inside the color circle or solid. Both the pure unclouded colors and all their possible mixtures with each other yield unique chromas. The color green, for example, may be mixed with yellow, orange, red, violet, blue, white, or black, and acquires a specific unique quality by each of these admixtures. Each possible modification of a color effect by simultaneous influences likewise generates specific color qualities.

When we are to specify the degree of lightness or darkness of a color, we may speak of its quantity or brilliance. This is what I occasionally refer to as tonal gradation. Brilliance can be varied in two ways; firstly, by mixing a color with white, black, or gray, and secondly, by mixing it with another color of unlike brilliance.
In 1676, Sir Isaac Newton, using a triangular prism, analyzed white sunlight into a spectrum of colors. Such a spectrum contains all hues except purple. Newton performed his experiment as follows (Fig. 1): Sunlight entering through a slit falls upon the prism. In the prism, the ray of white light is dispersed into the spectral colors. The dispersed ray of light can be projected on a screen to display the spectrum. A continuous band of color ranges from red through orange, yellow, green, blue, to violet. If this image is collected by means of a converging lens, addition of the colors will yield white light once again.

These colors are produced by refraction. There are other physical ways of generating colors, such as interference, diffraction, polarization, and fluorescence.

If we divide the spectrum into two parts, for example red-orange-yellow and green-blue-violet, and collect each of these two groups with a converging lens, the result will be two mixed colors, whose mixture with each other in turn yields white. Two kinds of colored light whose mixture with each other yields white are called complementary. If we isolate one hue from the prismatic spectrum, for example green, and collect the remaining colors — red, orange, yellow, blue, violet — with a lens, the mixed color obtained will be red, i.e., the complementary color of the green we isolated. If we take out yellow, the remaining colors — red, orange, green, blue, violet — will yield violet, the complementary of yellow.

Each spectral hue is the complement of the mixture of all the other spectral hues. We cannot see the component hues in a mixed color. The eye is not like the musical ear, which can single out any of the individual tones in a mixture.

Colors result from light waves, a particular kind of electromagnetic energy. The human eye can perceive light of wave lengths between 400 and 700 millimicrons only.
When people speak of color harmony, they are evaluating the joint effect of two or more colors. Experience and experiments with subjective color combinations show that individuals differ in their judgments of harmony and discord.

The color combinations called "harmonious" in common speech usually are composed of closely similar chromas, or else of different colors in the same shades. They are combinations of colors that meet without sharp contrast. As a rule, the assertion of harmony or discord simply refers to an agreeable-disagreeable or attractive-unattractive scale. Such judgments are personal sentiments without objective force. The concept of color harmony should be removed from the realm of subjective attitude into that of objective principle.

Harmony implies balance, symmetry of forces. An examination of physiological phenomena in color vision will bring us closer to a solution of the problem.

If we gaze for some time at a green square and then close our eyes, we see, as an afterimage, a red square. If we look at a red square, the afterimage is a green square. This experiment may be repeated with any color, and the afterimage always turns out to be of the complementary color. The eye posits the complementary color; it seeks to restore equilibrium of itself. This phenomenon is referred to as successive contrast.

In another experiment, we insert a gray square in an area of pure color of the same brilliance. On yellow, the gray will look gray-violet; on orange, bluish gray; on red, greenish gray; on green, reddish gray, on blue, orange-gray; and on violet, yellowish gray (Figs. 31–36). Each color causes the gray to seem tinged with its complementary. Pure chromatic colors also have the tendency to shift each other towards their complements. This phenomenon is referred to as simultaneous contrast.

Successive and simultaneous contrast suggest that the human eye is satisfied, or in equilibrium, only when the complementary relation is established. Let us ap-
proach this idea from a different direction.
In 1797, in Nicholson’s Journal, Rumford published his hypothesis that colors are harmonious if they mix to give white. As a physicist, he was speaking in terms of colored light. In the section on color physics, we stated that if one color of a spectrum, say red, is suppressed, and the other colored light rays — yellow, orange, violet, blue, and green — are collected with a lens, the sum of those residual colors will be green, or the complementary of the color suppressed. Physical mixture of a color with its complementary color yields the sum total of the colors, or white; pigmented mixture yields gray-black.

Ewald Hering, the physiologist, has this to say: “To medium or neutral gray corresponds that condition of the optic substance in which dissimilation — its consumption by vision — and assimilation — its regeneration — are equal, so that the quantity of optic substance remains the same. In other words, medium gray generates a state of complete equilibrium in the eye.”

Hering shows that the eye and brain require medium gray, or become disquieted in its absence. If we view a white square on a black ground, and then look away, a black square appears as afterimage. If we look at a black square on a white ground, the afterimage is a white square. The state of equilibrium tends to re-establish itself in the eye. But if we look at a medium-gray square against a gray background, no afterimage differing from the medium gray will appear. Thus medium gray matches the required equilibrium condition of our sense of sight.

Alterations in the optic substance correspond to subjective impressions. Harmony in our visual apparatus, then, would signify a psychophysical state of equilibrium in which dissimilation and assimilation of optic substance are equal. Neutral gray produces this state. I can mix such a gray from black and white, or from two complementary colors and white, or from several colors provided they contain the three primary colors: yellow, red, and blue in suitable proportions. In particular, any pair of complementary colors contains all three primaries:

\[
\begin{align*}
\text{red, green} &= \text{red (yellow and blue)} \\
\text{blue, orange} &= \text{blue (yellow and red)} \\
\text{yellow, violet} &= \text{yellow (red and blue)}
\end{align*}
\]

So we can say that when a set of two or more colors contains yellow, red, and blue in suitable proportions, the mixture will be gray. Yellow, red, and blue may be substituted for the sum total of colors. Satisfaction of the eye requires this totality, and the eye is then in harmonic equilibrium.

Two or more colors are mutually harmonious if their mixture yields a neutral gray.

Any other color combinations, the mixture of which does not yield gray, are expressive, or discordant, in character. There are many great paintings having a one-sided, expressive intonation, and their color composition is not harmonious, in the sense here defined. Their one-sided, emphatic use of a particular color and its expression has an exciting and provocative effect. Thus not all color composition needs be harmonious, and when Seurat said “Art is harmony,” he was mistaking a means of art for its end.

Apart from the relative positions of the colors, of course, their quantitative proportion and their degrees of purity and brilliance are also important.

The basic principle of harmony is derived from the physiologically postulated rule of complementaries. In his Farbenlehre, Goethe writes on the subject of harmony and totality: “When the eye beholds a color, it is at once roused into activity, and its nature is, no less inevitably than unconsciously, to produce another color forthwith, which in conjunction with the given one
encompasses the totality of the color circle. A particular color incites the eye, by a specific sensation, to strive for generality. In order, then, to realize this totality, in order to satisfy itself, the eye seeks, beside any color space, a colorless space wherein to produce the missing color. Here we have the fundamental rule of all color harmony."

Color harmony has also been discussed by Wilhelm Ostwald. He writes in his Primer of Colors, "Experience teaches that certain combinations of different colors are pleasing, other displeasing or indifferent. The question arises, what determines the effect? The answer is: Those colors are pleasing among which some regular, i.e. orderly, relationship obtains. Lacking this, the effect will be displeasing or indifferent. Groups of colors whose effect is pleasing, we call harmonious. So we can set up the postulate, Harmony = Order.

"To discover all possible harmonies, we must catalogue the possible instances of order in the color solid. The simpler the order, the more obvious or self-evident the harmony. Of such orders, we have found chiefly two: namely the color circles of equal shade (colors of like brilliance or like darkness) and the triangles of like hue (that is, the possible mixtures of a color with white or black). The circles of like shade yield harmonies of different hues, the triangles yield harmonies of like hue."

Where Ostwald says, "colors whose effect is pleasing, we call harmonious", he implies a subjective criterion of harmony. But the concept of harmony should be removed from the realm of subjective attitude to that of objective principle, as I said previously.

Where Ostwald says, "Harmony = Order", and gives the color circles of equal shade and the color triangles of like hue as instances of order, he neglects the physiological laws of afterimage and simultaneity.

One essential foundation of any aesthetic color theory is the color circle, because that will determine the classification of colors. The color artist must work with pigments, and therefore his color classification must be constructed in terms of the mixing of pigments. That is to say, diametrically opposed colors must be complementary, mixing to yield gray. Thus in my color circle, the blue stands opposite to an orange; upon mixing, these colors give gray. In Ostwald's color circle, the blue stands opposite to a yellow, the pigmented mixture yielding green.

Having provided ourselves with a definition of harmony, let us proceed to the quantitative relationships among colors in harmonious composition. Goethe estimated the luminosities of the primary colors, and derived the following proportionality of areas: yellow: red: blue = 3:6:8

We can make the general statement that all complementary pairs, all triads whose colors form equilateral or isosceles triangles in the twelve-member color circle, and all tetrads forming squares or rectangles, are harmonious (Fig. 2).
Locating the hues yellow, red, blue on the twelve-part color circle, we get an equilateral triangle. This triad expresses the highest intensity and force of color. In the combination, each has its static effect, that is, the yellow acts as yellow, the red as red, the blue as blue. The eye demands no additional, completing colors, and the mixture of the three is a dark gray-black.

Examples of harmonious tetrads are yellow/red-orange/violet/blue-green and the hues of the harmonious rectangle: yellow-orange/red-violet/blue-violet/yellow-green.

The geometrical figures used — equilateral and isosceles triangles, square and rectangle — may of course be drawn from any given point on the circle. I can rotate them on the circle, thus replacing the triangle yellow/red/blue by the triangle yellow-orange/red-violet/blue-green, or the triangle orange/violet/green, or the triangle red-orange/blue-violet/yellow-green.

I can do the same with the other geometrical figures. Further discussion will be found in the section on harmonic variations.
By way of introduction to color design, let us develop the 12-hue color circle from the primaries — yellow, red, and blue. As we know, a person with normal vision can identify a red that is neither bluish, nor yellowish; a yellow that is neither greenish, nor reddish; and a blue that is neither greenish, nor reddish. In examining each color, it is important to view it against a neutral-gray background.

The primary colors must be defined with the greatest possible accuracy. We place them in an equilateral triangle with yellow at the top, red at the lower right, and blue at the lower left.

About this triangle we circumscribe a circle, in which we inscribe a regular hexagon. In the isosceles triangles between adjacent sides of the hexagon, we place three mixed colors, each composed of two primaries. Thus we obtain the secondary colors:

\[
\begin{align*}
\text{yellow + red} & = \text{orange} \\
\text{yellow + blue} & = \text{green} \\
\text{red + blue} & = \text{violet}
\end{align*}
\]

The three secondary colors have to be mixed very carefully. They must not lean towards either primary component. You will note that it is no easy task to obtain the secondaries by mixture. Orange must be neither too red, nor too yellow; violet neither too red, nor too blue; and green must be neither too yellow, nor too blue.

Now, at a convenient radius outside the first circle, let us draw another circle, and divide the ring between them into twelve equal sectors. In this ring, we repeat the primaries and secondaries at their appropriate locations, leaving a blank sector between every two colors.

In these blank sectors, we then paint the tertiary colors, each of which results from mixing a primary with
a secondary, as follows:

- yellow + orange = yellow-orange
- red + orange = red-orange
- red + violet = red-violet
- blue + violet = blue-violet
- blue + green = blue-green
- yellow + green = yellow-green

Thus we have constructed a regular 12-hue color circle in which each hue has its unmistakable place (Fig. 3). The sequence of the colors is that of the rainbow or natural spectrum.

Newton obtained a continuous color circle of this kind by supplementing the spectral hues with purple, between red and violet. So the color circle is an artificially augmented spectrum.

The twelve hues are evenly spaced, with complementary colors diametrically opposite each other. One can accurately visualize any of these twelve hues at any time, and any intermediate tones are easily located. I think it is a waste of time for the colorist to practice making 24-hue, or 100 hue, color circles. Can any painter, unaided, visualize Color No. 83 of a 100-hue circle?

Unless our color names correspond to precise ideas, no useful discussion of colors is possible. I must see my twelve tones as precisely as a musician hears the twelve tones of his chromatic scale.

Delacroix kept a color circle mounted on a wall of his studio, each color labeled with possible combinations. The Impressionists, Cézanne, Van Gogh, Signac, Seurat, and others, esteemed Delacroix as an eminent colorist. Delacroix, rather than Cézanne, is the founder of the tendency, among modern artists, to construct works upon logical, objective color principles, so achieving a heightened degree of order and truth.
We speak of contrast when distinct differences can be perceived between two compared effects. When such differences attain their maximum degree, we speak of diametrical or polar contrasts. Thus, large-small, white-black, cold-warm, in their extremes, are polar contrasts. Our sense organs can function only by means of comparisons. The eye accepts a line as long when a shorter line is presented for comparison. The same line is taken as short when the line compared with it is longer. Color effects are similarly intensified or weakened by contrast.

The physiological problem of contrast effects lies in the special field of aesthesiology, and will not be taken up here.

When we survey the characteristics of color effects, we can detect seven different kinds of contrast. These are so different that each will have to be studied separately. Each is unique in character and artistic value, in visual, expressive, and symbolic effect; and together they constitute the fundamental resource of color design.

Goethe, Bezold, Chevreul, and Hölzel have noted the significance of the various color contrasts. Chevreul devoted an entire work to "Contraste Simultané". However, a systematic and practical introduction to the special effects of color contrast, with exercises, has been lacking. Such an exploration of the color contrasts is an essential part of my course of instruction.

The seven kinds of color contrast are the following:
1. Contrast of hue
2. Light-dark contrast
3. Cold-warm contrast
4. Complementary contrast
5. Simultaneous contrast
6. Contrast of saturation
7. Contrast of extension
Contrast of hue is the simplest of the seven. It makes no great demands upon color vision, because it is illustrated by the undiluted colors in their most intense luminosity. Some obvious combinations are: yellow/red/blue; red/blue/green; blue/yellow/violet; yellow/green/violet/red; violet/green/blue/orange/black.

Just as black-white represents the extreme of light-dark contrast, so yellow/red/blue is the extreme instance of contrast of hue (Fig. 4). At least three clearly differentiated hues are required. The effect is always tonic, vigorous, and decided. The intensity of contrast of hue diminishes as the hues employed are removed from the three primaries. Thus orange, green, and violet are weaker in character than yellow, red, and blue; and the effect of tertiary colors is still less distinct.

When the single colors are separated by black or white lines, their individual characters emerge more sharply. Their interaction and mutual influences are suppressed to some extent. Each hue acquires an effect of reality, concreteness. Though the triad yellow/red/blue represents the strongest contrast of hue, all pure, undiluted colors of course can participate in this contrast (Fig. 6).

Contrast of hue assumes a large number of entirely new expressive values when the brilliances are varied (Fig. 7). In the same way, the quantitative proportions of yellow, red, and blue may be modified. Variations are numberless, and so are the corresponding expressive potentialities. Whether black and white are included as elements of the palette will depend on subject matter and individual preference. As is shown by the illustrations under Color Agent and Color Effect, white weakens the luminosity of adjacent hues and darkens them; black causes them to seem lighter. Hence white and black may be powerful elements of color composition (Fig. 5).
The same exercises might be worked out in patches of color without preassigned shapes. However, this procedure would involve hazards. The student would start experimenting with shapes instead of studying color areas and tensions. He would draw outlines, and this practice is hostile to color design and should be strictly avoided. In most exercises, we use simple stripe or checkerboard patterns.

The exercise in Fig. 8 shows a checkerboard pattern in yellow, red, blue, white and black. The student is to develop the colors in two spatial directions, to strengthen his sense of tensions between color areas. Fig. 9 shows extremely luminous colors, with tints and shades, as well as white and black. When the harmony of Fig. 8 has been worked out, the student can go on to pick out the colors for the exercise in Fig. 10, locating the most luminous ones.

Very interesting studies are obtained if one hue is given the principal role, and others are used in small quantities, merely as accents. Emphasizing one color enhances expressive character. After each geometrical exercise is carried out, free compositions in the same kind of contrast should be attempted.

There are many subjects that can be painted in contrast of hue. The significance of this contrast involves the interplay of primeval luminous forces. The undiluted primaries and secondaries always have a character of aboriginal cosmic splendor as well as of concrete actuality. Therefore they serve equally well to portray a celestial coronation or a mundane still life.

Contrast of hue is found in the folk art of peoples everywhere. Gay embroidery, costume, and pottery testify to primitive delight in colorful effects. In the illuminated manuscripts of the Middle Ages, contrast of hue was used in manifold variations, often not from motives of aesthetic necessity but out of sheer pleasure in decorative invention.

Contrast of Hue

4. The strongest expression of contrast of hue: yellow/red/blue
5. Yellow/red/blue/white/black
6. Colors of greatest luminosity
7. Same colors as Fig. 6, in tints and shades
8. Checkerboard pattern in yellow, red, blue, white, and black
9. Colors of greatest luminosity with tints and shades, white and black
10. Colors of greatest luminosity
Contrast of hue is dominant also in early stained glass, its primordial force actually asserting itself over the plastic form of architecture. Stefan Lochner, Fra Angelico and Botticelli are among painters who have based compositions on contrast of hue.

Perhaps the grandest example of its significant use is Grünewald’s “Resurrection”, where this contrast displays all of its universalistic power of expression.

So, in Botticelli’s “Lamentation” (in the Pinakothek, Munich), contrast of hue serves to characterize the all-embracing grandeur of the scene. The totality of hues symbolizes the cosmic significance of the epochal event.

Here we see that the expressive potentialities of one and the same color contrast may be widely diverse. Contrast of hue may alike express boisterous joviality, profound grief, earthy simplicity, and cosmic universality.

Among the moderns, Matisse, Mondrian, Picasso, Kandinsky, Léger, and Miró have frequently composed in this mode. Matisse especially uses it in still-life and figure paintings. A good example is the portrait “Le Collier d’Ambre”, painted in the pure colors of red, yellow, green, blue, red-violet, white, and black. This combination expressively characterizes a young, sensitive, and clever woman.

The Blauer Reiter painters Kandinsky, Franz Marc, and August Macke, worked in contrast of hue almost exclusively during their early period.

Among a great many possible examples of the use of contrast of hue, I would suggest these four paintings: “L’Église d’Éphèse” from “Apocalypse de Saint Sever” (11th century), Paris, Bibliothèque Nationale; Enguerrand Charonton’s “Coronation of the Virgin” (15th century), Villeneuve-les-Avignon, Hôpital; Paul de Limbourg’s “May-Day Excursion” in “Les Tres Riches Heures du Duc de Berry” (1410), Chantilly, Musée Condé; Piet Mondrian (1872-1944), “Composition 1928”, Mart Stam Collection.
Day and night, light and darkness — this polarity is of fundamental significance in human life and nature generally. The painter's strongest expressions of light and dark are the colors white and black. The effects of black and white are in all respects opposite, with the realm of grays and chromatic colors between them. The phenomena of light and dark, both among white, black and gray, and among pure colors, should be thoroughly studied, for they yield valuable guides to our work.

Black velvet is perhaps the blackest black, and baryta is the purest white. There is only one maximal black and one maximal white, but an indefinitely large number of light and dark grays, forming a continuous scale between white and black.

The number of distinguishable shades of gray depends on the sensitivity of the eye and the response threshold of the observer. This threshold can be lowered by practice, increasing the number of perceptible gradations. A uniformly gray, lifeless surface can be awakened to mysterious activity by extremely minute modulations of shading. This very important factor in painting and drawing requires extreme sensitivity to tonal differences.

Neutral gray is a characterless, indifferent, achromatic color, very readily influenced by contrasting shade and hue. It is mute, but easily excited to thrilling resonances. Any color will instantly transform gray from its neutral, achromatic state to a complementary color effect corresponding mathematically to the activating color. This transformation occurs subjectively, in the eye, not objectively in the colors themselves. Gray is a sterile, neuter, dependent on its neighboring colors for life and character. It attenuates their force and mellows them. It will reconcile violent oppositions by absorbing their strength and thereby, vampirelike, assuming a life of its own.

Delacroix objected to gray for this reason, as injurious
to the power of color.
Gray may be mixed from black and white, or from yellow, red, blue, and white, or from any pair of complementary colors.

First we prepare a regular series of grays from white to black, in twelve steps. It is important to space the steps evenly. The gray of medium brilliance should be in the center of the scale. Each individual step should be perfectly uniform and spotless, with neither a light nor a dark line between it and its neighbors. Similar scales of brilliance can be prepared for any chromatic color. In the blue scale, blue is darkened with black down to blue-black, and lightened with white up to blue-white.

These exercises serve to sharpen the student's sensitivity to shading. The twelve steps are not intended, as in music, to represent a system of "equal temperament." In the art of color, not only precise intervals but inappreciable transitions, comparable to the glissando in music, may be important vehicles of expression.

The following exercises are intended to enlarge comprehension of light-dark contrast

Certain shades may be selected from the scale of grays obtained, and arranged in any sequence to form a composition. When five or six such compositions have been completed, they are rated comparatively. It is soon realized that some are good and convincing, others poor or false. This very simple exercise will assess a talent for chiaroscuro.

Fig 11 shows the development of a light-dark combination upon a checkered surface. This composition may be lightened or darkened as a whole; the main point is to cultivate vision and perception of light-dark gradations and their contrasts. When the problem of white, gray, black tonal values

Light-Dark Contrast
11 Light-dark composition in black, white, and grays
12 Same composition as Fig. 11, in blue
13 Colors of equal brilliance
14 Colors of equal darkness
has been grasped, contrast of proportion or extension can be added to light-dark contrast. Contrasts of proportion comprise large-small, long-short, wide-narrow, thick-thin. To gain familiarity with the problems of proportion, the exercises should be done in light-dark, developing not only the feeling for proportion but also for the relation of the positive, dark form to the negative, white form remaining.

Much European and Asian art is constructed upon pure light-dark contrast. Chinese and Japanese ink drawing is an outstanding example. The technique of this art stems from the art of writing in these countries, where ideographic characters, representing a wealth of forms, are made with the brush. Their semantically and rhythmically correct execution requires a repertoire of many different manual motions. Sense of form, rhythmic feeling, and relaxed attentiveness are necessary to "correct" brushwork. In China and Japan, writing is a fine art. "When an archer has thoroughly sighted his target, poised his body, grasped his bow firmly, and aimed accurately, the arrow will almost certainly hit the mark. So with the calligrapher: with the mind concentrated, the body upright and balanced, the brush vertical, the dot or stroke should fall exactly on the appointed place." (Chian Yee, "Chinese Calligraphy", Harvard University Press)

This writing proceeds from an inward automatism. After endless practice, the strokes at last flow effortlessly from the brush; and in the same way, the Chinese or Japanese painter practices the lexicon of nature until he can reproduce it at will. This discipline presupposes mental concentration and physical relaxation. Meditation as practiced particularly in Ch'an, or Zen, Buddhism provides the foundation of this training of mind and body. Accordingly, many monks of this sect are to be found among the great artists in black and white. They did not engage in meditation in order to become great painters; they worked with the brush as an aid to meditative internalization.

Other media of light-dark expression are the woodcut, copperplate, and etching. The artist, by shading and hatching, can produce extremely differentiated gradations of light and dark. Rembrandt's etchings cover a very wide range of subject matter. As is not surprising, he also executed pen-and-ink and brush drawings in masterful chiaroscuro, often rivaling the suggestive power and clarity of East Asian work. In his numerous sketches, Seurat explored light-dark gradations most conscientiously. Seurat's drawings, like his paintings, give one the feeling that he is devoting thought to each pinpoint in order to evoke the most delicate of shadings.

Thus far, we have considered light-dark contrast only in the range of black, white, and gray. The light-dark evaluation of chromatic colors and their relationships to the achromatic colors — black, white and gray — is far more complicated. The domain of grays extends between white and black, just as the world of colors burns between light and darkness.

Gradations and brilliancies of achromatic colors are easily distinguished, and so are those within each chromatic hue. Difficulties arise when gradations of unlike hues are to be compared. It is most important to be able to identify colors of equal brilliance accurately. The following exercise will help to develop this ability.

In a checkerboard array, we place yellow or red or blue. We are then required to add colors having the same amount of light or dark as the given color. We make a point of using yellowish, bluish, and reddish hues on each attempt. Brilliance must not be confused with the saturation, or purity, of the colors.

Special difficulties are presented by cold and warm colors. Cold colors seem transparent, weightless, and are commonly rendered too light, whereas the warm hues, because of their opacity, tend to be rendered
too dark. The exercise of painting all the hues in the same brilliance as yellow is difficult because it is not immediately realized how brilliant yellow is (Fig. 13). It is similarly difficult to render yellow as dark as red or blue. Shading and dilution necessarily deprive brilliant yellow of its yellowness; this naturally disinclines many people to darken yellow. In Fig. 14, all the colors are equal in darkness to the blue.

Equality of light or dark relates colors to each other, tying or bracketing them together. Light-dark contrast between them is extinguished. This is an invaluable resource of artistic design.

In the color sphere, Figs. 49 and 50, both the chromatic colors of the twelve-hue color circle and the achromatic colors are represented. Contrary to the chromatic colors, the achromatic colors produce an effect of the categorical, rigid, incorruptible, and abstract. They are in antithesis to the vibrant complexity of the chromatic colors. Yet it is possible for the achromatic colors to acquire a borrowed chromatic effect. By simultaneous contrast (Figs. 31–36), a neighboring hue may induce an achromatic gray to look like its complementary hue. When achromatic colors occur in a composition and adjoin chromatic colors of like brilliance, they lose their achromatic character.

If the achromatic colors are to retain their condition of abstraction, the chromatic colors must be of different brilliance. In a composition where whites, blacks, and grays are used as means for abstract effect, there should be no chromatic colors matching them in brilliance, or simultaneous contrast will activate the neutrals. But when gray is used as a vivid component in a color composition, then the adjoining chromatic tone must match the gray in brilliance.

The impressionists were interested in this active function of grays, whereas constructionists and concrete painters use black, white, and gray abstractly.

The problems of light-dark contrast in colors are illustrated by the exercise in Fig. 15. The twelve equidistant steps of gray from white to black in the first row have been repeated for the twelve hues of the color circle, in brilliances equal to the corresponding grays. We see that the pure yellow answers to the thirteenth step. Orange is at the fifth step, red at the sixth, blue at the eighth, and violet at the ninth step in the scale of grays. The chart shows saturated yellow to be the lightest of the pure colors, and violet the darkest.

Thus yellow must be muted from the fourth step on, in order to match the darker tones of the gray scale. Pure red and blue are at a lower level, leaving few steps to black, but many on the way to white. Each admixture of black or white reduces the vividness of a hue.

Along any horizontal row of the chart, all squares should be of the same brilliance as the corresponding gray. If we prepare a sequence of as many as eighteen gradations, instead of twelve, and connect the points of highest purity, we can see that the curve is parabolic. The fact that the pure, saturated hues, as they appear in the chart of Fig. 15, differ in brilliance, is extremely important. It must be realized that pure saturated yellow is very light, and that there is no such thing as a dark pure yellow. Saturated essential blue is very dark; light blues are pale and dim. Red can emit its considerable vivid power only as a dark color; red lightened to the level of pure yellow loses all radiance. The colorist positively must allow for these facts in his compositions.

When a saturated yellow is to produce the main effect, the composition generally must assume a light over-all character, whereas pure saturated red or blue requires a dark over-all expression. The radiant reds in Rembrandt's paintings are so only because of contrast with yet darker tones. When he wants radiant yellows, he can bring them out in comparatively light groups, where saturated red would be felt as merely dark, without chromatic splendor. Fig. 3 illustrates this principle. The unlike brilliances of hues in themselves pose difficult problems for textile designers. Familiarly, any textile design is likely to be produced in four or more differ-
ent colors or combinations. In the group as a whole, these must be somehow coordinated. A fundamental rule is that corresponding areas of the design should produce the same effect of contrast in each version.

Fig. 12 shows a version of Fig. 11 in blue. When a brilliant red occurs in a design, there will not be enough luminous shades on the same level as the red for the six or eight other combinations. But the brilliance intervals should be the same in all color versions. If a luminous orange were to replace the red, the whole color composition would have to be transposed to the brilliance level of the luminous orange. The material in orange would then have to be lighter upon the whole than the material in red. If the orange were put at the brilliance level of the red, the luminous red would correspond to a dim brown-orange, lacking in radiance.

A serious complication is that the light-dark values of the pure colors vary with the intensity of illumination. Red, orange, and yellow look darker in reduced light, while blue and green look lighter. Thus shadings may produce the right effect in full daylight, and yet appear false at twilight. Altarpieces painted for the semi-obscenity of churches, therefore, should not be exhibited under skylights in museums or in the glare of artificial light, since the light-dark values of their colors would be falsified.

The plates and exercises in this book are designed to be viewed in full daylight.

A composition painted in light-dark contrast may be constructed of two, three, or four principal tones. The painting is then said to have two, three, or four chief planes or groupings, which must be well attuned to each other. Each plane may have minor tonal differentiation within itself, but not so much as to blur the distinction between main groupings. An eye for hues of equal brilliance is necessary to the observance of this rule. If tones are not assembled into main groupings or planes, then order, clarity, and vigor of composition are sacrificed. An effect of pictorial surface is achieved
only with organization in planes.
The necessity of sustaining a flat over-all effect is the painter’s chief motive for constructing planes. They serve to frustrate and neutralize any undesired depth effects. This control of perspective results from the equating of tonal values to those of the planes. The planes can usually be grouped into foreground, middle ground, and background; but the foreground does not necessarily contain the principal figures; the foreground may be quite vacant, and the main action may take place in the middle ground.

The following paintings will suggest some of the possibilities of light-dark composition: “Lemons, Oranges and Rose” by Francisco de Zurbarán (1598–1664), Florence, Coll. A. Contini-Bonacossi; “Man in Golden Helmet” by Rembrandt (1606–1669), Berlin, Kaiser-Friedrich Museum; “Guitar on Mantelpiece” (1915), by Pablo Picasso.
It may seem strange to identify a sensation of temperature with the visual realm of color sensation. However, experiments have demonstrated a difference of five to seven degrees in the subjective feeling of heat or cold between a workroom painted in blue-green and one painted in red-orange. That is, in the blue-green room the occupants felt that 59°F. was cold, whereas in the red-orange room they did not feel cold until the temperature fell to 52–54°F. Objectively, this meant that blue-green slows down the circulation and red-orange stimulates it.

Similar results were obtained in an animal experiment. A racing stable was divided into two sections, the one painted blue, the other red-orange. In the blue section, horses soon quieted down after running, but in the red section they remained hot and restless for some time. It was found that there were no flies in the blue section, and a great many in the red section.

Both experiments illustrate the pertinence of cold-warm contrast to color planning of interiors. The properties of cold and warm colors are essential to color therapeutics in hospitals.

Going back to the color circle, we have seen that yellow is the lightest and violet the darkest hue; that is, these two hues have the strongest light-dark contrast. At right angles to the yellow-violet axis, we have red-orange versus blue-green, the two poles of cold-warm contrast. Red-orange, or minium, is the warmest, and blue-green, or manganese oxide, is the coldest. Generally the colors yellow, yellow-orange, orange, red-orange, red and red-violet are referred to as warm, and yellow-green, green, blue-green, blue, blue-violet and violet as cold; but this classification can be very misleading. Just as the poles white and black represent the lightest and the darkest color, while all grays are light or dark only relatively, according as they are contrasted with lighter or darker tones, so blue-green and red-orange, the cold and warm poles, are always cold and warm respectively; but the hues intermediate between them.
in the color circle may be either cold or warm according as they are contrasted with warmer or colder tones.

The cold-warm property can be verbalized in a number of other contrary terms:

<table>
<thead>
<tr>
<th>cold</th>
<th>warm</th>
</tr>
</thead>
<tbody>
<tr>
<td>shadow</td>
<td>sun</td>
</tr>
<tr>
<td>transparent</td>
<td>opaque</td>
</tr>
<tr>
<td>sedative</td>
<td>stimulant</td>
</tr>
<tr>
<td>rare</td>
<td>dense</td>
</tr>
<tr>
<td>airy</td>
<td>earthy</td>
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<tr>
<td>far</td>
<td>near</td>
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<tr>
<td>light</td>
<td>heavy</td>
</tr>
<tr>
<td>wet</td>
<td>dry</td>
</tr>
</tbody>
</table>

These diverse impressions illustrate the versatile expressive powers of cold-warm contrast. It can be used to produce highly pictorial effects. In landscape, more distant objects always seem colder in color because of the intervening depth of air. Cold-warm contrast, then, contains elements suggesting nearness and distance. It is an important medium of representation for plastic and perspective effects.

When a composition is to be done in the pure style of a particular contrast, all other, incidental contrast must be used with restraint, if at all.

In exercises on cold-warm contrast, let us eliminate light-dark contrast entirely; that is, all the colors of a composition are to be equally light or dark.

Fig. 16 illustrates cold-warm contrast in its polar antithesis: red-orange/blue-green.

Fig. 17 inverts the proportions by area.

Figs. 18 and 19 show the same violet; warm at the top, because the adjacent hues are colder, and cold at the bottom, because the adjacent hues are warmer.

Cold-Warm Contrast
16 The strongest cold-warm contrast: red-orange/blue-green
17 Inversion of proportions of Fig. 16
18 Red-violet seems warm relative to blue
19 Red-violet seems cold relative to orange
20 Checkered composition contrasting cold and warm colors
21 Cold-warm modulation in red
22 Cold-warm modulation in green
Fig. 21 shows cold-warm modulations in the range from red to orange.

Fig. 22 shows cold-warm modulations in the range from green to blue-green.

These modulations can be executed at any level of tonality, but a medium brilliance is the most effective. The variation of hue should go no further than four successive steps of the 12-hue color circle. An exercise in red-orange, then, may employ orange, yellow-orange, red, and red-violet, in addition to red-orange; and an exercise in blue-green may employ green, yellow-green, blue and blue-violet, in addition to blue-green.

If both poles, the extremes of cold and warm, are to be included, we must form a chromatic scale from blue-green through blue, blue-violet, violet, red-violet and red, to red-orange. This full scale may of course consist of a larger or smaller number of steps. A full chromatic cold-warm scale from blue-green to red-orange by way of yellow is feasible only if all the tones are of the same brilliance as the yellow; otherwise we get light-dark contrast.

These modulations achieve the perfection of their beauty only when light-dark differences are absent.

Whereas Figs. 21 and 22 show chromatic gradations of cold and warm colors, a checkerboard composition heightens the effect by contrast of cold and warm colors (Fig. 20).

Of all the seven color contrasts, the cold-warm contrast is the most sonorous. It provides the possibility of representing the music of the spheres in colors. Grünewald chose this contrast for the color design of his Angel choir, and also for two other parts of the Isenheim altarpiece - the group of angels attendant upon God the Father in the panel of the Madonna, and the painting of the Resurrection. He employed this color effect in portraying the celestial.

When Abbot Suger had the first stained glass windows installed in his Basilica of St. Denis near Paris, he justified his proceeding with the words, "... that the material sense of man may be directed to that which is beyond matter."

These windows were "flashing hieroglyphs," intelligible to all. Their mystic splendor gave the faithful an experience of radiant transcendence. This visual experience was a direct invitation to higher spirituality.

The stained glass window known as "La Belle Verrière" in Chartres Cathedral is composed in a symbolic use of warm red and cold blue. It breathes the same rhythm as the sun. The moving light of heaven continuously changes its incidence, and the sheen of the colors is different at every hour of the day. The translucent glass has a radiance like that of precious stones.

When Monet began to devote himself to landscape, he ceased to paint in the studio, and worked out-of-doors. He made intensive studies of seasons, times of day, and weather conditions, with their changing light and mood. He meant to portray the shimmer of light in the air and over warm fields, color refractions in cloud and mist, highlights of flowing, undulant water, and the alternation of sunny and shady green in the foliage of trees. He observed that light and shade, and rainbow reflections from all sides, resolved the local colors of objects into elements of cold and warm rather than light and dark variation. In his landscapes, the light-dark contrast emphasized by earlier painting is superseded in importance by cold-warm contrast.

The Impressionists noticed that the cold, transparent blue of the sky and atmosphere was everywhere in contrast, as a shadow color, with the warm tones of sunlight. The enchantment of Monet's, Pissarro's and Renoir's paintings is often achieved by the cunning play of modulations of cold and warm colors.
We call two colors complementary if their pigments, mixed together, yield a neutral gray-black. Physically, light of two complementary colors, mixed together, will yield white.

Two such colors make a strange pair. They are opposite, they require each other. They incite each other to maximum vividness when adjacent; and they annihilate each other, to gray-black, when mixed—like fire and water.

There is always but one color complementary to a given color. In the color circle, Fig. 3, complementary colors are diametrically opposite each other.

Examples of complementary pairs are:
- yellow, violet
- blue, orange
- red, green

If we analyze these pairs of complementaries, we find that all three primaries—yellow, red, blue—are always present.

\[
\begin{align*}
\text{yellow, violet} &= \text{yellow, red} + \text{blue} \\
\text{blue, orange} &= \text{blue, yellow} + \text{red} \\
\text{red, green} &= \text{red, yellow} + \text{blue}
\end{align*}
\]

Just as the mixture of yellow, red, and blue is a gray-black, so the mixture of any two complementaries is gray-black.

We also recall the experiment showing that if one hue of the spectrum is suppressed, all the others mixed together will yield its complementary. For every hue, the sum of all the other colors in the spectrum is the complementary of that hue.

Both the phenomenon of afterimage and the effects of simultaneity illustrate the remarkable physiological fact, as yet unexplained, that the eye requires any given color to be balanced by the complementary, and will spontaneously generate the latter if it is not present. This principle is of great importance in all practical work with color. In the section on concord of colors, we stated that the rule of complementaries is the basis of harmonious design because its observance establishes a precise equilibrium in the eye.

Complementary colors, used in the proper proportions, give the effect of a statically fixed image. Each color stands unmodified in its intensity. Here the agent coincides with the effect. This stabilizing power of complementary colors is especially important in mural painting.

Each complementary pair has its own peculiarities. Thus, yellow/violet represents not only complementary contrast but also an extreme light-dark contrast. Red-orange/blue-green is a complementary pair, and at the same time the extreme of cold-warm contrast. Red and green are complementary, and the two saturated colors have the same brilliance.

Some exercises will help illustrate the nature of complementary contrast.

Figs. 23–28 show six complementary pairs and their
mixtures towards gray. These scales are prepared by adding more and more of the complementary to a given color. In the center of each series, we get a gray. If the mixtures of two colors in all proportions fail to include a neutral gray, it follows that the two colors are not complementary.

Fig. 29 is a composition in a pair of complementaries and modulations of their mixtures. Instead, of course, two, three, or more pairs of complementaries can be used. Fig. 30 shows a square array of mixtures of the complementary pairs orange/blue and red-orange/blue-green.

Many paintings based on complementary contrast exhibit not only the contrasting complementaries themselves but also their graduated mixtures as intermediates and compensating tones. Being related to the pure colors, they unite the two into one family. In fact, these mixed tones often occupy more space than the pure colors.

Nature shows such mixed colors very elegantly. They are to be seen in the stems and leaves of a red rosebush before the blossoms appear. The red of the unblown rose mixes with the green of stem and leaf to lovely red-gray and green-gray nuances.

Two complementary colors can be used to make beautiful chromatic grays. The Old Masters produced such grays by the technique of striping a pure color with coats of the complementary, or by varnishing the first with a thin film of the second. Pointillism produces chromatic grays in still another way. The pure colors are laid side-by-side in tiny dots, and the mixing operation is performed visually in the eye.

These paintings exemplify the use of complementary contrast: "Madonna of the Chancellor Rolin" by Jan van Eyck (1390–1441), Paris, the Louvre; "Solomon Receiving the Queen of Sheba," by Piero della Francesca (1410/11–1492), from a mural at Arezzo; "La Montagne Sainte-Victoire" by Paul Cézanne (1839–1906), Philadelphia Museum of Art.

Complementary Contrast
23–28 Mixture bands of six complementary pairs
29 Composition in the complementary pair red/green and mixtures
30 Mixture square of two complementary pairs, orange/blue and red-orange/blue-green
Simultaneous contrast results from the fact that for any given color the eye simultaneously requires the complementary color, and generates it spontaneously if it is not already present. By virtue of this fact, the fundamental principle of color harmony implies the rule of complementaries. The simultaneously generated complementary occurs as a sensation in the eye of the beholder, and is not objectively present. It cannot be photographed. Simultaneous contrast may with reason be placed on a par with successive contrast.

One may make the following experiment: On a large, strongly colored area, examine a small black square, first laying a sheet of tissue paper on top. If the area is red, the black square will look greenish gray; if green, then reddish; if violet, then yellowish; if yellow, then the black square will look violet-gray. Each hue simultaneously generates its complementary. Figs. 31–36 illustrate this experiment in another form.

In each of the six pure colors, I place a small neutral gray square, exactly matching the surrounding color in brilliance. Each of the small squares is tinged, for the eye, with the complementary to the background hue.

Simultaneous Contrast

31–36 Each of six pure color squares contains a small neutral gray square, matching the background color in brilliance. Each gray square seems to be tinged with the complementary of the background. The simultaneous effect becomes more intense, the longer the principal color of a square is viewed.

37 Three small gray squares, surrounded by orange. Three grays barely distinct from each other have been used. The first gray is bluish, and intensifies the simultaneous effect; the second gray is neutral, and suffers simultaneous modification; the third gray contains an admixture of orange, and therefore fails to be modified.
When gazing at one of the colors, it is best to hide
the others and hold the page not too far from the eyes.
Simultaneous effects become more intense, the longer
the background is viewed and the more luminous the
color. The effect is intensified if the background is
lighted from in front and the example placed slightly
below eye level, so that the whole is viewed in obliquely
incident light.
The simultaneously appearing color, not being objec-
tively present but generated in the eye, induces a feeling
of excitement and lively vibration of everchanging inten-
sity. Under sustained viewing, the given color seems
to lose intensity, as the eye tires, while the sensation
of the simultaneous hue grows stronger.
The simultaneous effect occurs not only between a gray
and a strong chromatic color, but also between any
two colors that are not precisely complementary. Each
of the two will tend to shift the other towards its own
complement, and generally both will lose some of their
intrinsic character and become tinged with new effects.
Under these conditions, colors give an appearance
of dynamic activity. Their stability is disturbed, and they
are set in changeable oscillation. They lose their objec-
tive character and move in an individual field of action
of an unreal kind, as if in a new dimension. Color is as
if dematerialized. The principle that the agent of a color
sensation does not always agree with its effect is fully
operative.

Simultaneous effect is of paramount importance to all
who are concerned with color. Goethe said that simul-
taneous contrast determines the aesthetic utility of
color.
In Fig. 37 there are three small gray squares in an
orange field. Three just perceptibly different grays have
been used. The unlike effects of the three different
grays are due to the fact that a little blue has been
mixed with the first gray, and this cooperates with the
simultaneous effect; the second gray is neutral, and
shows the simultaneous effect alone; while the third
gray contains an admixture of orange just sufficient to
cancel the simultaneous effect, and therefore shows
no simultaneous modification. This experiment clearly
shows how the exciting effect of simultaneous contrast
can be amplified or suppressed by suitable devices.
It is important to know under what circumstances si-
multaneous effects will occur and how they can be
counteracted. There are many problems in color that
preclude solutions using simultaneous contrast. Some
years ago, the manager of a weaving mill called my
attention, in desperation, to some hundreds of meters
of costly tie silk that would not sell because a black
stripe on a red ground looked, not black, but green.
This effect was so pronounced that customers insisted
that the yarn was green. If brownish black yarn had
been used, the simultaneous effect would have been
neutralized, and heavy losses avoided.
In addition to this means of avoiding the effect of simul-
taneous contrast, there is another possibility: the sus-
ceptible hues may be used in unlike brilliance. Once
a light-dark contrast is present, simultaneous influences
are diminished.
Simultaneous effects occur among pure colors when
a complementary hue is replaced by its right- or left-
hand neighbor in the 12-hue color circle. For violet,
for example, in opposition to yellow, we substitute
red-violet or blue-violet. Effects of simultaneous con-
trast can be intensified with the aid of contrast of ex-
tension.
It is always advisable to juxtapose the hues to be em-
ployed in a composition, using a preliminary sketch
to check color effects, before proceeding to execution.

The following paintings may be cited as examples of
the use of simultaneous contrast: “Satan and the Lo-
custs”, from the “Apocalypse de St. Sever” (11th cen-
tury), Paris, Bibliothèque Nationale; “Stripping of Christ”
by El Greco (1541–1614), Munich, Pinakothek; “Café
at Evening” by Vincent van Gogh (1853–1890), Otter-
loo, Rijksmuseum Kröller-Müller.
Saturation, or quality, relates to the degree of purity of a color. Contrast of saturation is the contrast between pure, intense colors and dull, diluted colors. The prismatic hues produced by dispersion of white light are colors of maximum saturation or intensity of hue.

We have colors of maximum saturation among pigments also. We recall the curve pointed out in Fig. 15, connecting pigmentary colors of highest purity and intensity.

Colors may be diluted in four different ways, with very different results.

1) A pure color may be diluted with white. This renders its character somewhat colder. Carmine assumes a bluish cast as it is mixed with white, and becomes sharply altered in character. Yellow is cooled by white; the character of blue is hardly changed. Violet is extremely sensitive to white. Whereas saturated dark violet has something menacing about it, violet lightened with white — lilac — has an agreeable and quietly cheerful effect.

2) A color may be diluted with black. This admixture deprives yellow of its brilliant character, turning it into something sickly or insidiously poisonous. Its splendor is gone. Géricault's picture "Les Aliénés" is in black-yellow, and has an overwhelming expression of mental derangement.

Violet is enhanced by black in its "inherent" gloom, fading as it were into night.

By admixture of black, carmine acquires a timbre in the direction of violet.

Vermilion diluted with black gives a kind of burnt, reddish-brown pigment.

Blue is eclipsed by black. It will suffer only a few degrees of dilution before its light is extinguished.

Green admits of far more modulation than violet or blue, and has many possible alterations.

Quite in general, black deprives colors of their quality
of light. It alienates them from light, and sooner or later deadens them.

3) A saturated color can be diluted by mixing it with white and black, or in other words with gray. As soon as I mix gray with a saturated color, I get tones which may be of equal, greater or less brightness, but in any case less intense than the corresponding pure color. Admixture of gray renders colors more or less dull and neutral. Delacroix hated gray in a painting, and avoided it as much as possible. Mixed grays are easily neutralized by simultaneous contrast effects.

4) Pure colors may be diluted by admixture of the corresponding complementary colors. If I add yellow to violet, I get tones intermediate between the light yellow and the dark violet. Green and red are not much different in tonality, but when mixed they descend into gray-black. The various mixtures of two complementary colors lightened with white produce rare tints.

Contrast of Saturation

38–41 On a checkered pattern of 25 squares, luminous yellow, orange, red, or blue is placed in the center. The four corners are neutral gray in the same brilliance as the pure color. Graded admixture of gray with the pure color produces intermediate shades of low saturation.
When a mixture contains all three primaries, the resulting hue assumes a dim, diluted character. Depending on the proportions, it will appear yellowish, reddish or bluish gray or black. All degrees of dilution can be obtained with the three primaries. The same applies to the three secondaries, or to any other combination provided only that yellow, red, and blue are all present in the total mixture.

The effect of "dull-vivid" contrast is relative. A color may appear vivid beside a dull tone, and dull beside a more vivid tone.

Basic exercises in contrast of saturation can be performed on a checkerboard of twenty-five squares. We place a pure color in the center, and a neutral gray of the same brilliance in each of the four corners. We then mix gray with the pure color step-by-step, obtaining four more or less diluted intermediates. To comprehend contrast of saturation, we must eliminate light-dark contrast; hence the brilliances of all squares must be the same. The exercises of Figs. 38–41 show the delicate character of this contrast in its chromatic modulations. Similar exercises can be done by placing the complementary of the central color in the corner squares, instead of gray. In such an exercise, the effect will be more colorful than in the one found here.

If we wish to express pure contrast of saturation in a composition, without any other contrast, then the dull color must be mixed from the same hue as the intense one; that is, intense red must contrast with dull red, and intense blue with dull blue.

Otherwise, the pure contrast would be drowned out by other contrasts, such as cold-warm contrast, impairing the quiet and restful effect.

Dull tones, most especially grays, live by virtue of the vivid ones surrounding them. This may be observed by dividing an area checkerboard-fashion and placing a neutral gray in every other square, with vivid colors of the same brilliance as the gray in the remaining squares. The gray will be seen to take on vividness, while the surrounding chromatic colors appear reduced and comparatively weakened.

The use of contrast of quality is well seen in the following paintings for example: "Newborn Babe" by Georges de La Tour (d. 1659), Musée de Rennes; "Le Piano" by Henri Matisse (1868–1954), New York, Museum of Modern Art; "Magic Fish" by Paul Klee (1879–1940), Philadelphia Museum of Art.
Contrast of extension involves the relative areas of two or more color patches. It is the contrast between much and little, or great and small.

Colors may be assembled in areas of any size. But we should inquire what quantitative proportion between two or more colors may be said to be in balance, with no one of the colors used more prominently than another.

Two factors determine the force of a pure color, its brilliance and its extent. To estimate brilliance or light value, we must compare the pure colors on a neutral-gray background of medium brilliance. We find that the intensities or light values of the several hues are different.

Goethe set up simple numerical ratios for these values, best suited to our purpose. They are approximate, but who would demand precise data when commercial pigments sold under the same name can vary so widely? Ultimately, vision must decide. Furthermore, the color areas in a painting are often fragmentary and complicated in shape, and it would be difficult to reduce them to simple numerical proportions. The eye is trustworthy enough, provided it be properly sensitized.

Goethe's light values are as follows:

\[
\begin{align*}
\text{yellow} & : \text{orange} : \text{red} : \text{violet} : \text{blue} : \text{green} \\
9 & : 8 & : 6 & : 3 & : 4 & : 6
\end{align*}
\]

The proportionalities for complementary pairs are:

\[
\begin{align*}
\text{yellow} : \text{violet} &= 9 : 3 = 3 : 1 = \frac{3}{4} : \frac{1}{4} \\
\text{orange} : \text{blue} &= 8 : 4 = 2 : 1 = \frac{2}{3} : \frac{1}{3} \\
\text{red} : \text{green} &= 6 : 6 = 1 : 1 = \frac{1}{2} : \frac{1}{2}
\end{align*}
\]

In converting these values to harmonious areas, I must take the reciprocals of the light values; that is, yellow, being three times as strong, must occupy only one-third as much area as its complementary violet.
As Figs. 42–44 illustrate, we obtain the following harmonious relative areas for the complementaries:

\[
\begin{align*}
yellow : violet &= 1/4 : 3/4 \\
orange : blue &= 1/3 : 2/3 \\
red : green &= 1/2 : 1/2 \\
\end{align*}
\]

The harmonious areas for the primary and secondary colors are therefore as follows:

yellow : orange : red : violet : blue : green

\[
\]

Or:

\[
\begin{align*}
yellow : orange &= 3 : 4 \\
yellow : red &= 3 : 6 \\
yellow : violet &= 3 : 9 \\
yellow : blue &= 3 : 8 \\
yellow : red : blue &= 3 : 6 : 8 \\
orange : violet : green &= 4 : 9 : 6 \\
\end{align*}
\]

— and so forth; all the other colors are to be related to each other similarly.

Contrast of Extension

42–44 \textbf{Harmonious proportions of area for complementary colors:}

\[
\begin{align*}
\text{Yellow : Violet} &= 1/4 : 3/4 \\
\text{Orange : Blue} &= 1/3 : 2/3 \\
\text{Red : Green} &= 1/2 : 1/2 \\
\end{align*}
\]

45 Circle of primary and secondary colors in harmonious proportion

46 Equal proportions of red and green

47 A little red with a great deal of green makes the red highly active
Fig. 45 shows the primary and secondary color circle of harmonious extension. This is constructed as follows: First, a whole circle is divided into three equal parts and each third is in turn divided in the proportions for two complementary colors.

One third of the circle is divided for
yellow : violet :: $\frac{1}{3}$ : $\frac{1}{3}$
Another third is divided for
orange : blue :: $\frac{1}{3}$ : $\frac{1}{3}$ and
The last third is divided for
red : green :: $\frac{1}{3}$ : $\frac{1}{3}$

When all these arcs have been found, another equal circle is drawn, and the sectors are transferred in the sequence of the prismatic color circle, namely yellow, orange, red, violet, blue, green.

Harmonic areas yield static, quiet effects. Contrast of extension is neutralized when the harmonious proportions are used.
The ratios here stated are valid only when all the hues appear in their maximum purity. If these are altered, the equilibrium areas also change. The two factors of light value and extent of area turn out to be most intimately related.

If other than harmonious proportions are used in a color composition, thus allowing one color to dominate, then the effect obtained is expressive. What proportions are to be chosen in an expressive composition depends on subject matter, artistic sense, and personal taste.

What effect is obtained when contrast of extension is very pronounced? In Fig. 47, red is scantily represented. Because green is present in large quantity compared to red, it simultaneously generates an exciting luminosity of its complementary red in the eye. It was stated in the section on simultaneous contrast that the eye demands the complement to a given hue. It is not yet known why this is so. Perhaps we are ruled by some universal will to compensation or counterassertion.

Contrast of extension owes its special effect to a similar tendency. The minority color, in distress, as it were, reacts defensively to seem relatively more vivid than if, as in Fig. 46, it were present in a harmonious amount. A similar law of compensation is seen to operate in biology. In plants or animals, under adverse conditions of life, there is a mobilization of powers of resistance, expressing itself in heightened performance, given the opportunity. If a color present in minute amount is given opportunity, by protracted contemplation, to assert itself in the eye, it is found to become increasingly concentrated and provocative.

The use of two mutually intensified contrasts can produce very live and strange color expressions.

A special property of contrast of extension is here exemplified. It is capable of modifying and intensifying the effect of any other contrast. Mention was made of proportion under the heading of light-dark contrast. Contrast of extension is, properly speaking, a contrast of proportion. In light-dark composition, if a small bright spot contrasts with a large area of darkness, this antithesis may lend the picture an enlarged and deepened significance.

Attention to the color areas in composition is at least as important as the actual choice of colors. Any color composition should be evolved from the relationships of elements of area to each other.

Color areas should take their form, extent, and outline from chroma and intensity of color, and not be predetermined by delineation.

Observance of this rule is particularly important to the proper determination of color extensions. The correct sizes of color areas are not to be laid out by means of outline, since the proportions are governed by the chromatic forces evolving out of hue, saturation, brilliance,
and contrast effects.
A yellow area that is to hold its place among light tints must be of a different size than an area of the same yellow against dark shades. The tints call for a large yellow area; among shades, a small yellow area is enough to allow the brilliance of the hue to operate. Proportions of all color areas should be similarly derived from their relative potentials.
As an example of the contrast of extension, we may mention the painting "Landscape with Fall of Icarus" by Pieter Brueghel the Elder (1520–1569), Brussels, Musées Royaux des Beaux Arts.
Having given an account of the potential effects of colors in their seven contrasts, I shall attempt to provide a clear and complete map of the world of color. In Fig. 3, we developed a 12-hue color circle from the three primaries yellow, red, blue. However, this circular array is not adequate for a complete classification. Instead of a circle, we shall need a sphere, the solid adopted by Philipp Otto Runge as the most convenient for plotting the characteristic and manifold properties of the color universe. The sphere is the elementary shape of universal symmetry. It serves to visualize the rule of complementaries, illustrates all fundamental relationships among colors, and between chromatic colors and black and white. If we imagine the color sphere to be a transparent body, each point within which corresponds to a particular value, then all conceivable colors have a place. Each point on the sphere can be located by its meridian and parallel. For an adequate color classification, we require only six parallels and 12 meridians.
Color Harmony

2. Triads
If three hues are selected from the color circle so that their positions form an equilateral triangle, those hues form a harmonious triad.

Yellow/red/blue is the clearest and most powerful of such triads. I should be inclined to call it the fundamental triad. The secondary colors, orange/violet/green, form another distinctive triad.

Yellow-orange/red-violet/blue-green, or red-orange/blue-violet/yellow-green, are other triads whose arrangement in the color circle is an equilateral triangle.

If one color in the complementary dyad yellow/violet is replaced by its two neighbors, thus associating yellow with blue-violet and red-violet, or violet with yellow-green and yellow-orange, the resulting triads are likewise harmonious in character. Their geometrical figure is an isosceles triangle, as Fig. 54 shows. These equilateral and isosceles triangles may also be thought of as inscribed in the color circle. They may be rotated at will. Provided the point of intersection of the bisectors of their sides lies at the center of the sphere, the three colors related by their vertices make a harmonious triad. Two limiting cases occur when one vertex of the triangle is at white or black. If we use an equilateral triangle with one vertex at white, the other two vertices will point to the first shades of a pair of complementary hues. Then we get such a triad as white/dark blue-green/dark orange. Similarly, for black we get light blue and light orange.

These limiting cases illustrate how light-dark contrast will assume prominence when white or black is used.

1. Dyads
In the 12-hue color circle, two diametrically opposed colors are complementary. They form a harmonious dyad. Red/green, blue/orange, yellow/violet are such dyads. If I use the color sphere, I can get an indefinite number of harmonious dyads. The only requirement is that the two tones be symmetrical with respect to the center of the sphere. Thus if I take a tint of red, the corresponding green must be shaded in the same degree as the red is lightened.

3. Tetrads
If we choose two pairs of complementaries in the color circle whose connecting diameters are perpendicular to each other, we obtain a square, as in Fig. 55. The three tetrads of this kind in the 12-hue circle are:

yellow/violet/red-orange/blue-green
yellow-orange/blue-violet/red/green
orange/blue/red-violet/yellow-green
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More tetrads are obtained with a rectangle containing two complementary pairs:
yellow-green/red-violet/yellow-orange/blue-violet
yellow/violet/orange/blue/red
A third geometrical figure for harmonious tetrads is the trapezoid. Two hues may be adjacent, and two opposing ones found to the right and left of their complements. The resulting chords tend to simultaneous modification, but they are harmonious; for when mixed, they produce gray-black.

By inscribing the polygons shown in Fig. 55 in a color sphere and rotating them, a very large number of further themes could be derived.

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Tertiary colors are then obtained as a harmonious hexad. There are two such hexads in the 12-hue circle:
yellow/violet/orange/blue/red/green
yellow-orange/blue-violet/red-orange/blue-green/red-violet/yellow-green
This hexagon may be rotated in the color sphere. The resulting tints and shades yield interesting color combinations.

The other way to construct a hexad is to adjoin white and black to four pure colors. We place a square in the equatorial plane of the color sphere, obtaining a tetrad of two complementary pairs. Then each vertex of the square is joined to white above and black below, as shown in Fig. 56. The result is a regular octahedron.

Any tetrad obtainable in the equatorial plane may thus be expanded, into a hexad by inclusion of white and black.

4 Hexads
Hexads may be derived in two different ways.
A hexagon, rather than a square or triangle, may be inscribed in the color circle. Three pairs of complemen-
how the most diverse variations and effects can be
developed from a geometrically constructed theme.
One variation consists in placing yellow between blue
and red, or red between yellow and blue, or blue be-
tween yellow and red. The hues of the fundamental
chord can be combined with their shades, producing
contrast of saturation. All three colors may be taken in
tints and shades, for light-dark contrast. If all three
colors are lightened to the same brilliance, and the
pure colors added in small areas, a harmony in con-
trast of extension results. If one color predominates
quantitatively, timbres of expressive value are obtained.
By going on to replace a pure color of the chord by its
immediate neighbors in the color circle, thus substi-
tuting yellow-green and yellow-orange for yellow,
or red-orange and red-violet for red, or blue-green and
blue-violet for blue, the triad is expanded into a tetrad,
greatly enlarging the wealth of variations.
These suggestions are intended to show that a theory
of harmony does not tend to fetter the imagination,
but on the contrary provides a guide to discovery of
new and different means of color expression.

A rectangle may be used instead of a square; and an
equatorial triangle combined with white and black
yields pentads, such as yellow/red/blue/black/white
or orange/violet/green/black/white, etc.
Now that these elements of a color harmony have been
suggested, it should again be emphasized that the
choice of a chord and its modulation as the basis of a
composition cannot be arbitrary. All procedures are gov-
erned by the subject matter, presented representational-
ly or abstractly. The choice of a theme and its execu-
tion are a must, not a capricious will or a superficial
maybe. Each color and each group of colors is an in-
dividual of unique kind, living and growing according
to its immanent law.
The idea of color harmony is to discover the strongest
effects by correct choice of antitheses.

In terms of the fundamental chord yellow/red/blue
that we discussed in our theory of harmony, let us show