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COLOR HARMONY: An Annotated Bibliography

This Bureau has not conducted any work on color harmony; it does not issue color charts showing what combinations of colors are harmonious.

The combination of various colors in pleasing ways is the concern of the artist, the architect, the landscape architect, the interior decorator, and the textile designer. The following bibliography on color harmony not only serves to indicate some important sources of information but also to give a summary of the several conclusions reached. Contradictions between conclusions by the various authorities are not infrequent, and, indeed, are to be expected because of the complexity of the subject.

Rumford, Nicholson's Journal, Vol. 2, pp. 101-106, 1797. Rumford's rule: Two neighboring colors are in perfect harmony,- and then only,- when their mixture results in perfect white.

W. v. Goethe, Zur Farbenlehre (On the science of color), Vol. 1, Cotta, Tübingen, p. 301, 1810. If the eye perceives a color, there immediately appears another color which, with the first, represents the totality of the hue circle. Hence, one isolated color excites in the eye the need to see the general group. Here is the basis of the fundamental law of color harmony. Yellow demands reddish-blue, blue demands orange, and purple demands green. The view of the whole hue circle causes an agreeable sensation.

Field, Chromatics, London, 1845. Field's rule for a good combination: The separate colors must be so chosen and their areas so adjusted that their mixture, or the result by viewing from a great distance, is a neutral gray One way to accomplish this is to use 8 parts of blue, 5 of red, and 3 of yellow.

M. E. Chevreul, The Laws of Contrast of Color and Their Application to the Arts (translated from the French by J. Spanton), London, pp. 46-229 (1859). There are six distinct harmonies of color, comprised in two species, analogy and contrast. The harmonies of analogy are: (1) the harmony of lightness steps, - produced by colors of different lightnesses but of the same hue; (2) the harmony of hues, - produced by colors of nearly the same saturation and of neighboring hues; and (3) the harmony of a dominant hue, - produced by contrasting

colors but one of them predominating as would result from the view of the colored samples through a slightly colored glass. The harmonies of contrast are: (1) the harmony of lightness contrast, - produced by two colors of the same hue having widely different lightnesses; (2) the harmony of hue contrast, - produced by colors of different saturation and neighboring hue; and (3) the harmony of color contrast, - produced by colors of complementary or nearly complementary hues, often also of widely different saturation. The harmonies of analogy should usually be preferred. The harmonies of contrast unless employed sparingly result in distraction and in diffusing the attention. Gloss of the surfaces and form of the areas have their influence on these laws. Applications of these laws are given for painting (oil and water-color). tapestry design, calico prints, wall-paper, architecture, interior decoration, clothing, and horticulture.

William Benson, The Science of Colour, (Chapman-Hall, London, 1868), Chapter XI, The Harmony of Colours. Alternations of rest and excitement in each of the three modes of action of the eye give pleasure. There can be no discord in colors; but there are different degrees of pleasure derived from different successions or combinations. The chief grounds of excellence come from the following: (1) the due balance of the colors in quantity or strength, or the equivalence of the Red, Green, and Blue contained in the whole composition; (2) the symmetry, resemblance, or correspondence in nature and extent, of the gradations and contrasts in different parts of the composition; (3) the variety of the colors, and of the gradations and contrasts presented.

W. v. Bezold, Die Farbenlehre im Hinblick auf Kunst und Kungstgewerbe (Science of color with regard to arts and crafts). Westermann, Braunschweig, pp. 202-256, 1874. Field's rule is false (1) because the color of one area has an effect on those of neighboring areas; (2) because the colors must accord with the design; and (3) because the best paintings and best ornamental designs show a distinctly dominant hue. The combination of 8 parts of blue with 5 of red and 3 of yellow often fails to yield a pleasing combination. Furthermore, no theory of color harmony based on an analogy between color and music has any value. In general, however, any hue (of highest saturation) may be combined with the hues most resembling it, but if the immediate hue neighborhood be skipped over then the combination is very bad. If the hue difference be further increased, however, the combination commences to improve, and finally for complementaries and near complementaries, the best combinations result. In a 12-hue circle, therefore, the best combinations result from skipping at least three hues, the poorest from skipping two, but combinations which skip less than one are good. For combinations of nearly the same hue, it is important to preserve the lightness relation natural to the hues as illustrated in the hue circle. Color triads should be chosen so as to give equal spaces around the hue circle; groups of four, however, should be two Nearly complementary pairs.

E. Brücke, Die Physiologie der Farben für die Zwecke der Kungstgewerbe (Physiology of color for handicraft purposes), Hirzel, Leipzig pp. 185-282, 1887. There are two sorts of hue intervals which ma e good combinations, the small intervals and the large. Hue intervals of intermediate size make poorer combinations. For the small intervals, a large lightness difference is particularly good, but in this case the hue difference should be as found in nature; for example, a blue surface illuminated by direct sunlight is light greenish blue (cyan) but in the shadows is dark blue (ultramarine), hence cyan and ultramarine form a pleasing combination. Only those large int rvals which are greater than 1/3 of the hue circle are pleasing. We may, therefore, have large intervals in pairs and triads but not in larger groups. Black, white, or gray, however, may often be introduced, and small areas of very saturated color may be used as trimming. Each of the main hues may be used at different lightnesses, and also hues which make small intervals with the main hues. Complementary pairs make powerful, striking combinations; some of these are pleasing, others are not; there is no general law. Association of ideas with particular colors alters the purely physiological considerations; for example, gold may be used more freely than yellow partly because it is associated with splendor and riches. Luster of the surface is important, however, and the relative areas occupied by the various color Field's rule, however, is doubly wrong because (1) the proportions of blue, red, and yellow given do not result, as he says, in gray when viewed from a distance; and (2) because the best paintings and ornaments show a dominant hue anyway. A strict numerical rule is not to b expected in color harmony.

O. N. Rood, Colour, 3rd Ed., London, pp. 273-323, 1890. In general, two colors of nearly identical hue injure one another by contrast and produce a disagreeable combination; but if the two colors are also of widely differe t brightness so that they may be interpreted as the same surface illuminated to different degrees, they may be safely combined. In these cases it is important to have the direction of the hue change accord with that due to change in degree of illumination; otherwise a contradictory effect may be produced. Some pairs and triads of color are generally pleasing, others not; no simple general rule can be given. Harmful contrast is the most important source of unpleasantness, but an excess of helpful contrast is also harsh and unpleasant. Combining a warm color with a cold one increases this harshness; on this account violet and yellowish-green which are complementary combine with a minimum of harshness bec use they are of about equal warmth, while red and blue-green form the harshest combination. Large areas of green should be avoided because green is fatiguing; it is also cold so that it produces the contradictory impression of being intense and cold at the same time. Green is the most fatiguing color and yellow the least, the order being: green, violet, blue-violet, blue, red, orange, and yellow. There is less danger of fatiguing with violet or blue, however, because p g-ments of these colors are generally darker. Harmful contrast may be

mitigated (1) by considerably darkening one color; (2) by reducing the area of one color considerably; (3) by adding a third color of considerably differing hue; (4) by using a large amount of gradation; and (5) by introducing beauty and variety of form. In a good triad the hues are separated by about one-third of the hue circle, and two of the colors are warm. Neighboring hues can be added and small areas of strange hues; white or gray may also be added. There should be an aesthetic balance in a color harmony, but aesthetic balance is different from optical balance. Field's rule is therefore false; furthermore, his assertion that red, yellow, and blue in the ratio 5:3:8 gives an optical balance is also untrue since it refers to subtractive combination of glass wedges filled with colored liquids. Aesthetic balance is reached when there is till an optical chromatic excess. No theory of color harmony based on analogy to sound and music can possibly have value.

C. J. Jorgenson. The Mastery of Color. Milwaukee, pp. 72-79, 1906. One color must dominate, but the complementary should always be suggested. Use the less saturated colors for the background. Harmonizing pairs are either complementary or not far from complementary. Soft harmonies may be made up from mixtures on one side of the balance point between the components of a harmonizing pair; contrasting harmonies result from a combination of colors on each side of the balance point. Charts are given showing all mixtures between ninety pairs of harmonizing colors.

E. C. Andrews, Color and its Application to Printing, Inland, Chicago, pp. 40-90, 1911. Ninety per cent of the work of finding a balanced color scheme lies in finding the proper lightness relations. Colors, disregarding the question of position, size, or shape, will balance in lightness if the contrasts which they make with the background are lightness steps that are visually equal. Thus, on white paper with black type-matter use for ornamentation any color of medium lightness, or any pair whose average lightness is medium, in which case it is best to balance a warm color against a cool one. If the type color is of dark rather than black and the paper light rather than white the lightness average of the ornamenting colors should still fall about midway between those of the paper color and type color. Colors of slightly differing hue but identical lightness and saturation form analogous harmonies. Colors of the same hue and saturation but widely differing lightness form the shade-tint harmonies which are the safest for the novice because lightness alone must be balanced. Another set of harmonies may be formed by combining analogous harmony with shade-tint harmony, as, for example, light blue with dark blue-green. A more difficult set of harmonizing colors is formed by keeping lightness and hue constant and varying the saturation in constant steps, sometimes proceeding through gray to the complementary or other hue. Good color schemes are due to a balance which combines warmth and coolness (hue), light and shade (lightness), and colorfulness and grayness (saturation). The pleas-

ing proportions of these qualities may be indicated for the novice by rules which the artist by his experience may often disregard with successful result. In general, colors of high saturation should be confined to small areas, and, conversely, the color of a large area should be unsaturated. In contrasting harmonies glaring effects should be avoided; use the law of contrast to make up deficiencies in color medium; avoid injurious contrast. The harmony of balanced contrasts is made up of a triad, the second color of which is neither analogous nor contrasting to the first color, and the third color holds the second color in place, obviating the injurious results of contrast.

R. Beaumont, Color in Woven Design, Whittaker, London, pp. 58-59. 1912. The supposition that 8 parts of blue plus 5 parts of yellow plus 3 parts of red makes a harmonious composition is of no practical use. Acute and cultured discriminative power for color is of more consequence in this art than theoretical directions. Color harmony is intricate and more or less incapable of being reduced to rigid principles, yet its general qualities may be clearly defined. No one color should be conspicuous in the design; balance is an essential. The most saturated colors should be sparingly employed. When the various colors are of equal saturation the areas may be made more equa v ·iations being introduced only for imparting precision to the leading features of the design.

J.A.H. Hatt, The Colorist, VanNostrand, New York. pp. 35-52, 1913. Beauty in color is a matter of individual taste, and this taste is largely a matter of civilization, the child or savage preferring saturated colors, the mature or civilized individual preferring unsaturated colors. In an aesthetic sense, beauty consists either of harmony o h produced by saturated colors of nearly identical hue, or of c o nei,hbo ing hue combined in varying lightnesses (law of variety). In pictorial art, the lightness variation is large, in decorative art small, and in sartorial art small to intermediate. Large areas of contrasting colors are not beautiful; contrast should be used for accent and then sparingly. In this case, the contrasting colors should be grouped together in a relatively small space and in such proportion that viewed from a distance the result is gray or nearly gray. Combinations of a saturated color with its mixtures with gray, black, or white are pleasing and should be added for variety's sake to combinations of neighboring hues. The range of permissible hues in a combination is very small for saturated colors but progressively widens as saturation is decreased until it takes in the whole hue circle. Chevreul's false law of the contrast of hues had to be invented because of his wrong choice of subtractive primary colors; his harmony of lightness contrast is a restatement of the law of ariety.

M. A. Rosenstiehl, Traité de la couleur au point de vue physique, physiologique et esthétique, comprenant l'exposé de l'état actuel de

la question de l'harmonie des couleurs (Treatise on color from the physical, physiological, and aesthetic viewpoints, including a discussion of the actual state of the question of color harmony), Dunot-Pinat, Paris, pp. 194-267, 1913. Conditions of color harmony have been sought by two methods; (1) analogy with music (Unger, Newton, Seeman, Spangenberg); (2) physiological properties of the eye (Rumford, Goethe, Rosenstiehl). The first method is entirely unreliable. The second method leads to the rule of complementaries in such proportions as to produce white. Studies of the works of the old masters have resulted (Brücke, Schreiber, v.Bezold) in a repudiation of this rule; the use of complementaries should be limited. Chevreul, however, repudiates the rule only for saturated colors of the same lightness; in other cases he recommends its use. Chevreul's solution was good but his chromatic circle contained bad errors. A saturated color next to its saturated complementary is unpleasant because of the brusk transition, but complementaries are pleasant if the transition is gradual (examples, solar spectrum, hue circle). The brusk transition is unpleasant because of the chromatic aberration of the eye which causes us to see the colors in different planes. Hence, color harmony depends on two factors; (1) retinal fatigue which suggests the use of complementaries; and (2) chromatic abberation which prohibits the use of saturated complementaries in juxtaposition

M. Luckiesh, Color and Its Applications, VanNostrand, New York, pp. 312-326, 1915. Warns against drawing analogies between color and music as recently done by Rimington and Scriabine.

C. W. Hackleman, Commercial Engraving and Printing, Indianapolis, pp. 574-590, 1921. For a pleasing artistic effect, use on colored stock, darker ink of the same hue. Use saturated colors for the reading matter, unsaturated colors for the ornamental. In the use of contrasting colors, lightness should be kept about constant. Use saturated colors only as accents amid larger areas of unsaturated color. Complementary harmonies result from taking any two diametrically opposed members of the hue circle, and unsaturated colors give the best complementary harmonies. Analogous harmonies result from combining two or more colors of neighboring hue. Balanced harmonies result from any triad whose members are equally spaced around the hue circle. A self-toned harmony is made up of colors of the same hue but different lightnesses. A dominant harmony is obtained by mixing ink of any one color with a series of inks of other colors. In any harmonious combination variations in lightness may be made, and black, white, or gray added. These rules prevent bad combinations from being chosen; but a skillful artist will produce beautiful combinations without following them.

A. H. Munsell, A Color Notation, Munsell, Baltimore, pp. 78-88, 1923. Warns against the use of musical terms in drawing analogies with color. Good combinations result from colors chosen

along any path of the color solid; thus we have combinations in which lightness alone varies, combinations in which hue alone varies, and those in which saturation decreases through zero and then increases in the complementary hue. Other paths are composed of these three in combination. Smal areas of saturated color can be used to balan e large areas of unsaturated color.

Harriet Goldstein and Vetta Goldstein, Art in Everyday Life, Chapter 9, How to use color, New York, MacMillan, 1925. Every color is beautiful if used in the right amount in the right place. The principles of color design deal with balance or rest, proportion or beautiful sizes, rhythm of easy movement, emphasis or centers of interest, and harmony or unity. For balance by areas of contrasting colors use colors of high saturation in small areas with those of low saturation in large areas; use a small area of a light color to balance large areas of dark colors, and a small area of a dark color to balance large areas of light colors; use a small area of a light, saturated color to balance large areas of colors of complementary hue. This avoids retinal fatigue. Balance may also be achieved by repetition; arrange the areas of balancing colors so that the same sequenc of contrasting colors is repeated. Proportion in color is achieved by varying these repetitions; too much exact repetition gives monotony. Rhythm in colors is achieved by arranging them in the design so that the eye can move easily from one to another. In any color arrangement there should be one outstanding color effect; this gives emphasis Backgrounds should show less emphasis than the objects that are placed against them. Harmony in color comes from the impression that all the colors really belong together, and yet there must be sufficient variet that the arrangement does not become monotonous. For harmony, warm colors should be combined with warm, and cool with cool. Beauty in color schemes comes from those giving a single impression, - an impression of warmth with a note of coolness for variation, or of coolness with its accent of warmth. A color combination is said to be keyed when each color has something in common with every other color. This may be done by (1) neutralizing them, (2) mixing them with a common color, (3) glazing, veiling or topping them, (4) tying them together with a neutral color, or (5) through use of a rough texture. Standard color harmonies may be classed as related and contrasting. Related harmonies are those consisting of colors of the same hue (one-hue harmony), or those of neighboring hues (analogous harmony). Contrasting harmonies are those made up of colors of complementary hues, or two pairs of complementary hues, or one primary hue with hues on either side of its complementary (split complementary) or of three equally spaced hues (triads). The most beautiful designs have many colors but with a definite relationship among them.

A. B. Klein, Colour-Music, The Art of Light, Crosby-Lockwood, London, 1926. Chapter V, The Problem of Colour Harmony, gives a scholarly and critical review of opinions on color harmony. As advocates of color harmony by analogy with music he lists Aristotle,

Newton, Castel, Avison, Field, Hay, Jameson, MacDonald, Barrett, Garbett, Hughes, Seemann, Campbell, Wilkinson, Drobisch, Taylor, and Tudor-Hart. As advocates of harmony by neutral balance, all components cancelling to neutral gray by additive or subtractive admixture, the harmony of complementary colors, he lists Darwin, Rumford, Chevreul, Munsell, Rosenstiehl, and Beaudeneau. As advocates of harmony by measured and ordered divisions of the sensation scales of hue, brightness, and saturation, he lists Helmholtz, Rood, Church, Tanner and Ostwald. The second and third groups are, however, practically one. The final conclusion is that by some sort of regular division of the chief sensation-factor ranges we get color combinations which are not disagreeable. This constitutes a safe method, but it does not exclude the success of combinations which would not, on analysis, be found to conform to this condition. The bibliography on color harmony contains 11 titles, the bibliography on related subjects lists more than 100.

Arthur Pope, Tone Relations in Painting. Chapter III, Design in Tone Relations. Cambridge, Harvard University Press, 1927. Design is a matter of organization or order and may be classified under harmony, sequence, and balance. Harmony means uniformity of any sort in the different parts of a composition. Absolute harmony of lightness results from all of the colors of a composition having the same lightness. Approximate harmony of lightness means that all of the colors have lightnesses within a small range. This approximate harmony of lightness and darkness is important in design, more so than absolute lightness uniformity. Similarly we have absolute and approximate harmony of hue, and absolute and approximate harmony of saturation, and combinations of these in pairs or all three taken together. Absolute harmony of hue, lightness and saturation taken together produces monotony which is no design at all, but approximate harmony of this sort where the colors fall within a relatively small part of the whole color solid is frequently an important feature in fine color (= tone) design. Analyses and examples are given of designs showing lightness-saturation harmony with wide variations in hue, of those showing hue-saturation harmony with wide variations in lightness and of those showing hue-lightness harmony with wide variations in saturation. In any composition the contrast of each color with its neighbors exerts an attraction on the eye of the observer. Harmony of attraction results from having these attractions equal. The attraction of any color increases both with its area and the degree of its difference from its neighbors. By sequence is meant uniformity in change or movement, especially where there is uniformity or uniform change in the steps of differences between the separate parts of a series. The movement or change may be gradual or alternating. In the latter case it is called rhythm. We may have compositions organized on the basis of either gradual or alternate sequence of lightness, hue, or saturation, or of any

two, or of all three combined. As objects in nature model from light into shadow, the colors change in a pleasing regular sequence. Color sequences may be used in pure design so as to produce an emotionally pleasing effect. Balance in design consists in the achievement of an equilibrium in the attraction exerted by the various color contrasts in a composition on either side of a vertical axis, or around a central point. Although the principle ways of organizing a composition are harmony, sequence, and balance, these are merely possibilities, not requirements; and one cannot judge of the virtue of a composition simply by noting the presence or absence of these possibilities. The aesthetic reaction is the final test. What is wanted is as much order and as many different kinds of it as possible, so long as a monotonous effect is avoided.

W. J. Miskella, Practical Color Simplified, Finishing Research Laboratories, Inc., Chicago, 1928. Harmony of colors exists only when there is a common color present. Add gray to any two colors to make them harmonize, or add black to one and white to the other. Harmonies are of four kinds: (1) one-hue harmony, (2) associated harmony, (3) true complementary, and (4) split complementary harmony. Complementary colors harmonize only when both have considerable gray in them or when the areas are in proportion to the lightness.

Wilhelm Ostwald, Colour Science. (Chapter 10. The harmony of colors), London, Winsor & Newton, 1931. Harmony is obedience to law. Three grays harmonize when the two intervals are equal. The simplest geometrical relationships of the color solid are to be found in its principal sections and its circles. The principal sections correspond to constant hue; the circles correspond to isovalent colors (constant black and white content). Any two or three colors of the same hue taken at random are likely to be too slightly connected to be harmonious. More restricted relations are found in lines parallel to the sides of the one-hue triangles; the corresponding colors are the isochromes (constant fullcolor content or constant purity), the isotints (constant white content), and the isotones (constant black content). Three or more equidistant colors of a shadow series (isochromes) produce a color harmony. Likewise those from an isotint series. The isotone series resembles a good deal the very common extension of a pigment with white often mistakenly used with disappointing results where a shadow series is intended. On this account the isotone series provides color harmonies not generally appreciated now, though they may be later when aesthetic judgment becomes keener. Every chromatic color has two grays with which it harmonizes, the gray of the same white content, and that of the same black content; thus, every fullcolor harmonizes perfectly with white or black. Every chromatic color brings the sensation of its complementary with it owing to simultaneous contrast and after images. It follows that complementary hues give us the most direct isovalent harmonies. The hues, however, fail to be interchangeable first because some give an impression of warmth (yellow, orange and red) others an impression

of coolness (blue, violet) because of their natural black content, and second because the strongest colors (100% fullcolor) of some hues (greenyellow, yellow and orange) are much brighter than those of others (blue, violet). Considerations of natural brightness contrast and warmth of the various hues are important in color harmony, as is also the purity of the colors. Triads equally spaced in hue are harmonious, and also any two members of a triad taken separately. Subdivisions of the hue circle other than in two and three parts may also be harmonious, such as subdivision into 4, 6 and 8 equal parts. Here, too, the incomplete harmonies are still very interesting, often surpassing those that are complete. A particularly obvious and practicable method of discovering good intelligible harmonies is that of splitting. By splitting is meant that for one color in a design having colors of two or more hues, two colors are substituted whose hues depart equally and in opposite directions from that of the original color. Discords have no place in color design. The true beauty of a color combination cannot be realized unless the forms of their boundaries are likewise harmonious.

E. H. Lewis, Modern Color Charts and the New Color Theory, Albany, 1932. Harmonies are classed as related, complementary pairs, or complementary triads.

G. H. Opdyke, Art and Nature Appreciation, Macmillan, New York, 1933. The chapter, Color Harmony and Contrast, divides harmonies into analogous and complementary, the former quiet and restful, the latter lively and likely to be too forceful. The analogous harmonies, however, require a touch of the complementary to be perfectly satisfying. Short quotations on color harmony are given from the writings of Henri, Parker, Moreau-Vauthier, Matthews, Vanderpoel, Neuhaus, Hatton, Day, Sargent, Boigey, Rood, Carpenter, Weinberg, and Chase. A statement in another chapter (p.323), "There is an instrument at the Government Bureau of Standards at Washington that can give the exact color needed to harmonize with any color you may submit" is wrong; and, indeed, the implication that for every color there exists one, and only one, other color required to produce the perfectly harmonizing pair is not consistent with the discussion summarized above.

J. Littlejohns, Colour Harmony, J. Roy. Soc. Arts, 81, 592 (1933). Criticizes all systems of color harmony and proposes an experimental attack.

Faber Birren, Color Dimensions (creating new principles of color harmony and a practical equation in color definition), Section on Modern Color Harmony, pp. 36-45, Chicago, The Crimson Press, 1934. The six principles of color harmony are stated in terms of the Ostwald variables: full color content, white content,

and black content, and are: Those colors will harmonize that combine agreeably and (1) all have equal fullcolor, white and black contents; or (2) all have equal white content - although the contents of hue and black may vary in balanced sequence according to visual laws; or (3) all have equal black content - although the contents of hue and white may vary in balanced sequence according to visual laws: or (4) all have an apparent fullcolor content - although the contents of white and black may vary in balanced sequence according to visual laws, or (5) have a common relationship to gray and show visually balanced transitions toward this gray; and (6) those colors will harmonize that (with respect to the above principles) all have an equal fullcolor content. Perfectly complementary hues lack personality and are the first combination of hues to be avoided. Real beauty exists when the color scheme is off balance, when the general psychological effect is dominantly warm or cool Adjacent color schemes in particular are glorious things. The split-complement is also intriguing and far more appealing than a direct opposite. The triads are elegant and rich. The natural values of the various hues are an important element in harmony. In the Birren rational color circle the order of value is: yellow and greenish yellow (highest), yellow orange and yellow green, orange and leaf green, red orange and green (middle), red and turquoise, red violet and blue, and violet (lowest). The six principles of harmony given above do not describe all color harmonies, only the simpler ones. Elliptical paths in the color solid, for example, can be traced from hue to hue in various directions - toward white, black or gray. These yield more complicated harmonies.

Elizabeth Burris-Meyer, Color and Design in the Decorative Arts, Prentice-Hall, New York, 1935. Chapter IV deals with Color Harmony. Whether two adjacent colors produce a pleasing or harmonious effect depends somewhat upon the previous experience of the observer The development of color appreciation in an individual may be described in terms of three stages: recognition, imitation, creation. A set of rules may be written as a guide in the creation of color combinations; good and bad combinations result both from following these rules and from disregarding them, but the chance of getting a good combination is greater if the rules be followed. Only a few people are capable of cutting themselves free from all rules. These rules are as follows: (1) Use only a few colors of high saturation in the same scheme; but all hues may be used together if of low saturation. Small areas of strong colors balance or harmonize with large areas of low saturation into a pleasing scheme. (2) Lightness contrast is essential to a harmonious color scheme; if there is no lightness contrast there is no movement or interest to the composition. The center of interest in a composition must be accented by a sharp lightness contrast. (3 Hue contrast should be chosen to give aesthetic rather than optical balance; the Munsell 5-hue division is more helpful than the division according to the three pigment primaries, red, yellow, and blue.

Related harmonies are obtained from combinations of one hue with various grays and from combination of several colors of the same or nearly the same hue but of varying lightnesses, saturations and textures. Contrasting color schemes are given by a pair of complementary hues, by the double complementary combination consisting of any two pairs of complementary hues, by the split complementary combination consisting of one isolated hue balanced against two analogous hues which taken together are the complementary of the isolated hue, by the analogous-complementary combination consisting of a group of analogous hues with an accent of the complementary of the group, by the adjacent complementary triad consisting of a complementary pair with an additional color whose hue is equally distinct from either member of the pair, or by a triad whose hues are equally spaced in the hue circle.

Research Laboratories, International Printing Ink Corporation, Color in Use, No. 3 of a Series of Monographs on Color, New York, International Printing Ink Corporation, 1935. Lightness difference gives a design an effect of third dimension and distance by making a color stand out visibly against its background colors. Strong yellow on a black field illustrates maximum visibility. This visibility is due to extreme contrast plus the power of the yellow. The power of a color may be evaluated as the product of its Munsell value with its Munsell chroma. Sometimes a requirement in design is that the area-weighted average of its colors shall be a gray; this is called balance. In two-color designs balance may be achieved only by the use of complementary hues. The areas to be used should be in inverse proportion to the powers of the colors to achieve balance. This general principle of color relationship applies also to combinations of more than two colors even though the average is far from gray and may be stated thus: A color of higher saturation and higher lightness should occupy the smaller area, and a color of lower saturation and lower lightness should occupy the greater area. Color designs may be classed as one-hue, neighboring hues, complementary pairs, and triads in which two hues are chosen to have equal hue contrast to a third. If these two hues themselves differ little, the combination is called a split complementary. Use of these rules may not often produce real distinction in the use of color, but it will avoid many atrocities. Rules are made to be broken by genius. Forty designs in color are shown to illustrate the various principles.

Marjorie S. Cautley. Garden Design, Dodd-Meade, New York, 1935. The chapter on color harmony indicates two types: complementary hues, and analogous hues. Use of grays is advised to avoid glaring combinations. Charts are shown of certain of the Munsell samples illustrating the effect of background on garden design.

E. C. Allen and J. P. Guilford, Factors Determining the Affective Values of Color Combinations, Am. J. Psych. 48, 643-648 (1936). This is a report of an experiment on color harmony. Whether a pair of

colors is pleasing depends largely upon whether each one individually is pleasing. There is some evidence that either very small or very large hue differences give more pleasing combinations than do medium differences, especially for women. Pairs exhibiting large differences in lightness are preferred especially by men. There is a slight preference by women for combinations with small differences in saturation.

Faber Birren, Functional Color, Section on Functional Color Harmony, pp. 77-86. New York, The Crimson Press, 1937. It is often argued that since color comes from the vibrations of radiant energy, color harmony will answer to the laws of vibration - like music. This is untrue. Color harmony depends on color as an experience not as radiant energy. The psychological attributes of color are fullcolor content, white content, and black content, as pointed out by Hering and Ostwald. There is more to color harmony than simply hue; it depends also upon white and black and derivatives of them. Esthetic color terminology need contain but seven terms - hue, white, black, tint, shade, gray, and tone. A tint is a mixture of fullcolor with white; a shade is a fullcolor plus black; and tone is fullcolor plus black plus white. Tints and shades are in contrast rather than harmony and seldom look well together. White is by no means a "neutral" background. Large areas of it spoil rich shades by accenting the blackness. The perfect and universal form for a background is tone which contains all three primary elements, fullcolor, white and black, and accords with all types of colors. Contrasting colors should be kept away from each other and isolated but analogous hues may be combined without danger of clash. The warm hues generally make the best shades and harmonize perfectly with black; the cool hues generally make the best tints and harmonize well with white.

Faber Birren, Monument to Color (pp. 30-58), New York, McFarlane Warde McFarlane 1938. A balanced color circle, a series of colors covering the whole hue circuit with values and saturations grading evenly from one to the other so that no color injures its neighbor, is prerequisite to setting up color harmonies. The rational color circle shown is one of these. Hues may be chosen on the basis of analogy, which give preference to one side of the color circle; or contrast, which sets hues of differing personalities into collision; or balance, which yields triads and tetrads stepping neatly about the circle. Other elements to be considered are fullcolor, white, black, gray, tint, tone, and shade. These are represented on the one-hue triangle. All straight paths on the triangle lead to beauty. Contrasts as well as analogy may also lead to beauty, but the areas should be unequal, and brilliant colors should take small areas. Value is one element in a color scheme, but it is unimportant compared to those already mentioned and leads to inharmonious combinations if considered by itself; thus, yellow and blue of the same value necessarily mean a blue tint and a yellow shade and do not go well together. But value applies perfectly to combinations of grays since it is the only vari-

able, and the harmony of grays arises from equal value steps, not too large. Designs in color may be made to give the impression of chromatic illumination. They may also show areas that appear to be luminous, or depict colors seen through mist that is itself chromatic. These designs owe their effectiveness to our ability to separate object color from the color of the illumination, and they far transcend the beauty of designs developed simply from the classical rules of color harmony.

The Color Helm, Fiatelle, Inc., Ridgewood, New Jersey, 1940. An established range of notes, for example, the diatonic scale, provides the basis for a musical composition. The same principle applies to color. The color Helm consists of three disks each having printed specimens of 24 colors, making 72 in all. Each disk samples the whole 24-hue circuit by giving 8 hues, three colors of each (a fullcolor, a tint, and a shade), the hues on each disk being equally spaced and covering the whole hue circuit. The disks are mounted on a common center together with a gray slotted mask, and the two upper disks are slotted so that by adjustment of their angular positions all possible triads may be seen in juxtaposition. The disks are labeled so as to make it easy to set the hue intervals either at 1 step (adjoining), 2 steps (alternates), 5 steps (intermediates), 8 steps (triads), and 11 steps (split complementary). By using these labels the triads shown are harmonies of tints with tints, or shades with shades, or fullcolors with fullcolors.

Parry Moon and Domina Spencer. Geometric formulation of classical color harmony, Area in color harmony, Aesthetic measure applied to color harmony, J. Optical Soc. Amer. 34, 46, 93, 234 (1944). No satisfactory theory of color harmony is possible without a satisfactory method of color specification. The system recommended by the International Commission on Illumination (ICI system) correlated with the Munsell color system has provided this for the first time by giving unambiguous meaning combined with uniform color spacing. Color combinations are not equally pleasing; they can be arranged in the order of their esthetic merit either by expert or layman. Classical color harmony may be summed up as follows: Pleasing combinations are obtained when (1) the interval between any two colors is unambiguous, and (2) when colors are so chosen that the points representing them in color space are related in a simple geometric manner. It is a fundamental aesthetic principle that the observer should not be confused or left with a feeling of uncertainty. Applied to a variation in hue, this means that the hues should not be so close together as to leave doubt as to whether they were meant to be identical or only similar. Also ambiguity may arise from a hue step of such size that the observer does not perceive immediately whether it was intended to be contrasting or similar. Good intervals are either nearly zero (identity) definitely appreciable (similarity), or definitely near the maximum (contrast). These intervals apply not only to hue differences, but

also to lightness and saturation differences. Amounts of these differences determined from preliminary experiments with a few observers and expressed in terms of Munsell hue, value and chroma are approximately as follows.

	Munsell steps		
	Hue	Value	Chroma
Identity	0	0	0
First ambiguity	4	-	2
Similarity	10	1	4
Second ambiguity	20	2	6
Contrast	28-50	3-10	8

Similar amounts apply to color differences composed of combinations of these types of variation. Single variable harmonies may be classed as those of lightness variations, both achromatic (grays) and chromatic, those of hue variations, and those of variations in saturation. Two-variable harmonies may be classed as constant hue harmonies (with points in color space falling on a straight line, a triangle, a rectangle, or a circle), constant lightness harmonies (any two points in constant lightness plane, three points on isosceles triangle, five points on two triangles, n points on a circle with center on neutral axis, or n points on a circle with center on a chromatic point), and constant saturation harmonies (any two points in cylinder of constant saturation, or n points on an ellipse with center on neutral axis). Three-variable harmonies may be classed as those composed from points on two or more planes of constant hue, those composed from points on two or more planes of constant lightness, those composed from points on two or more cylinders of constant saturation, and those composed from points on one or more tilted planes. There is an unlimited possibility of building up harmonies from color points on space curves and geometric surfaces in the color solid. Classical color harmony is confined to relations among colors, irrespective of area. The aesthetic effect may be increased by adjustment of relative areas because this introduces new elements of order. This adjustment is determined primarily by the average color, or balance point, of the design and the adaptation point, or color perceived as middle gray by the observer. It has been found that a pleasing sense of balance is obtained if for each color patch the product of area by the departure of the color point from the adaptation point is equal to the same product for all other color patches. The psychological effect of a set of color patches depends on the balance point. In the practical application of scientific color harmony, hues appropriate to the application

are first selected, then the type of harmony is decided on. Either large or small color steps are chosen so as to avoid the regions of ambiguity. Areas are then determined relative to the adaptation point, either by making the area-departure products constant, or by making this product two or three times as great as the others for any one color it is desired to emphasize. Finally the balance point is calculated and the designer decides whether the psychological effect (warmth or coolness) is suitable, or should be changed. The aesthetic measure of a color design is based on the ratio of its order to its complexity. Complexity is measured by the number of different colors in the design plus the number of pairs of colors having hue difference, plus the number of pairs having value difference plus the number of pairs having chroma difference. Order is measured by counting up, each with its proper weight, the elements of order which are identity, similarity, contrast and the ambiguities, all with respect to hue, value and chroma differences taken separately for each pair of colors in the design. The weights of these elements have been found approximately by preliminary experiment with two-color combinations, to be:

	Munsell			
	Hue	Value	Chroma	Gray
Identity	1.5	-1.3	0.8	1.0
Similarity	1.1	0.7	0.1	
Contrast	1.7	3.7	0.4	
First ambiguity	0.0	-1.0	0.0	
Second ambiguity	0.65	-0.2	0.0	

Identity of the product of area and color separation for each pair of colors is counted 1.0 as an element of order, a difference in the product by a factor of 2 is counted 0.5 one by a factor of 3 is counted 0.25, and all those differing by higher factors are counted 0.0. Fifty color designs have been evaluated in this way and good correlation with direct judgments of aesthetic merit was found.

(Abstractor's comment: It should be noted that value identity theoretically supposed to be an element of order was found experimentally to lower (-1.3) the aesthetic merit, while an ambiguity of the second kind in hue was found to raise it (+0.65). The preliminary experiments thus do not wholly support the summary of classical color harmony on which the work was based. This serves to emphasize the tentative nature of the principles of color harmony. The fact that the other 14 constants accord with the classical principles should encourage further quantitative studies. D.B.J.)

Arthur Pope, Notes on the problem of color harmony and the geometry of color space, with reference to articles by Moon and Spencer, J. Optical Soc. Amer. 34, 759 (1944). Moon and Spencer have attempted to oversimplify a very complicated subject. They have considered area in connection with contrast of each area to the adaptation point, but they should have considered the contrast of each area with its neighbors. Furthermore, contrast is not an element of order, but one of disorder (diversity). Areas unrelated in color may be brought into relationship by changing their colors in many different ways, such as reducing all contrasts uniformly and so bringing them all into some restricted region of color space so as to have a common element (lightness, darkness, blueness, or grayness), or making them nearly of the same hue, value, or chroma, or the same Ostwald black or white content. Therefore, the concept of ambiguity is open to considerable doubt. No specific virtue is to be attributed to certain value intervals and lack of it to others. Enhancement of harmony by making constant the product of area and color separation from the adaptation point is proved wrong by the work of Bradley (A theory of tone attraction, Technical Studies, Fogg Museum of Art, Cambridge, 2, 3; 1933) who showed that equal attraction of two colors placed on a background is reached when their areas are inversely proportional to the cube of the contrasts with the background color. Area is important in color harmony, but is not to be determined as indicated by Moon and Spencer. A color solid in which distances in all directions correspond to actual color contrasts is needed for the study of general principles underlying color harmony. The great disadvantage of the Ostwald solid is that geometrical distances have no relation to contrasts. A perfect color solid will not yield rules for color harmony, however. There are no rules; there are only possibilities.

Parry Moon and Domina Spencer, Reply to Arthur Pope, J. Optical Soc. Amer. 34, 765 (1944). There are relations among colors that tend to make a pleasing design. We have called all such relations elements of order, irrespective of whether they cause a pleasing sense of similarity or a pleasing sense of contrast. Our treatment of area is admittedly imperfect. We have ignored the complexity associated with the difference in contrast between contiguous parts of the design. In this way we have found simple mathematical expressions that appear to approximate the truth. More comprehensive formulations may be found later. The present theory has quantitative significance in the simpler applications such as poster design, interior decoration, fabric design, and dress.

Faber Birren, Selling with Color, New York, McGraw-Hill, 1945. The pure colors (red, yellow, green, blue) with white and black form the best combinations for selling. The next best are tan, cream, or ivory ground embellished with orange, red-orange, yellowish green, brown, and (sometimes) a touch of purple. Where a pure color is left predominant the trim colors should be white, black, gold or

silver; nothing else is safe. Color harmony in industry is a problem of correlating all elements in terms of one predominant hue. It is not a color scheme but a color effect that is demanded - such effect to glorify and enhance the one preference that the buyer has in mind and heart.

Arthur G. Abbott, The Color of Life, Chapter 11, Harmonies and Discords, Chapter 12, Colors in combination. New York, McGraw-Hill, 1947. Any colors that are consistent with nature and pleasant to see on this account constitute a color harmony. Harmonies include unity, consistency, and fitness. No color is universally good or bad; all may produce either harmony or discord. A single hue with variations of lightness produces a "monochromatic" harmony. Two or more closely related colors produce an analogous harmony. Hues that are nearly alike and those that contrast strongly both produce better harmonies than those that contrast by an intermediate amount. The lightness relationship of the various hues must correspond to that in the spectrum if a harmony is to result. Color harmony is judged according to the degree of satisfaction and pleasure it gives to the observer. Three hues equi-distant on the hue circuit produce a harmony; likewise any three analogous hues. Black, white, gray, glass, gold, and silver do not clash with any colors and can often accompany them with pleasing effect. Discords are generally unpleasant and cause irritation. They are produced by deviating from the standards of nature. Discords can be used in small amounts in an otherwise harmonious composition to good effect. They contribute a false note, a sourness, that prevents a rich harmony from being too sweet. (Harmonies, discords, and harmonies relieved by small discords are shown in two illustrations in color). Black is more pleasing when it is presented with two brilliant colors than it is with one that is brilliant and one that is dull. White is more pleasing when it is accompanied by one brilliant and one dull color than it is with two alike. The details of a design should be smaller, purer, and brighter than the general surrounding areas.

J. H. Dusthanoby, Principles of Color and Color Mixing, New York, McGraw-Hill, 1947. Paints of two opposite colors, such as red and green, may be made to harmonize by mixing a little of the first with the second, and a little of the second with the first. An illustration in color (Plate 4) shows color combinations exemplifying the following kinds of harmony: one hue, analogous hues, triadic (equally spaced hues), complementary, split complementary, and double split complementary.

Egbert Jacobson, Basic Color, Chicago, Theobald, 1948. Color combinations are harmonious if (1) they reflect properly balanced amounts on varieties of chromatic light (complementary colors), (2) they satisfy a need of rhythm (repetition of interval), (3) they suggest a sense of form, of direction, or of space, (4) they please us

with their similarities (recognizable relationships), (5) they surprise or stir us with their opposition (contrast), or (6) they arouse welcome memories. Harmony is the antithesis of confusion. Color combinations based on measured relationships are pleasing. The systematic double-cone arrangement of colors developed by Ostwald serves for color harmony much as the musical scale serves for musical harmony. Each color in the solid, like each tone on the keyboard, may be found in proper relation to every other. Color harmony is not guaranteed by the use of the color solid any more than a tuned piano guarantees a harmonious musical composition, but a color harmony found without the color solid is an accident. Harmonies in gray require at least three grays so that the two intervals represented may be equal. This repetition of a constant visual interval satisfies our need of rhythm. According to Ostwald those colors seem harmonious whose attributes are definitely and simply related to each other. The colors in any one-hue triangle of the Ostwald solid are already in an established relationship. We have only to make a systematic selection depending on the effect desired. These selections may take the form of: equal white content, equal black content, equal white content and equal black content with gray, equal purity (shadow series), light clear and shadow series, equal white content and equal black content, one chromatic color and two grays, and fullcolor with white and black. These one-hue harmonies (illustrated by triads in color) have widely different effects. Almost any two colors may be used together. Pairs making unsatisfactory combinations are: (1) those of nearly the same lightness (2) those confusibly near in hue, (3) those producing eye strain, as in "vibration", (4) those arousing unwelcome associations. Harmonious designs involving more than one hue may be classed as (1) colors of constant black and constant white content with hues spaced equally (especially adjacent, complementary and split-complementary hues), (2) combinations of two or more one-hue pairs, and (3) combinations with elements (fullcolor content, white content, or black content) in common (these are indicated in the Ostwald system by the same hue number or the same letters). Complementary relationships permit a design to suggest objects in natural light. Designs not having complementary relations cannot produce this effect unless they are viewed in complementary surroundings. Some color contrast must always be included or we cannot say where one color ends and the other begins. There is no absolute rule in color harmony, but the two basic relationships are complementarism and the presence of common elements. Printed renditions of 8 chromatic colors of the same hue are shown near the left-hand edge of 24 separate sheets in the book (pages 40-86), one group of 8 colors for each of the 24 hues of the Ostwald hue scale. This permits color combinations to be viewed that involve any desired hue interval. The principles of color harmony are further illustrated by 5 designs in chromatic color (pages 73, 107, and 199), and the color schemes of 12 famous paintings (shown in black and white) are analyzed according to the Ostwald system.

Ralph M. Evans, An Introduction to Color (Chapters 20 and 21, Color in Art, Design and Abstraction). New York, Wiley, 1948. The basic principle of decoration is that the design must be felt to be a pleasing unity of colors that belong together. There are three predominant factors: (1) average color, (2) color range, and (3) relative areas. Making the average color of the scene different from neutral goes a long way toward producing unity. It is sufficient to shift all the colors slightly from their daylight appearance by a uniform amount. In color photography this average color in a print is known as color balance; if right, it may help; if wrong, it may hurt. Color balance is always felt as a degree of unity. Restricting the color range in a composition also produces the impression that they belong together. Areas should be chosen so that no one color stands out predominantly from the background color to the exclusion or near exclusion of the others. This may be done by using smaller areas of those colors that contrast strongly with the background. The importance of the background is often overlooked. It usually determines the adaptative state of the observer's eyes. Colors of the same hue, or the same lightness, or the same saturation tend to appear to belong together. Colors that are alike simultaneously in any two of these attributes produce a strong feeling of unity, the strength depending on the size of the difference in the remaining attribute, and its nature. An important factor in this connection is the shift in appearance exhibited by any one color when it is viewed directly after looking at another color in the design. There will be no shift in hue of one color caused by being adapted to another color provided they are either of the same hue, or of complementary hue. But if the two hues are different and both lie in one half of the hue circuit adaptation to one will make the other appear to shift away from it. Perhaps this instability of hue makes the combination a poor one. At any rate it leads to a well established principle of harmony: colors closely adjacent in hue and those that are complementary form the most pleasing combinations. Perhaps the individual differences between judgments of the aesthetic merit of a color design are due to one observer habitually viewing the elements of the design in a time sequence differing from that used by another.

Arthur Pope, The Language of Drawing and Painting (Appendix I, Design in tone relations) Cambridge, Harvard University Press, 1949. Design is a matter of achieving as much organization as possible within the diversity inherent in the original concept. Perfection depends on a maximum of organization combined with a minimum of diversity for the particular concept. Total value depends first, on the degree of perfection in this relation of order and diversity, and second, on the quantity of order achieved. There are many ways of achieving ordered arrangement of colors in a composition, and of maintaining at the same time the necessary contrast or diversity to make this emotionally appreciable. Attempts to summarize these by one or two simple rules, or by a superficial analogy to music, must fail. The analysis presented follows closely that already abstracted from Pope's 1927 paper

John Leroy Kellogg, The Analogy Between Color and Music, The Kellogg System, J. L. Kellogg, 600 Middlefield Rd., Palo Alto, California, 1950. A notation for color is applied to derivation of color combinations in which the hue intervals are taken at various sizes by analogy to musical chords.