. We are glad to note this report from Louisiana; it verifies results obtained by several Council members who have worked with subjects hoping to improve their color vision by taking vitamin-A.

COLOR VISION PAPERS

The first three papers of the symposium on color blindness arranged by the Inter-Society Color Council for the March meeting of the Optical Society of America appear in the June JOSA (vol. 33). Other papers in the series will be published later, and the papers will then be collected and bound for distribution to Council delegates and members. Meanwhile some may wish to refer to the three papers already published:

Facts of Color Blindness, by Deane B. Judd, pages 294-307
Methodology of Test Preparation, by Forrest L. Dimmick, pages 308-15
Evolution of Color Vision Tests, by Elsie Murray, pages 316-34

I.C.I. SPECIFICATIONS OF THE MUNSELL COLOR SYSTEM MADE AVAILABLE

The July number of the Journal of the Optical Society of America contains four papers of fundamental importance to those working in technical color fields. For ISCC members and delegates who do not receive the Society's journal, it is noted that separate copies of the July number may be obtained from the Institute of Physics, 175 Fifth Avenue, New York City, or from the Munsell Color Company, Inc., 10 East Franklin Street, Baltimore, Md. These papers contain full charts and tables of I. C. I. specifications for 20 standard Munsell hues for four illuminants; tables of I. C. I. specification for 20 intermediate Munsell hues and several hundred "special" papers under illuminant C; and charts and tables presenting the recommendations of the subcommittee of the Optical Society's Colorimetry Committee that has been working for the past several years on the development of a smoothed set of curves for Munsell hue, value and chroma. This last report presents the characteristics of a modified and enlarged Munsell solid which has been evolved from the 1940 visual estimates of the Munsell Book of Color samples. The newly defined loci of constant hue have been extended closer to the extremes of value, while the loci of constant chroma have been extrapolated to the pigment maximum. The dimension of value has been redefined without substantial departure from the Munsell-Sloan-Godlove scale. By the above changes a color solid is achieved which approaches closely to A. H. Munsell's dual ideal of psychological equi-spacing and precise applicability. The new solid is defined in terms of the 1931 I.C.I. standard coordinate system and illuminant C. The four papers comprise a series that is the result of many years of fruitful cooperative effort on the part of the several authors:

(1) Tristimulus Specification of the Munsell Book of Color from Spectrophotometric Measurements, by K. L. Kelly, K. S. Gibson and Dorothy Nickerson;

(2) Trichromatic Specifications for Intermediate and Special Colors of the Munsell System, by W. C. Granville, Dorothy Nickerson and C. E. Foss;

(3) Final Report of the OSA Subcommittee on the Spacing of the Munsell Colors, by S. M. Newhall, Dorothy Nickerson and D. B. Judd;

(4) A Psychological Color Solid, by Dorothy Nickerson and S. M. Newhall.

PHYSICAL SOCIETY COLOUR GROUP

Notification has been received of a meeting of this group in London on May 12, the twelth meeting of the British Colour Group. The lecture announced was to be given by one of our ISCC members, Mr. G.S. Fawcett, on "Sixty Years of Colorimetry." Mr. Fawcett is in charge of Tintometer, Ltd., makers and distributors of the Lovibond Tintometer. The paper will be concerned with the history and development of the Lovibond work, including its present standardization.

GREEN INTO PINK

The following item is from Time, Nov. 23, 1942. Died. A nameless mouse of uncertain age; by devouring (by a pink rat); in Hurstmonceaux, England. His distinction: he was green. He was a triumph of the Rev. Dr. Rosslyn Bruce, an amateur geneticist, who bred 50 mouse generations to achieve the greenness.

COLOR MATERIALS FOR ART EDUCATION IN SCHOOLS

With letter of June 3, 1943, we have received from the Division of Trade Standards of the National Bureau of Standards, Proposed Commercial Standard TS-3492 having the title given in our heading. This standard, which is proposed for consideration and comment, was submitted by the Crayon, Water Color and Craft Institute. After stating the purpose and scope of the proposed standard and defining the terms hue, chroma and value, the proposal outlines detailed requirements. Each of the materials: wax crayons, pressed crayons, semi-moist water colors, dry cake water colors, liquid tempera, powder tempera (types A and B), white dustless blackboard crayons, sight saving dustless blackboard crayons, colored dustless crayons, molded white chalk crayons, lecturer's colored chalk crayons and lecturer's colored dustless crayons, are discussed under several headings. These headings include size, material and workmanship, waxes, working qualities, toxicity, packaging, chroma and color range. In the case of tempera, the preservatives are also described, while in the case of crayons standards for transverse strength are also set up. The 13-page mimeographed pamphlet ends with methods of test and proposed guarantee. The whole appears to be a thorough and workmanlike job.

ANOTHER THEORY OF COLOR VISION

In News Letter No. 46, under the heading "Dominator-Modulator Theory of Color Vision," we reviewed Granit's theory and suggested that that interesting theory would provoke comment. We invited our readers to use these pages for the purpose. Meanwhile, E. N. Willmer, Nature 151, 213-5 (Feb. 20, 1943), has stated that Granit's theory stimulated him to develop a different explanation.

Starting with the fact that there are two different response systems, that responsible for the light-intensity sense and that leading to color vision, Willmer states that two hypotheses may follow. The first and usual one is that color vision is mediated entirely by the retinal cones. As a corollary, we must postulate two or more types of cones or cone sensitivities. Histological evidence for differentiation of these is meager. Theoretical red, green and blue cone sensitivities, such as those of Hecht (1930), are required by visual data to be so nearly identical in form and position, that Willmer believes there is no neural mechanism so delicately adjusted as to be able to distinguish the subtle differences indicated.

The second possibility is that the elements required for color vision are those actually known to exist, namely rods and cones. This hypothesis has not been popular because of belief that the central, foveal region is rod-free, and generally free from the Purkinje shift. Willmer starts, however, by assuming this possibility. He then sketches the scotopic and photopic retinal luminosity curves of Ludveigh (1938) and 1940, respectively), which have been corrected for absorption of eye media and put in terms of quanta of light energy. The maximum of the rod curve is at 500 mu and that of the cones at 560 mu. The rod curve shows remarkable resemblance to the absorption spectrum of visual purple. The idea that the photopic sensitivity curve is the cone curve receives direct support from Granit's observations, in which the existence of a dominator is coincident with the presence of cones in the retina; and further support comes from the luminosity curves for pure-cone retinas, these having maxima at 560 mu. Ludveigh finds the curve to be remarkably symmetrical, suggesting that it is made up of the absorption spectrum of either one or a large number of substances, not 3 or 4 as required by the Young-Helmholtz and other theories.

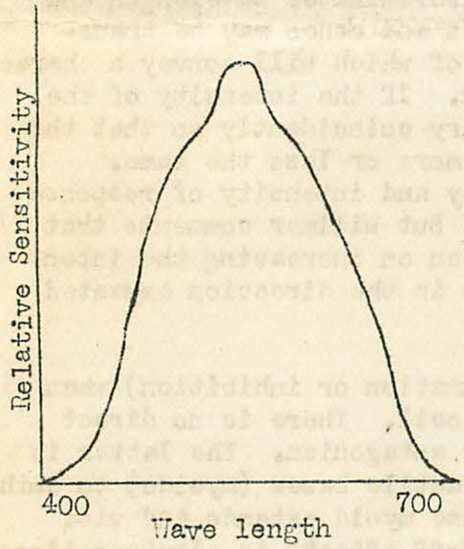
If the luminosity curves are essentially sensitivity curves, there is a different rod and cone sensitivity at every wavelength (except where the curves cross) and we have two elements necessary and sufficient to discriminate wavelength and intensity. Probably the responses of rods and cones are related to their sensitivities and we may consider the curves as response curves and think of the ordinates in terms of impulse or discharge frequencies, probably multiplied by some factor. Thus at any wavelength there will be a characteristic ratio of impulses initiated from rods and cones; and it is necessary to think of their destinations. Of the intricate retinal connections we may note at least that many of the cones are individually connected with the optic-nerve fibers through midget bipolar and ganglion cells; that a great number of cones project their impulses together with those from adjacent rods onto "flat bipolar" cells, and probably that over much of the retina the "mop bipolar," or "rod bipolar" of Cajal, conveys impulses arising in rods only. The rod bipolar is absent from the foveal slope; and it may be significant that foveal color vision is weakest for those colors which are purely rod-mediated, namely the violets. In the end regions of the spectrum, where impulses are propagated from rods or cones alone (no overlap of the two curves), the eye barely discriminates wavelength and intensity. It is clear that the impulses set up by rods and cones may be transmitted to the brain by at least three routes, each one of which will convey a characteristic frequency of impulses for any given wavelength. If the intensity of the light be varied, the frequency along each route will vary coincidently so that the rod-cone response ratio for any wavelength will remain more or less the same. Information is lacking on the relation between frequency and intensity of response necessary for more detailed analysis of the mechanism. But Willmer comments that the subjective changes in hue toward blue and orange seen on increasing the intensity of red and violet light, respectively, are changes in the direction expected from his hypothesis.

Presumably, there must be some form of interaction (summation or inhibition) when rods and cones both project onto the same flat bipolar cell. There is no direct evidence, but indirect evidence for either summation or antagonism. The latter is suggested in the case of those animals which have contractile bases (myoids) to both rods and cones, when the rod myoid contracts and the cone myoid extends and vice versa (Detwiler, 1940); also as an explanation of the "off effect" in electroretinograms, e.g., when white light is acting on the retina the rods and cones may completely antagonize each other in their effects upon the flat bipolar cells, except at the beginning ("on effect") and end ("off effect") when differences of reaction time prevent complete synchronization. Also important is the observation of Kravkov (1941) that the sensitivity to certain colors may be changed, after some 30 minutes, by the application of pilocarpine or adrenalin to the eye. The latter increases the sensitivity to blue-green and reduces it to orange, but has no effect on the colors corresponding to the ends of the spectrum, where rods and cones act alone; and there is a neutral or stable point in the yellow-green, strongly suggesting the crossing point of the rod and cone curves. Precisely the reverse effects were obtained with pilocarpine. If this phenomenon be shown to be retinal in origin, it would be explicable in terms of the balance of response set up by rods and cones; but it is difficult to incorporate into current theories.

The analyses of retinal activity recorded by Granit are all based on impulses picked up from the optic nerve fibers and therefore are not necessarily recordings from the sensitive elements themselves but from retinal units. It would be possible to interpret his dominator as the response of the cone unit and his modulator as that of the rod-cone units or rod units.

The equation $Q = aR + bG + cB$, expressing the relation between the intensities (a, b, c,) of the three primary colors (R, G, B) required to match any given color Q can be modified by substitution for R, G, and B of the ratio of rod response to cone response, i.e., R_1/C_1 for the red primary, R_2/C_2 for the green and R_3/C_3 for the blue. The three primaries are chosen so that $R_1 + R_2 + R_3 = C_1 + C_2 + C_3$; that is, so that the total rod response is equal to the total cone response, which is the condition for the perception of white light. If this substitution be carried out, and the values of a, b and c for any given color be read from the 1931 I.C.I. color-stimulus mixture diagram, the value of Q turns out to be the rod to cone ratio for the color match. A figure shows good agreement between this ratio for various wavelengths and that calculated from the color equation.

A "particularly interesting, though somewhat mysterious" confirmation of the author's hypothesis is obtained from summation of the rod and cone responses, which physiologically could occur on the bipolar cells or on the ganglion cells. There is thus obtained the curve shown here.



This figure shows all the salient characteristics of the previously entirely empirical "color triangle." The lines joining points on the curve corresponding to complementary pairs all pass through nearly the same point; all wavelengths shorter than 440 mu or longer than 640 mu are complementary to 570 mu and 496 mu, respectively; and greens can have only purples as complementaries. In this diagram, the limits of the spectrum turn outwards, whereas in the "color triangle" they are generally represented as turning inwards. The interpretation of this whole phenomenon is obscure.

So far the simplest assumption has been made that, owing to adaptation, rod and cone responses can be represented on the same scale; that is, that the luminosity curves can be directly compared in order to estimate the frequency of impulses travelling up the separate rod and cone fibers. It follows that if for any reason the relative rod and cone sensitivities are increased or decreased, then some form of color blindness should result. For example, many of the properties of the deuteranope would be explained if his rods were relatively less sensitive than his cones; and the protanope would correspond to less-than-normally sensitive cones. Willmer thinks such a system more probable than the presence or absence of whole systems of hypothetical sensory units.

A complete color-vision theory would have to explain many other facts; but those already treated as examples indicate at least the possibility of interpretation in terms of the known activity of rods and cones. "Naturally there are difficulties, not the least of which is the structure and behavior of the fovea, but these may perhaps yield to further investigation; and the hypothesis has the merits of not multiplying the sensory elements and of not invoking any structures which are not demonstrable.

In reading Willmer's account, questions arose in the mind of the Editor, especially at the point where Guild's form of trichromatic equation for the color Q is written. It was not clear, if we have three routes of transmission, each conveying a characteristic frequency, that all three frequencies are independent; and it requires three independent variables in order to account for trichromatic vision. Not feeling qualified to discuss this question adequately, the Editor asked Dr. Judd to discuss both the Granit and the Willmer theories. His discussion of the former follows, while his discussion of the latter will appear in the next issue. Of the former Dr. Judd writes:

From the review by Godlove (ISCC News Letter, March, 1943) of Granit's paper (A physiological theory of color perception, Nature 151, 11; 1943) it would seem that the dominator-modulator theory is essentially the particular form of the Young-Helmholtz theory in which one of the components (the dominator) carries all of the brightness leaving the other component or components (modulators) to combine with the dominating response so as to yield chromaticity as well as brightness. A. König is, I believe, the first to note that human vision could be described in those terms; he said from his studies of red-green blindness that in normal vision the luminosity goes practically hand in hand with the action of the red component. He did not publish this conclusion but discussed it about 1890 with his star pupil, Dr. Christine Ladd-Franklin, who told me about it in 1928 although she thought he was all wrong. This idea is also ascribed to König by v. Kries in his appendix to the 3rd edition of the Helmholtz Physiological Optics (v. 2, p. 412, footnote 1, English Edition, 1924).

The theory of color vision proposed by Dr. E. Q. Adams (Psychol. Rev. 30, 56; 1923; J. Opt. Soc. Amer. 32, 168; 1942) could be described as a "dominator-modulator" theory. The standard ICI colorimetric coordinate system is, itself, congruent with this theory, although the inclusion of the luminosity function as one of the three component functions was in this case inserted, not because of any theoretical argument, but for the sake of time-saving in computations. At the OSA meeting last March I presented a paper, Standard Response Functions for Protanopic and Deuteranopic Vision, based on a coordinate system which accords with one form of the dominator-modulator theory although I had not at that time learned of Granit's espousal of the theory nor of his newly coined name for it.

The dominator-modulator theory could hold regardless of whether the response of the retina is photoelectric or photochemical, but it is most often thought of as photochemical.

It will be noted, therefore, that the idea is about 50 years old, has attracted sporadic attention since König's time, and is of some current interest apart from Granit's work. Granit, however, has collected direct evidence favoring the theory from measurement of impulses in single optic nerve fibers of various animals (frog, snake, cat, rat, pig, and so on), has coined the apt name, "dominator-modulator," and has shown how different forms of "dominator-modulator" retino-neural connections can account for the facts of vision not only of man but also of various subhuman animals.

Again we invite our readers to bring forth other comment suggested by the presently reviewed theory and the dominator-modulator theory.

THIS IS FASHION This is the title of the latest book by the well-known ISCC member, Mrs. Elizabeth Burris-Meyer. The book is published by Harper and sells for $6.00. As it is not a book on color, we shall not review it, but we shall instead refer you to a review in Time of July 12, which does include some color notes from the book. Such notes are the Egyptian use of white, their lower-class use of black trimming, and their use of saffron for mourning; the seven colors of Etruscan royalty, with a smaller number for heads of families and officers; the yellow color popular in England under James I; Zenobia of Palmyra's purple robe; and the Pennsylvania Mennonites' distinguishing colors for indicating female marital status. The fantastic color names used by the French are also mentioned in this interesting book.

OUTLINE HISTORY OF COLOR

Inquiries received from time to time by the Editors on questions of the historical development of color knowledge prompt us to introduce some chronological notes on this subject when space is available. We shall be pleased to have our readers make any additions or corrections, especially when original sources can be mentioned. We begin with the time of the Greek philosophers.

C. 540 B.C. Pythagoras taught that the color of an object is partly objective and partly subjective; its cause is to be sought in the properties of the number 5, which was arrived at because of his studies of arithmetical, geometrical, harmonical and musical progressions. Minute but material images are continually being cast off from all illuminated bodies, and of these, which flow in all directions, some enter the pupil of the observing eye. Pythagoras was the first to suspect the function of the brain.

----? Alcmaeon of Crotona discovered the optic nerve; taught that the brain is the seat of intelligence.

c. 440 B.C. Anaxagoras was the first to state that the moon shines by reflected light and to explain its phases correctly.

C. 440 B.C. Empedocles taught that light has a finite velocity; rays emitted from the eye run out, antennae-like, to the objects of visual perception and return with information; the sun is an image of the earth, produced by reflection; perception is due to the contact of an element found in the sense organs (fire, for example, in the eye) with the same element placed outside us.

c. 430 B.C. Hippocrates of Cos, the father of medicine and ophthalmology, said that the eye consists of three membranes: the white, the soft, and the spider-web-like; these are distended by the ocular humors: aqueous, vitreous and crystalline; the essential organ of vision is one of the latter two. Hippocrates knew the optic nerve, but did not understand its function.

c. 400 B.C. Demokritos wrote "On Color" and "On Painting," often quoted later by Theophrastus; held that vision is due to small particles from an object entering the eye.

c. 380 B.C. Plato held that vision is due to particles from the eye running out and mingling with light from the sun and an emanation from the object and returning to the eye with information. He discussed optical (not pigment) fusion of colors; was opposed to illusionistic painting (by Apollodorus and others) because it was "deception"; Apollodorus replied: "It is easier to criticize than to imitate." But Plato showed an artist's pleasure in color.

c. 340 B.C. Aristotle held a visual theory like that of Empedocles and Demokritos; in his treatise "De Sensu et Sensilibus" he gave the germ of the modern theory of optical fusion of colors: instead of mixing pigments on the palette, allow the colors to mix in the eye through juxtaposition at a distance. He advanced a theory of color contrast; thought drawing more important than color in painting, for one "color" sufficed for the ancient masters; the rainbow is only a phenomenon of reflection, the droplets of a cloud acting as mirrors to the sunlight; believed colors are made of mixtures of black and white. He discovered the nerves of sensation and called them the "canals of the brain."

c. 330 B.C. Theophrastus quoted Demokritos at length on painting; according to him, there are 4 principal pigments: red, yellow, black and white, and from these by mixing, gold, bronze, purple, indigo, green, bluish black and brown can be obtained.

c. 330 B.C. Apelles, a great painter, wrote books on the theory and practice of color and painting. A contemporary, Melanthios, also wrote a book on painting.

c. 300 B.C. Euclid wrote a book on catoptrics (optics of reflected light) and one on optics, beginning with the assumption that objects are seen by rays emitted from the eye in straight lines (Empedocles' view), "for if light proceeded from the object we should not, as we often do, fail to perceive a needle on the floor"; he knew refraction and the equality of the angles of incidence and reflection.

(The visual theory of Empedocles was held by Euclid, the Stoics, Kleomedes, Plutarch and Galen; that of Plato by the Platonists and Pliny; that of Pythagoras by the Pythagoreans, the Atomists and the Epicureans. All of these from Euclid's time held that rays from the eye expand into a "visual cone" resting on the object looked at.)

c. 300 B.C. Herophilus was the first to discover the nervous system and explain its nature and function.

c. 280 B.C. Strato probably wrote the pseudo-Aristotelian tract "De Coloribus" (On Color) containing theories of perception and observation of light and the modifications to which color is susceptible both by mixing and by modulation with light and shadow, by superposition and by juxtaposition; passages make it probable that the modern "impressionistic" technique for retinal fusion of small patches of color (probably used by Antiphilos of Alexandria in the 4th century B.C.) was understood.

c. 270 B.C. Erasistratus described the brain and its convolutions, the division between the cerebrum and the cerebellum and knew that nerves carry messages to the brain from the body, distinguishing nerves of sensation and motion.

c. 60 B.C. Lucretius, Roman poet, emphasized trust in the direct knowledge contributed by the senses.

c. 50 B.C. Hero of Alexandria deduced the law of reflection from the principle of the shortest path (anticipating Fermat's principle.)

~~29 A.D.~~ Celsus wrote "De Medicina" containing two chapters on the eye.

c. 50 A.D. Kleomedes mentioned the apparent elevation of a coin in a cup into which water is poured; pointed out that in the same way, atmospheric refraction might render the sun visible after it is somewhat below the horizon. His visual theory like that of Empedocles.

c. 60 A.D. Pliny the Elder followed the Platonists in his visual theory; mentioned madder dye and litmus (gratulian purple); knew the pigments white lead, cinnabar, vermilion, smalt, verdigris, iron ochers, soot, etc.; described the use of the combustion product of sulfur to destroy impure "color"; gave accounts of many of the painters. (A.P. Laurie states that there were also known in Pliny's time: red lead, dragon's blood, madder and kermes lakes, yellow ocher, yellow lead oxide, malachite, terre verte, vegetable green, indigo, Egyptian blue, azurite, Tyrian purple, chalk, gypsum, charcoal and bone black.)

c. 150 A.D. Claudius Ptolemy of Alexandria measured angles of refraction for air-water, air-glass and water-glass interfaces and wrote on atmospheric refraction; accepted Plato's views of vision.

c. 160 A.D. Galen wrote an "Optics" and "Anatomy and Physiology of the Eye." Held a view of vision like that of Empedocles. Described the visual nerves and the retina; the brain (not the heart) was said to be the organ of sensation; the crystalline body, the seat of vision.

(Greek knowledge was preserved by the Nestorians, who were declared heretics and driven into exile, and who, in the 5th century, translated into Syriac and then into Arabic the Greek works. About 800 A.D. Caliph Haroun Al Raschid ordered the translation of Aristotle, Hippocrates and Galen into Arabic.)

c. 880 A.D. Rhazes discovered the reaction of the pupil to light.

c. 1000 A.D. Al Hazen described the optical system of the eye; thought the lens the seat of vision; first to teach that angles of reflection and incidence are equal; reversed earlier teachings by insisting that visual rays pass not from the eye to the object, but in infinite number from the object to the eye. He gave explanations for many illusions, including that of the enlargement of the moon at the horizon, and accounted for twilight. Made many optical discoveries.

c. 1025 A.D. Ali Ben Isa wrote a textbook on the eye: "The Memorandum Book for Oculists," very widely used for centuries.

c. 1050 A.D. Constantinus Africanus and (c. 1140) A. Ben Ezra were influential in bringing Arab knowledge back to the Christian world.

1267 A.D. Roger Bacon stated the laws of reflection and refraction and used them to explain the rainbow; had germs of an undulatory theory of light; taught that there can be only 5 colors in the rainbow, because 5 is a more perfect number than 7.

1270 A.D. Vitellio published a book on optics; explained the twinkling of the stars.

(Note. If there is any interest in this outline history of color and vision, it will be continued in an early number I.H.G.)

COLOR IN PAINTING THROUGH THE AGES XVI.

The Southwest. From Sicily, the Western Neolithic folk passed to the Italian mainland to sites in Apulia, where the pottery was decorated with angular patterns in black paint on buff. Characteristic of both Apulia and Sicily were cylinder-lug handles recalling those of Gerzean stone-vases of pre-dynastic Egypt and the "horned lugs" of Thermi III. Certain elements of decoration, described (for Sicily) in an earlier issue, were derived from North Africa, while the pottery-painting tradition came from the Balkans. The early colonists in West Sicily are known by their remains in certain caves. Here were found buried skeletons, tools of bone and local obsidian, plain pottery and a ware decorated with incised "ladder patterns." The latter ware, ornamented with a scatter or row of nail marks, plain and dotted lines, zigzags, herring-bone and hatched bands of ladder design, was coarse and black to red in color. It is believed that the neolithic people who lived in the caves were akin to the folk of Southern Spain who left paintings in their caves, both being derived ultimately from Africa. But very early they were in contact with voyagers from around the Aegean Sea; and the island resources of copper ore soon led to the development of a Copper Age civilization. In Spain, the Almerian culture of El Garcel (News Letter No. 42) developed to a "second neolithic" with Egyptian-looking plain dark pottery.

Britain. Ireland and the "Highland Zone" of Great Britain have supplies of tin, copper and gold; but these must be reached by colonists from the Continent by passage through the Lowland Zone. In the latter, reached by short sea crossing, cultures long preserved the marks of their Continental development; the former zone was filled by more insular cultures. When neolithic peasants crossed from France and Belgium, at first they occupied the chalk cliffs while the mesolithic hunters and fishers were pushed inland. Their "Neolithic A" sites extended from Eastern Sussex to Devon and Cornwall. The "classic" site (clearly defined in 1925) is Windmill Hill, Wilthsire. The hill-tops were fortified by systems of ditches, supplemented by causways and palisades. Maiden Castle covered 12 acres. The camps' occupants lived mostly by breeding cattle and other animals and cultivating bread wheat. Highly skilled miners mined flint for export, though this industry flourished to its fullest extent several centuries later. Carved figurines and phalli and antler combs are elements of this culture, while the vases are "leathery" or "baggy" round-bottomed pots with simple rims and vertically pierced lugs for handles. This ware and other culture elements are typical of the general Western Neolithic, but some other elements were lost in the sea crossing.

Megalithic Cultures. In News Letter No. 42 we mentioned the megalithic (large stone) temples of Malta. It is now necessary to digress somewhat to trace the spread of the megalithic idea, which we have stated goes back ultimately to Arpachiyah. Evidence of the spread of Near Eastern culture to Western Europe is afforded by the architecture of megalithic tombs which dot the supposed maritime route and the land routes supplementing them from the Mediterranean Sea to the Atlantic. The tomb contents prove the cultures and the peoples to be varied, but the regular recurrance of architectural details and the distribution of the tombs suggest the diffusion of some religious idea expressed in funery ritual. Except in Egypt they served everywhere as collective sepulchers or family vaults. Collective burial enters simultaneously with megalithic architecture. The form of the tombs depended on local conditions.

There were "beehive tombs" ("Tholos"), so-called because of their shape; "passage graves," with burial chamber entered by a lower, narrower passage; "long stone cists" or "gallery graves" with short wide porches. Sometimes there was division into compartments, producing "segmented cists." Small chambers with entrance passage built of 3 to 6 megalithic uprights supporting a large capstone are known as "dolmens." In Scandinavia, the chronological sequence: dolmen, passage grave, long stone cist, holds good; but the old idea, influenced by a supposition of evolution followed by degeneration, that this sequence applied also elsewhere, has been disproved. An elaborate theory that the megalithic tomb was diffused by "Prospectors" or "Children of the Sun," setting out from Egypt to find metal ores or precious stones, valued for their magical qualities as "givers of life," has also been discredited, though we have accepted the idea as applying partially to red ocher. Megalithic distribution does correlate in a general way with sources of mineral wealth; but the tomb furniture fails to support the idea of the exploitation of these resources. In fact the quantity of metal from the tombs is not in direct ratio to their number but in inverse ratio to their distance from natural sources or trade channels for metals. It is now believed that one route of diffusion spread from the Copper Age Mediterranean countries by way of the Catalan end of the Pyrenees in Spain, across to the west coast of France to the northwest and north of Europe (the "Pyrenean route"). A later and longer route was by way of Southwest Spain, Portugal, Galicia and the Atlantic ocean.

The former route brought to Scandinavia the dolmens, the latter the passage graves; while long stone cists evolved in the North under southern influences. A stone-walled sepulcher for collective burial was found in an Almerian site (dating to about 2600 B.C.?) of the Second Neolithic; and in the succeeding Spanish Copper Age the tombs were regularly corbelled tholoi or other megaliths. Passage graves were introduced by colonists, apparently from Sardinia, into Catalonia between Barcelona and the French border, perhaps by 2550 or even 2600 B.C. Gallery graves and other types, as the monumental rock-cut tombs at Arles, were built west of the Rhone as well as in the Basque Provinces; and soon they spread north and across France to Brittany, whose gallery graves and cists may be dated near 2550 B.C., and long mounds slightly later. The country round the Gulf of Morbihan and the Channel Islands were an important halting place on the road to the Cornish tin-lodes and Irish gold-fields; and a new group of cultures were blended onto the Western Neolithic.

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