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With the Compliments of
DR. CASEY A. WOOD,
108 E. Adams St.,
CHICAGO.

Color Measurement, and its Application in Medicine and the Arts.

BY

CASEY A. WOOD, M.D.

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1102 RELIANCE BLDG.,
CHICAGO.

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[REPRINTED FROM MEDICINE, MARCH 1896.]

COLOR MEASUREMENT, AND ITS APPLICATION IN MEDICINE AND THE ARTS.

BY CASEY A. WOOD, M.D.,
Professor of Ophthalmology in the Post-Graduate Medical School, Chicago.

For some reason or other, chromometry continues to be one of the neglected sciences, and as result we are, even in this age of universal standards, without generally accepted color units or a nomenclature having a scientific basis. Not only in America, but in England, France, and all the other Continental countries, arbitrary names continue to be given to color shades and mixtures, without reference to their spectral or other value.

The recent advances in the art of dyeing and the discovery of so many new shades and color combinations are the direct outcome of a study of modern chemistry; and yet the technology of dyeing and dye-stuffs is not comparable in definiteness with chemical terms. Even in formal treatises on stains, paints, and pigments, one occasionally sees such absurd color designations as "oriental drab," "apple blossom," "Nile green," "ashes of roses," "French gray," etc.

The metrical system of weights and measures, the centigrade readings for the thermometer, the comparatively recent notation used in electrical measurements, and numerous other instances might be quoted as well known examples of the demand for and the supply of convenient and universal standards of measurement in various departments of the arts and sciences. Quite otherwise is it with chromatics. Even the most scientific and exact writer upon this and kindred subjects must continue, for want of something better, to employ the phraseology of the bargain counter and the penny paint-box.

There would not be so much room for criticism of this unscientific nomenclature if it were a constant one or if it were universal—*i. e.*, if it could be translated into color names in use in other countries. Such, however, is by no means the case. It is instructive to compare the color charts to be seen in the shops of German and French dealers with those exposed for sale in the artists' material stores of America. It will be found that each nation has its own more or less local and more or less fanciful names for color combinations—the new ones especially. Not only is this true of different countries, but differences in color nomenclature are often found in the catalogues of dealers in paints and dyes, as well as in color-cards issued by sellers of artists' materials, within the *same* country. The "terra cotta" of one paint-manufacturer is not necessarily the same color mixture sold by his rivals in the same city. A comparison of the sample color-cards issued by such representative firms as Winsor & Newton in England, the Johns Manufacturing Company in this country, Paillard in France, and Schmincke in Germany, at once shows this. Hardly a color named on the card of one firm is an exact reproduction of a color sample of any other. Thus the French firm's "*Terre de Sienne brûlée*," the German "*Gebrannte Terre di Sienna*," and the English and American "burnt Sienna," all contain varying proportions of red. In the same way Schmincke's "*Elfenbeinschwarz*" is blacker than Paillard's "*noir d'ivoire*," while Winsor & Newton's "ivory black" is pale when compared with either of these.

This is what Ludwig Fischer* says about the chemical constitution of that well known color, "Van Dyck brown:" "This pigment consists for the most part of oxide of iron and aluminum silicate, and is often obtained by burning yellow ochre. *The color shade depends upon the amount of heat applied*, and these variations in tint have gained for it in commerce many names, such as Prussian red, English red, Nuremberg red, Roman ochre, Italian earth, red ochre, and *ocre rouge*. The genuine Van Dyck brown, which the artist whose name it bears loved to use, is said by him to have been prepared from deposits found in the neighborhood of Cassel."

The so-called "Schweinfurth green" has as many different names as variations in its yellow-green color. Fischer (p. 32) says it is known in the German paint-shops under at least twenty-one different designations.

At least two investigators — Captain Abney and Mr. J. W. Lovibond, of Salisbury, England—have suggested a rational color measurement as part of an attempt to resolve all colors, shades and tints into terms of certain primary colors accepted as a standard. In the case of Mr. Lovibond† many years of experiment have resulted in the perfection of an instrument called by him the "tintometer," by means of which any color combination can be read off in terms of *blue*, *yellow*, and *red*. The chief difficulties encountered by one who attempts to establish a standard of color are that of finding a pure white for purposes of comparison, of deciding upon an illumination which shall be fairly constant, and, lastly, of choosing the colors which are to act as standards.

Captain Abney‡ obtains his standard white by isolating a beam

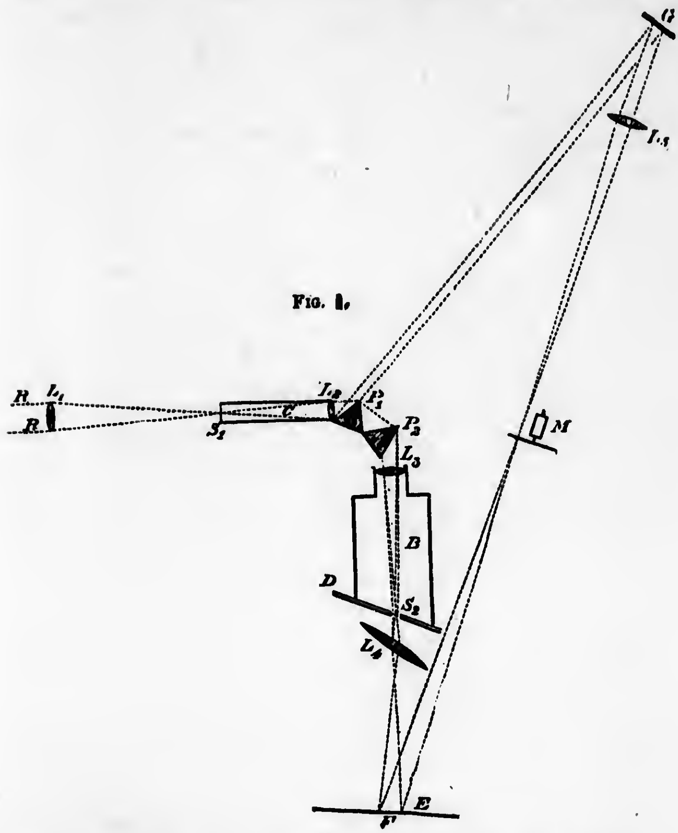
*Die Technick der Arquarell-Malerei, p. 28.

†Measurement of Light and Colour Sensations, p. 132.

‡See his Colour Vision, and an earlier work on Colour Measurement and Mixture, pp. 15-41.

from the centre of an electric light. This beam is directed into a two- or three-prism spectroscope, and the light reflected from the surface of the first prism—considered to be half of the impinging beam—is received on a mirror which reflects it for *illuminating* the

FIG. 1.



color to be matched. The other half, as a prismatic spectrum, illuminates a piece of standard white paper placed beside the colored surface. By an ingenious shutter arrangement the spectral colors are used for matching and then determining the color composition of the beam.

Abney's latest modification of his instrument is shown in Fig. 1, and described on pages 18–20 of his published Tyndall Lectures:

"R R are rays coming from the source of light, be it sunlight or the electric light, and an image of the one or the other is formed by the lens L_1 on the slit S_1 of the collimator C. The parallel rays produced by the lens L_2 are partially refracted and partially reflected. The former pass through the prisms P_1, P_2, and are focused to form a spectrum at D by the lens L_3. D is a movable screen in which is an aperture S_2, the width of which can be varied as desired. The rays are again collected by a lens, L_4, and form a white image of the surface of the last prism on the screen E. If the light passing through S_2 is alone used, the image at E is formed practically of monochromatic light. Part of the rays falling on P_1 are, as just said, reflected, but as it and the refracted part are portions of the light passing through the slit S_1, they both must vary proportionally. If then we use the reflected portion as a comparison light to the spectrum colors, the relative intensities of the two, though they may vary intrinsically will remain the same. The rays reflected from P_1 fall on G, a silver or glass mirror, and by means of another lens, L_5, also can be caused to form a white patch on the screen E, alongside the patch of color. At M, or anywhere in the path of the beams, an electro-motor driving a sector with apertures which can be opened or closed whilst rotating, is placed, and the illumination of either beam can be altered at will. To obtain a large spectrum on the screen E, all that is necessary is to interpose a lens of fairly short focus in front of L_4, when a spectrum of great purity and brightness can be formed."

In the Lovibond instrument the depth of color in liquids and solids can be accurately measured in degrees, placed in their position in a permanent color scale, and registered. The instrument consists (see Figs. 2, 3, 4, and 5) of a graded series of standards, made of colored glasses, numbered according to their depth of color, and an instrument for holding the glasses and the object to be measured. Only three color scales are necessary for investigation work; these are red, yellow, and blue; but for some special purposes, such as for brewers, for the estimation of carbon in steel, for urinalysis, etc., scales in other colors are found convenient. Each ordinary scale consists of glass slips all of one color but differing in depth, the divisions of difference being regular, forming degrees or units as in the case of temperature degrees on a thermometer scale, or inches on a foot-rule.

The color units are not only of equal depth throughout each scale, but have also a color equivalence in relation to each other; that is, a given number of units in one scale has an equivalence of color value in relation to the same number of units in the other two scales, so that upon combinations of equal units of any two or of the three a color nomenclature is founded which consists of eight fundamental terms by means of which every possible color can be first measured and then described.

The instrument consists essentially of a double, parallel-sided, wooden tube, ending in an eye-piece at one end, and equal apertures for viewing the color to be measured and for the glasses used as measurers at the other end. Provision is made for the equal illumination of the color to be measured and the standard white or reflector from which the light is conveyed to the comparison tube; and also for the easy adjustment of the glasses used in the measurements. The mechanism also avoids the side lights (falling on the eyes) which often render the critical estimation of color under ordinary conditions of observation absolutely impossible. Both fields of view are evenly illuminated with indirect sunlight. When this is effected, either side can be used for the standard white without affecting the measurement.

The colored light from the object to be measured is transmitted through one tube, and the light from a standard white through the other; this standard white light is then intercepted by the graded color glasses until it corresponds in color to the object to be measured, when the numerical color value of the glasses used can be read off. I append a description of the accompanying cuts, from Lovibond's book:

"A longitudinal section of the instrument is shown in Fig. 2, which consists of a rectangular tube about ten inches long, divided

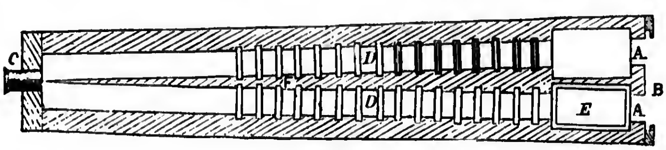


Fig. II.

in the middle by a taper partition, B, terminating in a knife-edge at the eye-piece C, the aperture of which it divides into two equal parts. This cell is represented crosswise in aperture.

"At the other end are two openings, A, A, which admit two equal but separate beams of light to the eye-piece in such a manner that, on looking through it, the eye commands a simultaneous distinct view of both openings. The knife-edge of the partition, being inside the range of vision, does not disturb this distinctness of view.

The grooves, D, D, are intended to receive the graded slips of colored glass for intercepting the beams of light transmitted through the tubes before reaching the eye.

"The opening at E is intended to receive the gauged vessel containing the colored liquid to be measured.

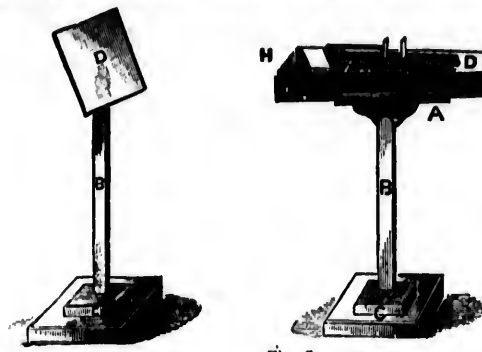


Fig. 3

"Fig. 3 represents the instrument as arranged for measuring color in liquids up to two inches in thickness. The optical instrument, D, slides into the upright stand at A, to receive the gauged

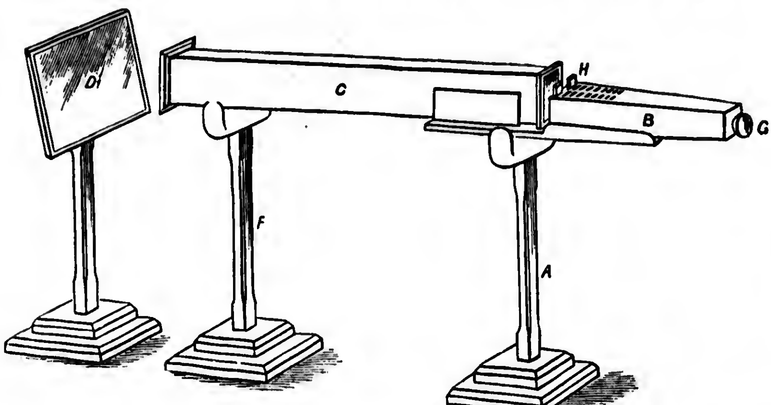


Fig. 4

cells at H on either side. Light is taken from the standard white reflector, D, on stand D B C, for transmission through the tubes to the eye-piece.

"A separate stand is required for cells which are longer than two inches. The method of arrangement is shown in Fig. 4, where one end of the longer cell rests on the stand A, which also carries the optical instrument B, whilst the other is supported by a separate stand, F, which can be moved to accommodate a tube of any length. The reflector, D, is used as in Fig. 3.

"Fig. 5 shows the arrangement for measuring color in opaque objects. The optical instrument, B, is here shown as a binocular,

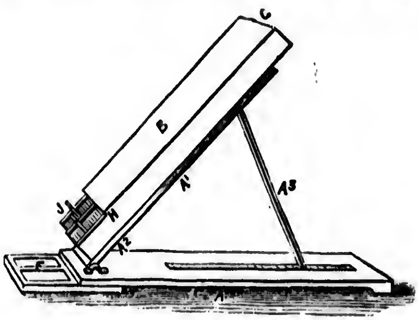


Fig. 5

but the monocular described in Fig. 3 fits equally well into the shoe A^1, the bottom of which is commanded by both tubes of the instrument. Under one side, at F, is placed the opaque substance to be measured, and under the other the standard white (pure precipitated lime sulphate pressed to an even surface) for reflecting the beam of white light, which is then intersected at J by the suitable standard glasses, as already described for transparent colors."

At my request the inventor of this valuable instrument has measured a number of pigment samples selected at random from the stock of a large American color and paint manufacturer. I give the results in a few cases: The paint sold under the name of "primrose" was found to contain 1.16 red units, 2.9 yellow units, and .04 of a blue unit; the so-called "salmon" color equals 1.3 units of red, 2.7 of yellow, and 1.5 of blue; "lilac" equals red 1.85, yellow 1.7, and blue 3 units; "green stone" is composed of red 1.3, yellow 2.7, and blue 1.5 units; "apple blossom" is composed of red 1.9, yellow .95, blue .8; "light blue" is composed of red .95, yellow 1.2, blue 4.9; "cream" comprises red 1.25, yellow 2.5, blue .04; "yellow stone," red 4.3, yellow 3.4, blue 1.5; "dark drab," red 6.2, yellow 7, blue 7; "extra light" drab, red 1.25, yellow 1.35, blue 2.8; "golden brown," red 7.4, yellow 7.4, blue 3.2.

I would suggest that in giving the composition of a color we write it like a chemical formula: for instance, "golden brown" might be indicated as follows, $R_{7\cdot4}Y_{7\cdot4}B_{3\cdot2}$. As Lovibond* points out, many of these formulas are capable of reduction to simpler terms, but for all practical purposes it is, perhaps, as well to speak of them in terms of the primary colors accepted as standards.

The purposes for which the tintometer is now used are numerous and embrace almost every department of the arts. A few of these may be mentioned:

It has been found that the amount and kind of adulteration in most foods and commercial products, as well as the impurities commonly found in drinking-water and other fluids, can be determined by the deviation, measured by the tintometer, from the normal tint of the pure article. Instead of making a laborious and complicated chemical examination of the suspected compound, its color value is determined in a few minutes. Such a chromometric examination is usually found to answer all the purposes of a quantitative analysis. In this way the tintometer is now employed in England, and to some extent elsewhere, by all sorts of commercial houses, and it is also used with great success by the health departments of cities for the ready detection of impurities and adulterations in milk, water, beer, and other foods. The slightest departure from purity, whether in food or any other product, is at once shown by a measurable and corresponding variation in color.

The substitution of an exact color measurement for a chemical analysis is not new in physics. For example, the Bessemer process of converting iron into steel is almost entirely regulated by color changes observed in the furnace flame. It is exactly on this principle, except that the examination is made leisurely, that in a mixture or solution any departure from the standard, both as to kind and amount, is estimated by this instrument. When an exact color measurement has been made of a certain product (it matters not whether it be liquid or solid), the tintometer very readily shows whether a commercial sample is of equal purity.

To a limited extent chromometry has also been made use of for diagnostic purposes in medicine. In urinary analysis we have the Vogel scale of colors, where variations from the tint exhibited by normal urine are intended to indicate something of the chemical composition of that excretion.

The best example, however, of the use of a chromometer as an aid to medical diagnosis is the hemoglobinometer, by which color-

* Measurement of Light and Colour, p. 39.

changes in the blood, pointing to an excess of or a diminution in certain important constituents, are measured by reference to a normal blood color taken as a standard. In Gower's instrument the blood under examination is diluted with water, drop by drop, until it corresponds in color to that of a tube of red fluid assumed to exactly correspond in shade with a one-per-cent. solution of normal blood. In practice this little instrument presents several defects, which I intend, later on, to point out. A more pretentious measurer of abnormal blood, and one which conforms more closely than Gower's to those conditions that have been found necessary for exact chromometry, is that of Fleischel von Marxow, first patented in 1885. Here the blood is compared with a standard ruby glass, the shade of which is increased or diminished by a simple screw movement until it corresponds in color with the blood mixture under examination. The absence of any arrangement for cutting off the side lights appears to me to reduce the value of this instrument for chromometric purposes.

The attempt to compare the standard glass now used in the Fleischel instrument with blood samples is beset with difficulties. Lovibond's early experiments (*loco cit.*, p. 14) showed this. "Colored glass," he says, "was next tried, and long rectangular wedges in glass of different colors, with gradually graded tapers, were ground and polished for standards, whilst corresponding tapered vessels were made for the liquids to be measured. These were arranged to work, at the end of the instrument, up and down at right-angles before two apertures, side by side, with a fixed centre line to read off the thickness of each before the aperture when a color match was made; but here also the difference of ratio between the thickness and color depth of the different colored glass and liquids proved fatal to the method.

"An incidental observation was made during these experiments concerning the difficulty of arriving at a final judgment with tapering colors, owing to one shade gradually blending into the next without a break of any kind to arrest the vision. The mental effort to arrive at a decision, under these conditions of gradual color-blending, was troublesome and vexatious in the extreme. Any person may realize this difficulty by attempting to fix a definite point by the vision in a graduated color line. I was enabled entirely to remove the difficulty by using separate glass slips for standards; the line of color decision made by each additional standard-glass slip used being a precise definition between the most minute shades."

I am myself now engaged in experimenting with a hemometer, constructed on the same lines as the tintometer, which I shall introduce to the profession shortly if I find it of any especial value.

A rather curious application of the tintometer has been made in a certain Agricultural Experiment Station where the value of fertilizers under examination is determined by the change in color produced in the leaves of certain plants whose growth was used as a test.

The degree of dryness, as well as the amount of yellow, in samples of white lead, can be accurately measured chromometrically, while the analysis of natural waters is after a few trials made exceedingly simple, from the fact that the amount and kind of impurities in them bear a fixed relation to their color. So it is with flour, glucose, indigo, annatto, lard, butter, chlorophyll, steel, petroleum, wine, glycerin, and a hundred other articles of everyday production.

But quite apart from these practical applications of a color-measure to medicine and in the arts, it is to be hoped that some universal chromometric standard will finally be adopted, and so there will be added another to that long list of sciences whose technology is, in the widest sense, the common property of all scientific men.

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