

Capítulo I.

NOMBRES DE COLOR.

Escribiendo desde Samoa a Sidney Colvin en Londres, [Stevenson 1](#) dice: "Quizá en De la misma manera que te podría divertir enviarnos cualquier patrón de papel tapizado Eso podría parecerte barato, bonito y adecuado para una habitación en un lugar caluroso y un clima extremadamente brillante. Debe tenerse en cuenta que nuestro El clima también puede ser extremadamente oscuro. Nuestro salón es para estar madera barnizada. La habitación que tengo especialmente en mente es una especie de cama y el salón, bastante grande, iluminado por tres lados, y el color en el favor de su propietario actualmente es de un amarillo topazio. Pero entonces, con ¿De qué color se alivia? Para un pequeño taller propio al fondo Me gustaría ver algunos patrones de sin brillar—bueno, lo haré que me cuelguen si puedo describir este rojo. No es turco, y no lo es Romano, y no es indio; pero parece participar de los dos últimos, y Sin embargo, no puede ser ninguno de los dos, porque debería poder ir con él Bermellón. ¡Ah, qué enmarañada red tejemos! En fin, ¿qué cerebro tienes han dejado elegirme y enviarme algunos—muchos—patrones de la tono exacto."

(1) Donde se pudiera encontrar un grito más encantador por alguna forma racional de ¿Describir el color? Quiere "un amarillo topacio" y un rojo que no sea turco ni romano ni indio, pero que "parece participar de los dos últimos, y pero no puede ser ninguno de los dos." Como cierre del clímax llega su demanda para "patrones del mismo tono exacto." Por tanto, uno de los más claros y más claros Escritores enérgicos de 10English no puede describir el color que quiere. ¿Y por qué? Simplemente porque el lenguaje popular no indica claramente ninguna de las tres cualidades unidas en cada color, y que deben conocerse antes de que uno pueda siquiera esperar transmitir sus concepciones de color a otro.

(2) La naturaleza incongruente y extraña de nuestros nombres actuales de colores debe aparecer ante cualquier persona reflexiva. Azul bebé, azul pavo real, verde Nilo, Verde manzana, amarillo limón, amarillo paja, rosa rosa, heliotropo, real morado, magenta, solferino, ciruela y automóvil son términos populares, transmitiendo ideas diferentes a distintas personas y fallando por completo Define colores. Los términos usados para un solo tono, como verde guisante, mar verde, verde oliva, verde hierba, verde salvia, perenne, verde invisible, no se les puede confiar al pedir un trozo de tela. Invitan a los errores y decepción. No solo son inexactas: son inapropiado. ¿Podemos imaginar tonos musicales llamados alondra, canario, cacatúa, cuervo, gato, perro o ratón, porque tienen algún lejos. ¿parecido con los gritos de esos animales? Véase el párrafo [131](#).

El color necesita un sistema.

(3) La música está equipada con un sistema mediante el cual define cada sonido en términos de su tono, intensificación y duración, sin alargarse alusiones a los sonidos infinitamente variados de la naturaleza. También debería ser el color suministrado con un sistema adecuado, basado en el matiz, el valor y croma² de nuestras sensaciones, y no intentar describirlas por lo indefinido y colores variables de objetos naturales. El sistema que ahora debe considerarse representa las tres dimensiones del color y mide cada una mediante un escala adecuada. No depende del capricho de un individuo, sino mediante mediciones físicas posibles gracias a un color especial ¹¹aparato. Los resultados pueden ser analizados por cualquiera que acuda al problema con "una mente clara, buen ojo y una buena cantidad de paciencia."

Las imágenes mentales claras forman un habla clara. Pensamientos vagos encuentran vagos enunciación.

(4) El niño recoge flores, acumula cuentas de colores, persigue mariposas y pide los juguetes pintados más llamativos. Al principio sus fuertes sensaciones de color se describen suficientemente con los términos simples rojo, amarillo, verde, azul y morado. Pero pronto ve que algunos son ligeros, mientras que otros lo son oscuro, y más tarde llega a percibir que cada tono tiene muchos grados más grises. Ahora, si quiere describir un rojo en particular,—como el suyo gorro desvaído,—no se conforma con llamarlo rojo, porque lo es consciente de otros objetos rojos que no son nada distintos a él. Así que busca a tanteas significa definir este rojo en particular; y, al no tener un estándar de comparación,—sin escala para estimar,—él vaciló dice que es un "rojo algo apagado."

(5) Así de temprano está limitado por la pobreza del lenguaje racializado. Nunca lo ha hecho se le ha dado una palabra adecuada para esta cualidad de color, y tiene que tomar prestada una que significa lo opuesto a afilado, que pertenece más bien a las herramientas de filo que a los colores.

La mayoría de los términos de color están tomados de otros sentidos.

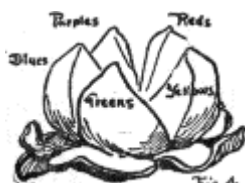
(6) Cuando su hermana mayor se refiere al "tono" de su vestido verde, o habla de la "clave de color" en una imagen, se confunde naturalmente, porque Tono y tonalidad son términos asociados en su mente con la música. Puede que no lo sea mucho antes de que escuche que "una nota de color ha sido demasiado aguda," o que cierto artista "pinta en tonalidad menor". Todos estos términos conducen a ideas mixtas e indefinidas, y le dejan sin preparación para lo claro expresión de cualidades de color.

(7) El arte musical no está tan limitado. Tiene un establecimiento 12escala con intervalos medidos y términos definidos. Igualmente, colorística El arte debe establecer una escala, medir sus intervalos y nombrar su cualidades inconfundibles.

El color tiene tres dimensiones.

(8) Puede sonar extraño decir que el color tiene tres dimensiones, pero es así Fácilmente demostrado por el hecho de que cada uno de ellos puede medirse. Así, en el en el caso de la gorra desvaída del niño, su enrojecimiento o TONO³ está determinado por un instrumento; la cantidad de luz en el rojo, que es su VALOR³, se encuentra mediante otro instrumento; mientras aún un tercer instrumento determina la pureza o CHROMA³ de la Rojo.

La omisión de cualquiera de estas tres cualidades nos deja en duda En cuanto al carácter de un color, tan verdaderamente como el carácter de este El estudio seguiría sin definir si se omitiera la duración y nosotros La describió como de 22 pies de ancho por 14 pies de alto. La imaginación sería libre de asignar cualquier longitud que eligiera, de 25 a 100 pies. Esta longitud puede ser concebida de forma diferente por cada persona que intenta suministrar El factor que faltaba.



(9) Para ilustrar la naturaleza tridimensional de los colores.

Supongamos que pelamos un naranja y dividirlo en cinco partes, dejando las secciones ligeramente conectados abajo (Fig. 4). Entonces digamos que todos los rojos que tenemos se han visto en una de las secciones, todos los amarillos en otra, todos verdes en la tercera, azules en la cuarta y moradas en la quinta. A continuación, clasificaremos estos HUES en cada uno Sección de modo que las más ligeras estén cerca de la parte superior y se inclinen regularmente hasta el más oscuro cerca de la parte inferior. Una oblea blanca conecta todos los secciones en la parte superior, y se puede añadir una oblea negra debajo. Ver [Placa I](#).

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(10) El fruto se rellena con varios colores, graduados desde blanco hasta negro, según sus VALORES, y dispuestos por sus HUES en los cinco secciones. Una porción cerca de la parte superior revelará valores de luz en todos tonos, y una porción cerca de la parte inferior encontrará valores oscuros en el mismo tonos. Una porción en el centro revela un circuito de tonos todos de VALOR MEDIO; es decir, a mitad de camino los extremos de blanco y negro.

(11) Dos dimensiones de color se muestran así en el naranja, y se mantiene en exhiben el tercero, que se llama CROMA, o intensidad del color. Para ello, tenemos solo para tomar cada sección por turno y, sin alterar los valores ya variado, empuja el más gris hacia el borde estrecho, y inclina hacia afuera hacia lo más puro en la superficie. Cada rodaja sobre la fruta aún muestra el circuito de tonos en un valor uniforme; pero los cromas fuertes están en el exterior, mientras que los cromas más grises y grises forman una gradación hacia dentro a gris neutro en el centro, donde queda todo rastro de color desaparece. Los bordes finos de todas las secciones se unen en una escala de gris desde negro a blanco, sin importar el tono que tenga cada uno.

El exterior curvado de cada sección muestra su particular tonalidad graduada de negro a blanco; y, si la sección debe cortarse en ángulo recto a el borde delgado, mostraría el tercer dimensión,—croma,—para el color se grada uniformemente respecto a la De la superficie a gris neutro. Un pasador incrustado en cualquier punto traza el Tercera dimensión.

Una esfera de color puede usarse para unir las tres dimensiones del matiz, valor y cromaticidad.



(12)  Fig. 5. Habiendo utilizado la estructura familiar de la naranja como ayuda en Clasificando colores, sustituyamos un sólido geométrico, como un esfera,4 y utilizar términos geográficos. El polo norte es blanco. El sur El poste es negro. 14El ecuador es un circuito de rojos medios, amarillos, verdes, azules y morados. Los paralelos sobre el ecuador describen este circuito en menor medida los valores y paralelos inferiores lo trazan en valores más oscuros. El eje vertical Al unir el blanco y el negro hay una escala neutra de valores de grises, mientras que Perpendiculares a él (como un alfiler que se clava en el naranja) son escamas de Chroma. Así, nuestras nociones de color pueden entrar en una relación ordenada por la esfera de color. Cualquier color describe su luz y fuerza por su ubicación en el sólido o en la superficie, y recibe su nombre por su lugar en las escalas combinadas de tono, valor y croma.

Two dimensions fail to describe a color.

(13) Much of the popular misunderstanding of color is caused by ignorance of these three dimensions or by an attempt to make two dimensions do the work of three.

(14) Flat diagrams showing hues and values, but omitting to define chromas, are as incomplete as would be a map of Switzerland with the mountains left out, or a harbor chart without indications of the depth of water. We find by aid of the measuring instruments that pigments are very unequal in this third dimension,—chroma,—producing mountains and valleys on the color sphere, so that, when the color system is worked out in pigments and charted, some colors must be traced well out beyond the spherical surface (paragraphs [125–127](#)). Indeed, a COLOR TREE⁵ is needed to display by the unequal levels and lengths of its branches the individuality of pigment colors. But, whatever solid or figure is used to illustrate color relations, it must combine the three scales of hue, value, and chroma, and these definite scales furnish a name for every color based upon its intrinsic qualities, and free from terms purloined in other sensations, or caught from the fluctuating colors of natural objects.

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How this system describes the spectrum.

(15) The solar spectrum and rainbow are the most stimulating color experiences with which we are acquainted. Can they be described by this solid system?

(16) The lightest part of the spectrum is a narrow field of greenish yellow, grading into darker red on one side and into darker green upon the other, followed by still darker blue and purple. Upon the sphere the values of these spectral colors trace a path high up on the yellow section, near white, and slanting downward across the red and green sections, which are traversed near the level of the equator, it goes on to cross the blue and purple well down toward black.

(17) This forms an inclined circuit, crossing the equator at opposite points, and suggests the ecliptic or the rings of Saturn (see outside cover). A pale rainbow would describe a slanting circuit nearer white, and a dimmer one would fall within the sphere, while an intensely brilliant spectrum projects far beyond the surface of the sphere, so greatly is the chroma of its hues in excess of the common pigments with which we work out our problems.

(18) At the outset it is well to recognize the place of the spectrum in this system, not only because it is the established basis of scientific study, but especially because the invariable order assumed by its hues is the only stable hint which Nature affords us in her infinite color play.

(19) All our color sensations are included in the color solid. None are left out by its scales of hue, value, and chroma. Indeed, the imagination is led to conceive and locate still purer colors than any we now possess. Such increased degrees of color

sensation can be named, and clearly conveyed by symbols to another person as soon as the system is comprehended.

[1.](#) Vailima Letters, Oct. 8, 1902.

[2.](#) See color variables in Glossary.

[3.](#) For definitions of Hue, Value, and Chroma, see paragraphs [20–23](#).

[4.](#) See [frontispiece](#).

[5.](#) For description of the Color Tree see paragraphs [33 and 34](#).

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Appendix to Chapter I.

Misnomers for Color.

The Century Dictionary helps an intelligent study of color by its clear definitions and cross-references to HUE, VALUE, and CHROMA,—leaving no excuse for those who would confuse these three qualities or treat a degree of any quality as the quality itself.

Obscure statements were frequent in text-books before these new definitions appeared. Thus the term “shade” should be applied only to darkened values, and not to hues or chromas. Yet one writer says, “This yellow shades into green,” which is certainly a change of hue, and then speaks of “a brighter shade” in spite of his evident intention to suggest a stronger chroma, which is neither a shade nor brighter luminosity.

Children gain wrong notions of “tint and shade” from the so-called standard colors shown to them, which present “tints” of red and blue much darker than the “shades” of yellow. This is bewildering, and, like their elders, they soon drop into the loose habit of calling any degree of color-strength or color-light a “shade.” *Value* is a better term to describe the light which color reflects to the eye, and all color values, light or dark, are measured by the *value-scale*.

“Tone” is used in a confusing way to mean different things. Thus in the same sentence we see it refers to a single touch of the brush,—which is not a tone, but a paint spot,—and then we read that the “tone of the canvas is golden.” This cannot mean that each paint spot is the color of gold, but is intended to suggest that the various objects depicted seem enveloped in a yellow atmosphere. Tone is, in fact, a musical term appropriate to sound, but out of place in color. It seems better to call the brush touch

a *color-spot*: then the result of an harmonious relation between all the spots is *color-envelope*, or, as in Rood, “the chromatic composition.”

“Intensity” is a misleading term, if chroma be intended, for it depends on the relative light of spectral hues. It is a degree rather than a quality, as appears in the expressions, intense heat, light, sound,—intensity of stimulus and reaction. Being a degree of many qualities, it should not be used to describe the quality itself. The word becomes especially unfit when used to describe two very different phases of a color,—as its intense illumination, where the chroma is greatly weakened, and the strongest chroma which is found in a much lower value. “Purity” is also to be avoided in speaking of pigments, for not one of our pigments represents a single pure ray of the spectrum.

Examples are constantly found of the mental blur caused by such unfortunate terms, and, since misunderstanding becomes impossible with measured degrees of hue, value, and chroma, it seems only a question of time when they will take the place of tint, tone, shade, purity and intensity.

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Chapter II.

COLOR QUALITIES.

(20) The three color qualities are hue, value, and chroma.

HUE is the name of a color.

(21) Hue is the quality by which we distinguish one color from another, as a red from a yellow, a green, a blue, or a purple. This names the hue, but does not tell whether it is light or dark, weak or strong,—leaving us in doubt as to its value and its chroma.

Science attributes this quality to difference in the LENGTH of ether waves impinging on the retina, which causes the sensation of color. The wave length M. 5269 gives a sensation of green, while M. 6867 gives a sensation of red. [6](#)

VALUE is the light of a color.

(22) Value is the quality by which we distinguish a light color from a dark one. Color values are loosely called tints and shades, but the terms are frequently misapplied. A tint should be a light value, and a shade should be darker; but the word “shade” has become a general term for any sort of color, so that a shade of yellow may prove to be lighter than a tint of blue. A photometric [7](#) scale of value places all colors in relation to the extremes of white and black, but cannot describe their hue or their chroma.

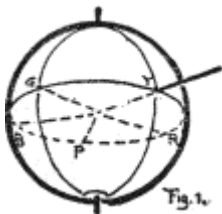
Science describes this quality as due to difference in the HEIGHT or amplitude of ether waves impinging on the retina. Small amplitudes of the wave lengths given in paragraph [21](#) produce the sensation of dark green and dark red: larger amplitudes give the sensation of lighter green and lighter red.

CHROMA is the strength of a color.

(23) Chroma is the quality by which we distinguish a strong color from a weak one. To say that a rug is strong in color gives no hint of its hues or values, only its chromas. Loss of chroma is loosely called fading, but this word is frequently used to include changes of value and hue. Take two autumn leaves, identical in color, and expose one to the weather, while the other is waxed and pressed in a book. Soon the exposed leaf fades into a neutral gray, while the protected one preserves its strong chroma almost intact. If, in fading, the leaf does not change its hue or its value, there is only a loss of chroma, but the fading process is more likely to induce some change of the other two qualities. Fading, however, cannot define these changes.

Science describes chroma as the purity of one wave length separated from all others. Other wave lengths, INTERMINGLING, make its chroma less pure. A beam of daylight can combine all wave lengths in such balance as to give the sensation of whiteness, because no single wave is in excess.[8](#)

(24) The color sphere (see Fig. 1) is a convenient model to illustrate these three qualities,—hue, value, and chroma,—and unite them by measured scales.



(25) The north pole of the color sphere is white, and the south pole black. Value or luminosity of colors ranges between these two extremes. This is the vertical scale, to be memorized as *V*, the initial for both value and vertical. Vertical movement through color may thus be thought of as a change of value, but not as a change of hue or of chroma. Hues of color are spread around the equator of the sphere. This is a horizontal scale, memorized as *H*, the initial for both hue and horizontal. Horizontal movement around the color solid is thus thought of as a change of hue, but not of value or of chroma. A line inward from the strong surface hues to the neutral gray axis, traces the graying of each color, which is loss of chroma, and conversely a line beginning with neutral gray at the vertical axis, and becoming more

and more colored until it passes outside the sphere, is a scale of chroma, which is memorized as C, the initial both for chroma and centre. Thus the sphere lends its three dimensions to color description, and a color applied anywhere within, without, or on its surface is located and named by its degree of hue, of value, and of chroma.

HUES first appeal to the child, VALUES next, and CHROMAS last.

(26) Color education begins with ability to recognize and name certain hues, such as red, yellow, green, blue, and purple (see paragraphs [182 and 183](#)). Nature presents these hues in union with such varieties of value and chroma that, unless there be some standard of comparison, it is impossible for one person to describe them intelligently to another.

(27) The solar spectrum forms a basis for scientific color analysis, taught in technical schools; but it is quite beyond the comprehension of a child. He needs something more tangible and constantly in view to train his color notions. He needs to handle colors, place them side by side for comparison, imitate them with 21 crayons, paints, and colored stuffs, so as to test the growth of perception, and learn by simple yet accurate terms to describe each by its hue, its value, and its chroma.

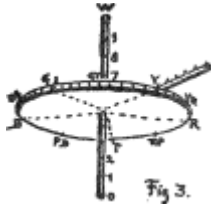
(28) Pigments, rather than the solar spectrum, are the practical agents of color work. Certain of them, selected and measured by this system (see [Chapter V.](#)), will be known as MIDDLE COLORS, because they stand midway in the scales of value and chroma. These middle colors are preserved in imperishable enamels, [9](#) so that the child may handle and fix them in his memory, and thus gain a permanent basis for comparing all degrees of color. He learns to grade each middle color to its extremes of value and chroma.

(29) Experiments with crayons and paints, and efforts to match middle colors, train his color sense to finer perceptions. Having learned to name colors, he compares them with the enamels of middle value, and can describe how light or dark they are. Later he perceives their differences of strength, and, comparing them with the enamels of middle chroma, can describe how weak or strong they are. Thus the full significance of these middle colors as a practical basis for all color estimates becomes apparent; and, when at a more advanced stage he studies the best examples of decorative color, he will again encounter them in the most beautiful products of Oriental art.

Is it possible to define the endless varieties of color?

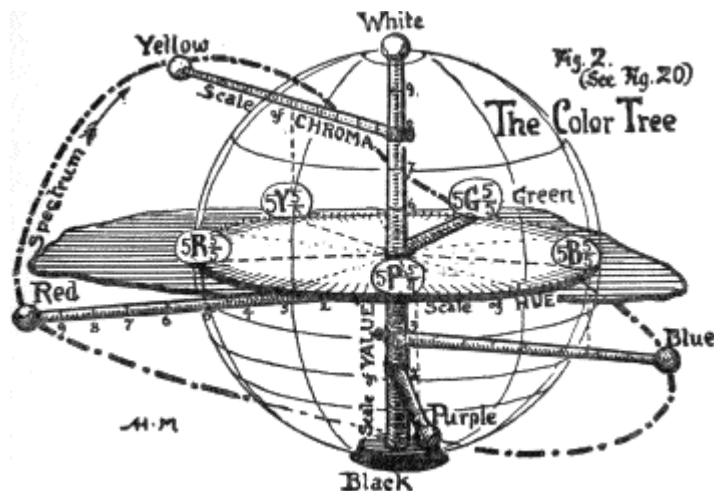
(30) At first glance it would seem almost hopeless to attempt the naming of every kind and degree of color. But, if all these varieties possess the same three qualities, only in different degrees, and if each quality can be measured by a scale, then there is a clue to this labyrinth.

A COLOR SPHERE and COLOR TREE to unite hue, value, and chroma.



(31) This clue is found in the union of these three qualities by measured scales in a *color sphere and color tree*.¹⁰ The equator of the sphere¹¹ may be divided into ten parts, and serve as the scale of hue, marked R, YR, Y, GY, G, BG, B, PB, P, and RP. Its vertical axis may be divided into ten parts to serve as the scale of value, numbered from black (0) to white (10). Any perpendicular to the neutral axis is a scale of chroma. On the plane of the equator this scale is numbered 1, 2, 3, 4, 5, from the centre to the surface.

(32) This chroma scale may be raised or lowered to any level of value, always remaining perpendicular to the axis, and serving to measure the chroma of every hue at every level of value. The fact that some colors exceed others to such an extent as to carry them out beyond the sphere is proved by measuring instruments, ²³but the fact is a new one to many persons. (Figs. 2 and 3.)



(33) For this reason the COLOR TREE is a completer model than the sphere, although the simplicity of the latter makes it best for a child's comprehension.

(34) The color tree is made by taking the vertical axis of the sphere, which carries a scale of value, for the trunk. The branches are at right angles to the trunk; and, as in the sphere, they carry the scale of chroma. Colored balls on the branches tell their Hue. In order to show the MAXIMA of color, each branch is attached to the trunk (or neutral axis) at a level demanded by its value,—the yellow nearest white at the top, then the green, red, blue, and purple branches, approaching black in the order of their lower values. It will be remembered that the chroma of the sphere ceased with 5 at the equator. The color tree prolongs 24 this through 6, 7, 8, and 9. The branch ends carry colored balls, representing the most powerful red, yellow, green, blue, and purple pigments which we now possess, and could be lengthened, should stronger chromas be discovered. [12](#)

(35) Such models set up a permanent image of color relations. Every point is self-described by its place in the united scales of hue, value, and chroma. These scales fix each new perception of color in the child's mind by its situation in the color solid. The importance of such a definite image can hardly be overestimated, for without it one color sensation tends to efface another. When the child looks at a color, and has no basis of comparison, it soon leaves a vague memory that cannot be described. These models, on the contrary, lead to an intelligent estimate of each color in terms of its hue, its value, and its chroma; while the permanent enamels correct any personal bias by a definite standard.

(36) Thus defined, a color falls into logical relation with all other colors in the system, and is easily memorized, so that its image may be recalled at any distance of time or place by the notation.

(37) These solid models help to memorize and assemble colors and the memory is further strengthened by a simple NOTATION, which records each color so that it cannot be mistaken for any other. By these written scales a child gains an instinctive estimate of relations, so that, when he is delighted with a new color combination, its proportions are noted and understood.

(38) Musical art has long enjoyed the advantages of a definite scale and notation. Should not the art of coloring gain by similar definition? The musical scale is not left to personal whim, nor does it change from day to day; and something as clear and stable would be an advantage in training the color sense.

(39) Perception of color is crude at first. The child sees only the most obvious distinctions, and prefers the strongest stimulation. But perception soon becomes refined by exercise, and, when a child tries to imitate the subtle colors of nature with paints, he begins to realize that the strongest colors are not the most beautiful,—

rather the tempered ones, which may be compared to the moderate sounds in music. To describe these tempered colors, he must estimate their hue, value, and chroma, and be able to describe in what degree his copy departs from the natural color. And, with this gain in perception and imitation of natural color, he finds a strong desire to invent combinations to please his fancy. Thus the study divides into three related attitudes, which may be called recognition, imitation, and invention. Recognition of color is fundamental, but it would be tedious to spend a year or two in formal and dry exercises to train recognition of color alone; for each step in recognition of color is best tested by exercise in its imitation and arrangement. When perception becomes keener, emphasis can be placed on imitation of the colors found in art and in nature, resting finally on the selection and grouping of colors for design. [13](#)

Every color can be recognized, named, matched, imitated, and written by its HUE, VALUE, and CHROMA.

(40) The notation used in this system places Hue (expressed by an initial) at the left; Value (expressed by a number) at the right and above a line; and Chroma (also expressed by a number) at the right, below the line. Thus R^5_9 means

HUE (red), $\frac{\text{VALUE (5)}}{\text{CHROMA (9)}}$, and will be found to represent the qualities of the pigment vermilion. [14](#)

Hue, value, and chroma unite in every color sensation, but the child cannot grasp them all at once. *Hue-difference appeals to him first*, and he gains a permanent idea of five principal hues from the enamels of MIDDLE COLORS, learning to name, match, imitate, and finally write them by their initials: R (red), Y (yellow), G (green), B (blue), and P (purple). Intermediates formed by uniting successive pairs are also written by the joined initials, YR (yellow-red), GY (green-yellow), BG (blue-green), PB (purple-blue), and RP (red-purple).

(41) Ten differences of hue are as many as a child can render at the outset, yet in matching and imitating them he becomes aware of their light and dark quality, and learns to separate it from hue as *value-difference*. Middle colors, as implied by that name, stand midway between white and black,—that is, on the equator of the sphere,—so that a middle red will be written R^5 , suggesting the steps 6, 7, 8, and 9 which are above the equator, while steps 4, 3, 2, and 1 are below. It is well to show only three values of a color at first; for instance, the middle value contrasted with a light and a dark one. These are written R^3 , R^5 , R^7 . Soon he perceives and can imitate finer differences, and the red scale may be written entire, as R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 , R^8 , R^9 , with black as 0 and white as 10.

(42) *Chroma-difference is the third* and most subtle color quality. The child is already unconsciously familiar with the middle chroma of red, having had the enamels of MIDDLE COLOR always 27in view, and the red enamel is to be contrasted with the strongest and weakest red chromas obtainable. These he writes $R \frac{1}{1}$, $R \frac{1}{5}$, $R \frac{1}{9}$, seeing that this describes the chromas of red, but leaves out its values. $R^5 \frac{1}{1}$, $R^5 \frac{1}{5}$, $R^5 \frac{1}{9}$, is the complete statement, showing that, while both hue and value are unchanged, the chroma passes from grayish red to middle red (enamel first learned) and out to the strongest red in the chroma scale obtained by vermilion.

(43) It may be long before he can imitate the intervening steps of chroma, many children finding it difficult to express more than five steps of the chroma scale, although easily making ten steps of value and from twenty to thirty-five steps of hue. This interesting feature is of psychologic value, and has been followed in the color tree and color sphere.

Does such a scientific scheme leave any outlet for feeling and personal expression of beauty?

(44) Lest this exact attitude in color study should seem inartistic, compared with the free and almost chaotic methods in use, let it be said that the stage thus far outlined is frankly disciplinary. It is somewhat dry and unattractive, just as the early musical training is fatiguing without inventive exercises. The child should be encouraged at each step to exercise his fancy.

(45) Instead of cramping his outlook upon nature, it widens his grasp of color, and stores the memory with finer differences, supplying more material by which to express his sense of coloristic beauty.

(46) Color harmony, as now treated, is a purely personal affair, difficult to refer to any clear principles or definite laws. The very terms by which it seeks expression are borrowed from music, and suggest vague analogies that fail when put to the test. Color 28 needs a new set of expressive terms, appropriate to its qualities, before we can make an analysis as to the harmony or discord of our color sensations.

(47) This need is supplied in the present system by measured CHARTS, and a NOTATION. Their very construction preserves the *balance of colors*, as will be shown in the next chapter, while the chapter on harmony ([Chapter VII.](#)) shows how harmonious pairs and triads of color may be found by MASKS with measured intervals. In fact, practice in the use of the charts supplies the imagination with scales and sequences of color quite as definite and quite as easily written as those sound intervals by which the musician conveys to others his sense of harmony. And,

although in neither art can training alone make the artist, yet a technical grasp of these formal scales gives acquaintance with the full range of the instrument, and is indispensable to artistic expression. From these color scales each individual is free to choose combinations in accord with his feeling for color harmony.

Let us make an outline of the course of color study traced in the preceding pages. [15](#)

PERCEPTION of color.

(48) *Hue-difference.*

Middle hues (5 principals).

Middle hues (5 intermediates).

Middle hues (10 placed in sequence as SCALE of HUE).

Value-difference.

Light, middle, and dark values (without change of hue).

Light, middle, and dark values (traced with 5 principal hues).

10 values traced with each hue. SCALE of VALUE. *The Color Sphere.*

29

Chroma-difference.

Strong, middle, and weak chroma (without change of hue).

Strong, middle and weak chroma (traced with three values without change of hue).

Strong, middle, and weak chroma (traced with three values and ten hues).

Maxima of color and their gradation to white, black, and gray. *The Color Tree.*

EXPRESSION of color.

(49) *Matching and imitation* of hues (using stuffs, crayons, and paints).

Matching and imitation of values and hues (using stuffs, crayons, and paints).

Matching and imitation of chromas, values, and hues (using stuffs, crayons, and paints).

Notation of color.

Hue Value , H V ,

$\overline{\text{Chroma}}$ $\overline{\text{C}}$

Initial for hue, numeral above for value, numeral below for chroma.

Sequences of color.

Two scales united, as hue and value, or chroma and value.

Three scales united,—each step a change of hue, value, and chroma.

Balance of color.

Opposites of equal value and chroma ($R^5/5$ and $BG^5/5$).

Opposites of equal value and unequal chroma ($R^5/9$ and $BG^5/3$).

Opposites unequal both in value and chroma ($R^7/3$ and $BG^3/7$).

Area as an element of balance.

30

HARMONY of color.

(50) *Selection of colors* that give pleasure.

Study of butterfly wings and flowers, recorded by the NOTATION.

Study of painted ornament, rugs, and mosaics, recorded by the NOTATION.

Personal choice of color PAIRS, balanced by H, V, C, and area.

Personal choice of color TRIADS, balanced by H, V, C, and area.

Grouping of colors to suit some practical use: wall papers, rugs, book covers, etc.

Their analysis by the written notation.

Search for principles of harmony, expressed in measured terms.

A definite plan of color study, with freedom as to details of presentation. [16](#)

(51) Having memorized these broad divisions of the study, a clever teacher will introduce many a detail, to meet the mood of the class, or correlate this subject with other studies, without for a moment losing the thread of thought or befogging the presentation. But to range at random in the immense field of color sensations, without plan or definite aim in view, only courts fatigue of the retina and a chaotic state of mind.

(52) The same broad principles which govern the presentation of other ideas apply with equal force in this study. A little, well apprehended, is better than a mass of undigested facts. If the child is led to discover, or at least to think he is discovering, new things about color, the mind will be kept alert and seek out novel illustrations at every step. Now and then a pupil will be found ³¹who leads both teacher and class by *intuitive* appreciation of color, and it is a subtle question how far such a nature can be helped or hurt by formal exercises. But such an exception is rare, and goes to prove that systematic discipline of the color sense is necessary for most children.

(53) Outdoor nature and indoor surroundings offer endless color illustrations. Birds, flowers, minerals, and the objects in daily use take on a new interest when their varied colors are brought into a conscious relation, and clearly named. A tri-dimensional perception, like this sense of color, requires skilful training, and each lesson must be simplified to the last point practicable. It must not be too long, and should lead to some definite result which a child can grasp and express with tolerable accuracy, while its difficulties should be approached by easy stages, so as to avoid failure or discouragement. The success of the present effort is the best incentive to further achievement.

[6.](#) See Glossary for definitions of Micron, Photometer, Retina, and Red, also for Hue, Tint, Shade, Value, Color Variables, Luminosity, and Chroma.

[7.](#) See Photometer in paragraph [65](#).

[8.](#) See definition of White in Glossary.

[9.](#) When recognized for the first time, a middle green, blue, or purple, is accepted by most persons as well within their color habit, but middle red and middle yellow cause somewhat of a shock. "That isn't red," they say, "it's terra cotta." "Yellow?" "Oh, no, that's—well, it's a very peculiar shade."

Yet these are as surely the middle degrees of red and yellow as are the more familiar degrees of green, blue, and purple. This becomes evident as soon as one accepts physical tests of color in place of personal whim. It also opens the mind to a generally ignored fact, that middle reds and yellows, instead of the screaming red and yellow first given a child, are constantly found in examples of rich and beautiful color, such as Persian rugs, Japanese prints, and the masterpieces of painting.

[10.](#) See Color Tree in paragraph [14](#).

[11.](#) Unaware that the spherical arrangement had been used years before, I devised a double tetrahedron to classify colors, while a student of painting in 1879. It now

appears that the sphere was common property with psychologists, having been described by Runge in 1810. Earlier still, Lambert had suggested a pyramidal form. Both are based on the erroneous assumption that red, yellow, and blue are primary sensations, and also fail to place these hues in a just scale of luminosity. My twirling color solid and its completer development in the present model have always made prominent the artistic feeling for color value. It differs in this and in other ways from previous systems, and is fortunate in possessing new apparatus to measure the degree of hue, value, and chroma.

[12.](#) See [Plate I](#).

[13.](#) See Course of Study, Part II.

[14.](#) See [Chapter VI](#).

[15.](#) See Part II., A Color System and Course of Study.

[16.](#) See Color Study assigned to each grade, in Part II.

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Appendix to Chapter II.

PLATE I.

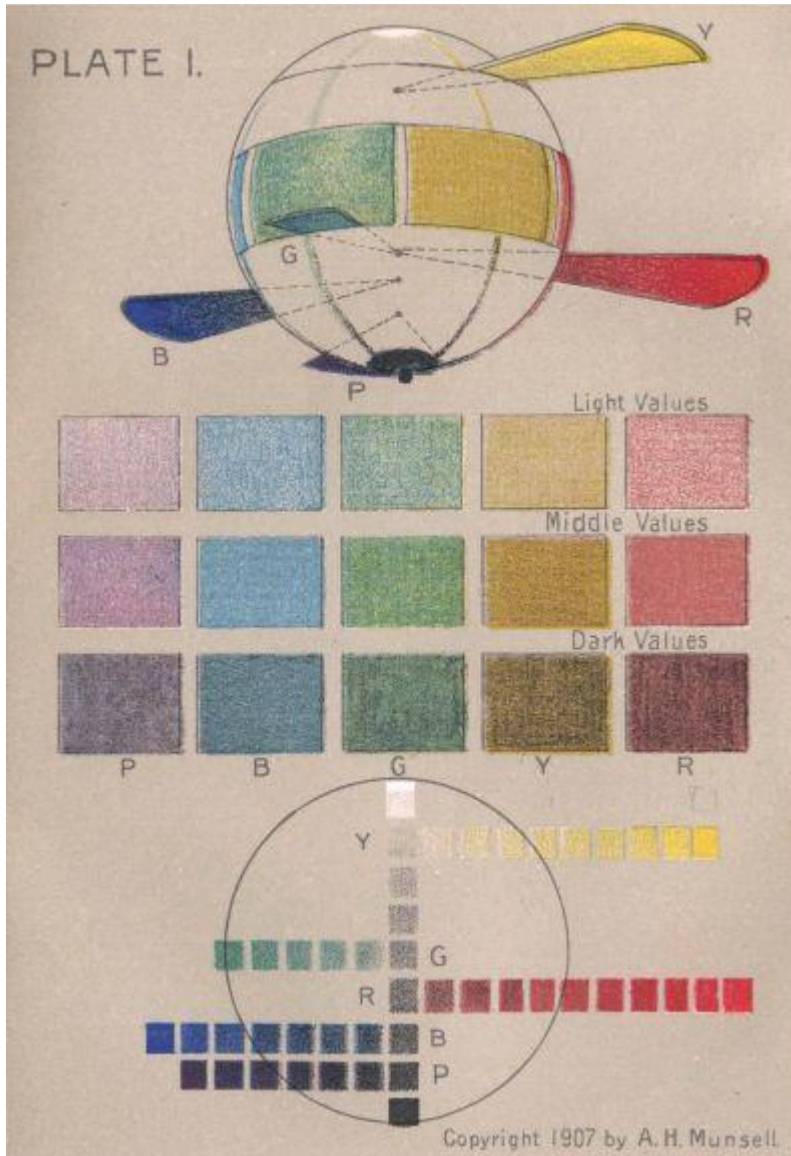
THE COLOR SPHERE, with Measured Scales of HUE, VALUE, and CHROMA.

The teacher of elementary grades introduces these scales of tempered color as fast as the child's interest is awakened to their need by the exercises shown in Plates II. and III. Thus the Hue scale is learned before the end of the second year, the Value scale during the next two years, and the Chroma scale in the fifth year. By the time a child is ten years old these definite color scales have become part of his mental furnishing, so that he can name, write, and memorize any color group.

1. *The Color Sphere in Skeleton.* This diagram shows the middle colors on the equator, with strong red, yellow, green, blue, and purple, each at its proper level in the value scale, and projecting in accordance with its scale of chroma. See the complete description of these scales in [Chapter II](#).

2. *The Color Score.* Fifteen typical steps taken from the color sphere are here spread out in a flat field. The Five Middle Colors form the centre level, with the same hues in a lighter value above and in a darker value below. [Chapter VI](#). describes the making of this Score, and its use in analyzing colors and preserving a written record of their groups.

3. *The Value Scale and Chroma Scale.* Each of the five color maxima is thus shown at its proper level in the scale of light, and graded by uniform steps from its strongest chroma inward to neutrality at the axis of the sphere. Pigment inequalities here become very apparent.



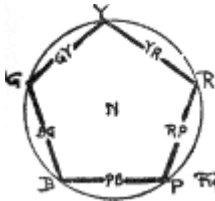
Chapter III.

COLOR MIXTURE AND BALANCE.

All colors grasped in the hand.

(54) **Fig. 6** Let us recall the names and order of colors given in the last chapter, with their assemblage in a sphere by the three qualities of HUE, VALUE, and CHROMA. It will aid the memory to call the thumb of the left hand RED, the forefinger YELLOW, the middle finger GREEN, the ring finger BLUE, and the little finger PURPLE (Fig. 6). When the finger tips are in a circle, they represent a circuit of hues, which has neither beginning nor end, for we can start with any finger and trace a sequence forward or backward. Now close the tips together for white, and imagine that the five strong hues have slipped down to the knuckles, where they stand for the equator of the color Sphere. Still lower down at the wrist is black.

(55) The hand thus becomes a color holder, with white at the finger tips, black at the wrist, strong colors around the outside, and weaker colors within the hollow. Each finger is a scale of its own color, with white above and black below, while the graying of all the hues is traced by imaginary lines which meet in the middle of the hand. Thus a child's hand may be his substitute for the color sphere, and also make him realize that it is filled with grayer degrees of the outside colors, all of which melt into gray in the centre.

Neighborly and opposite hues; and their mixture.

(56) **Fig. 7** Let this circle (Fig. 7) stand for the equator of the color sphere with the five principal hues (written by their initials R, Y, G, B, and P) spaced evenly about it. Some colors are neighbors, as red and yellow, while others are opposites. As soon as a child experiments with paints, he will notice the different results obtained by mixing them.

First, the neighbors, that is, any pair which lie next one another, as red and yellow, will unite to make a hue which retains a suggestion of both. It is *intermediate* between red and yellow, and we call it YELLOW-RED.[17](#)

(57) Green and yellow unite to form GREEN-YELLOW, blue and green make BLUE-GREEN, and so on with each succeeding pair. These intermediates are to be written by their initials, and inserted in their proper place between the principal hues. It is as if an orange (paragraph [9](#)) were split into ten sectors instead of five, with red, yellow, green, blue, and purple as alternate sectors, while half of each adjoining color pair were united to form the sector between them. The original order of five hues is in no wise disturbed, but linked together by five intermediate steps.

(58) Here is a table of the intermediates made by mixing each pair:—

Red and yellow unite to form yellow-red (YR), popularly called orange.[17](#)

Yellow and green unite to form green-yellow (GY), popularly called grass green.

Green and blue unite to form blue-green (BG), popularly called peacock blue.

Blue and purple unite to form purple-blue (PB), popularly called violet.

Purple and red unite to form red-purple (RP), popularly called plum.

36

Using the left hand again to hold colors, the principal hues remain unchanged on the knuckles, but in the hollows between them are placed intermediate hues, so that the circle now reads: red, yellow-red, yellow, green-yellow, green, blue-green, blue, purple-blue, purple, and red-purple, back to the red with which we started. This circuit is easily *memorized*, so that the child may begin with any color point, and repeat the series clock wise (that is, from left to right) or in reverse order.

(59) Each principal hue has thus made two close neighbors by mixing with the nearest principal hue on either hand. The neighbors of red are a yellow-red on one side and a purple-red on the other. The neighbors of green are a green-yellow on one hand and a blue-green on the other. It is evident that a still closer neighbor could be made by again mixing each consecutive pair in this circle of ten hues; and, if the process were continued long enough, the color steps would become so fine that the eye could see only a circuit of hues melting imperceptibly one into another.

(60) But it is better for the child to gain a fixed idea of red, yellow, green, blue, and purple, with their intermediates, before attempting to mix pigments, and these ten steps are sufficient for primary education.

(61) Next comes the question of opposites in this circle. A line drawn from red, through the centre, finds its opposite, blue-green.¹⁸ If these colors are mixed, they unite to form gray. Indeed, the centre of the circle stands for a middle gray, not only because it is the centre of the neutral axis between black and white, but also because any pair of opposites will unite to form gray.

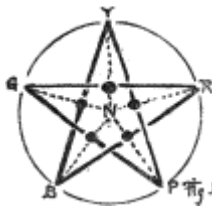
37

(62) This is a table of five mixtures which make neutral gray:

	Red &	Blue-green	
	Yellow	Purple-blue	
Opposites	Green	Red-purple	Each pair of which unites in neutral gray.
	Blue	Yellow-red	
	Purple	Green-yellow	

(63) But if, instead of mixing these opposite hues, we place them side by side, the eye is so stimulated by their difference that each seems to gain in strength; *i.e.*, each *enhances* the other when separate, but *destroys* the other when mixed. This is a very interesting point to be more fully illustrated by the help of a color wheel in Chapter V., paragraph ¹⁰⁶. What we need to remember is that the mixture of neighborly hues makes them less stimulating to the eye, because they resemble each other, while a mixture of opposite hues extinguishes both in a neutral gray.

Hues once removed, and their mixture.



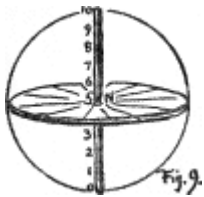
(64) There remains the question, What will happen if we mix, not two neighbors, nor two opposites, but *a pair of hues once removed in the circle*, such as red and green? A line joining this pair does not pass through the neutral centre, but to one side nearer yellow, which shows that this mixture falls between neutral gray and yellow, partaking somewhat of each. In the same way a line joining yellow and blue shows that their mixture contains both green and gray. Indeed, a line joining any two colors in the circuit may be said to describe their union. A radius crossing this line passes to some hue on the circumference, and describes by its intersection with the first line ³⁸the chroma of the color made by a mixture of the two original colors.

Red	&	Green	make	Yellow-gray
Yellow		Blue		Green-gray
Green		Purple		Blue-gray
Blue		Red		Purple-gray
Purple		Yellow		Red-gray

Each pair unites in a *colored* gray, which is an intermediate hue of weak chroma.

Mixture of white and black: a scale of grays.

(65) So far we have thought only of the plane of the equator, with its circle of middle hues in ten steps, and studied their mixture by drawing lines to join them. Now let us start at the neutral centre, and think upward to white and downward to black (Fig. 9.)



This vertical line is the *neutral axis* joining the poles of white and black, which represent the opposites of light and darkness. Middle gray is half-way between. If black is called 0, and white is 10, then the middle point is 5, with 6, 7, 8, and 9 above, while 4, 3, 2, and 1 are below, thus making a vertical scale of grays from black to white (Chapter II., paragraph [25](#)).

If left to personal preference, an estimate of middle value will vary with each individual who attempts to make it. This appears in the neutral scales already published for schools, and students who depend upon them, discover a variation of over 10 per cent. in the selection of middle gray. Since this VALUE SCALE underlies all color work, it needs accurate adjustment by scientific means, as in scales of sound, of length, of weight, or of temperature.

A PHOTOMETER (*photo*, light, and *meter*, a measure)[19](#) is shown ³⁹on the next page. It measures the relative amount of light which the eye receives from any source, and so enables us to make a scale with any number of regular steps. The principle on which it acts is very simple.

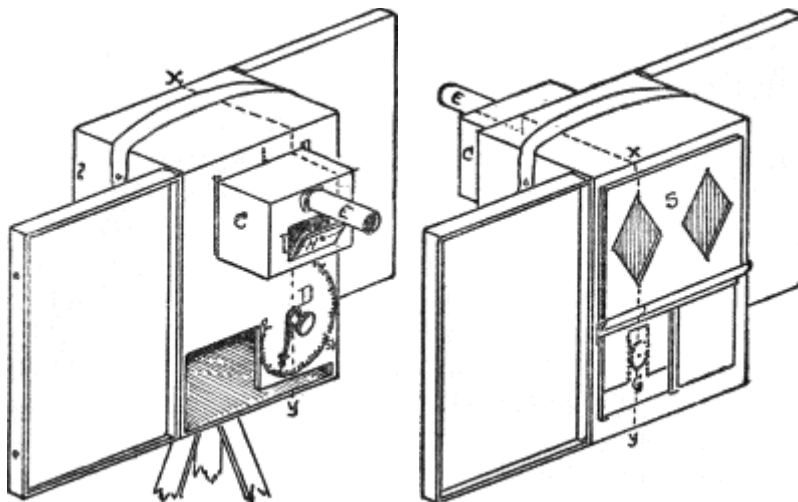
A rectangular box, divided by a central partition into halves, has symmetrical openings in the front walls, which permit the light to reach two white fields placed upon the back walls. If one looks in through the observation tube, both halves are seen to be exactly alike, and the white fields equally illuminated. A valve is then fitted to one of the front openings, so that the light in that half of the photometer may be gradually diminished. Its white field is thus darkened by measured degrees, and becomes black

when all light is excluded by the closed valve. While this darkening process goes on in one-half of the instrument, the white field in the other half does not change, and, looking into the eyepiece, the observer sees each step contrasted with the original white. One-half is thus said to be *variable* because of its valve, and the other side is said to be *fixed*. A dial connected with the valve has a hand moving over it to show how much light is admitted to the field in the variable half.

Let us now test one of these personal decisions about middle value. A sample replaces the white field in the fixed half, and by means of the valve, the white field in the variable half is alternately darkened and lightened, until it matches the sample and the eye sees no difference in the two. The dial then discloses the fact that this supposedly MIDDLE VALUE reflects only 42 per cent. of the light; that is to say, it is nearly a whole step too low in a decimal scale. Other samples err nearly as far on the light side of middle value, and further tests prove not only the varying color sensitiveness of individuals, but detect a difference between the left and right eye of the same person.

40

PHOTOMETER.

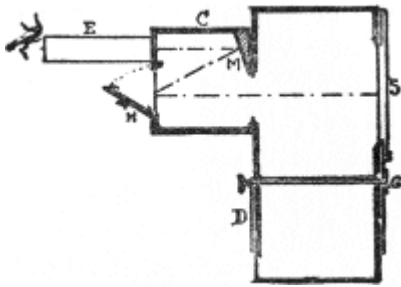


Back View.

Front View.

The vagaries of color estimate thus disclosed, lead some to seek shelter in “feeling and inspiration”; but feeling and inspiration are temperamental, and have nothing to do with the simple facts of vision. A measured and unchanging scale is as necessary and valuable in the training of the eye as the musical scale in the discipline of the ear.

It will soon be necessary to talk of the values in each color. We may distinguish the values on the neutral axis from color values by writing them N^1 , N^2 , N^3 , N^4 , N^5 , N^6 , N^7 , N^8 , N^9 , N^{10} . Such a scale makes it easy to foresee the result of mixing light values with dark ones. Any two gray values unite to form a gray midway between them. Thus N^4 and N^6 being equally above and below the centre, unite to form N^5 , as will also N^7 and N^3 , N^8 and N^2 , or N^9 and N^1 . But N^9 and N^3 will unite to form N^6 , which is midway between 6 and 9.



Vertical Section through light openings.

PARTS.

C, Cabinet, with sample-holder (*H*) and mirror (*M*), which may be removed and stored to left of dial (*D*) when instrument is closed for transportation.

D, Dial: records color values in terms of standard white (100), the opposite end of the scale being absolute blackness (0).

E, Eye-piece: to shield eye and sample from extraneous light while color determinations are being made. Fatigue of retina should be avoided.

G, Gear: actuates cat's-eye shutter, which controls amount of light admitted to right half of instrument. Its shaft carries index-hand over dial.

H, Field-Holder: retains sample and standard white in same plane, and isolates them. Is hinged upon lower edge, and secured by pivot clamp.

M, Mirror: permits observation of the isolated halves of the holder, bearing standard white and the color to be measured. Should be clean and free from dust on both sides of central partition.

S, Diffusing Screen, placed over front apertures, to evenly distribute the light.

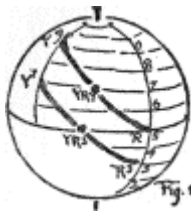
(66) When this numbered scale of values is familiar, it serves not only to describe light and dark grays, but the value of colors which are at the same level in the scale. Thus R^7 (popularly called a tint of red) is neither lighter nor darker than the gray of N^7 .

A numeral written above to the right always indicates *value*, whether of a gray or a color, so that $R^1, R^2, R^3, R^4, R^5, R^6, R^7, R^8, R^9$, describes a regular scale of red values from black to white, while G^1, G^2, G^3 , etc., is a scale of green values.

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(67) This matter of a notation for colors will be more fully worked out in [Chapter VI.](#), but the letters and numerals already described greatly simplify what we are about to consider in the mixture and balance of colors.

Mixture of light hues with dark hues.



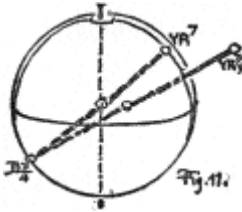
(68) Now that we are supplied with a decimal scale of grays, represented by divisions of the neutral axis (N^1, N^2 , etc.), and a corresponding decimal scale of value for each of the ten hues ranged about the equator ($R^1, R^2, —YR^1, YR^2, —Y^1, Y^2, —GY^1, GY^2, —$ and so on), traced by ten equidistant meridians from black to white, it is not difficult to foresee what the mixture of any two colors will produce, whether they are of the same level of value, as in the colors of the equator already considered, or whether they are of different levels.

(69) For instance, let us mix a light yellow (Y^7) with a dark red (R^3). They are neighbors in hue, but well removed in value. A line joining them centres at YR^5 . This describes the result of their mixture,—a value intermediate between 7 and 3, with a hue intermediate between R and Y. It is a yellow-red of middle value, popularly called “dark orange.” But, while this term “dark orange” rarely means the same color to three different people, these measured scales give to YR^5 an unmistakable meaning, just as the musical scale gives an unmistakable significance to the notes of its score.

(70) Evidently, this way of writing colors by their degrees of value and hue gives clearness to what would otherwise be hard to express by the color terms in common use.

(71) If Y^9 and R^5 be chosen for mixture, we know at once that they unite in YR^7 , which is two steps of the value scale above the middle; while Y^6 and R^2 make YR^4 , which is one step below the middle. Charts prepared with this system show each of these colors and their mixture with exactness.

(72) The foregoing mixtures of dark reds and light yellows are typical of the union of light and dark values of any neighboring hues, such as yellow and green, green and blue, blue and purple, or purple and red. Next let us think of the result of mixing different values in opposite hues; as, for instance, YR^7 and B^3 (Fig. 11). To this combination the color sphere gives a ready answer; for the middle of a straight line through the sphere, and joining them, coincides with the neutral centre, showing that they *balance in neutral gray*. This is also true of any opposite pair of surface hues where the values are equally removed from the equator.



(73) Suppose we substitute familiar flowers for the notation, then YR^7 becomes the buttercup, and B^3 is the wild violet. But, in comparing the two, the eye is more stimulated by the buttercup than by the violet, not alone because it is lighter, but because it is stronger in chroma; that is, farther away from the neutral axis of the sphere, and in fact out beyond its surface, as shown in Fig. 11.

The head of a pin stuck in toward the axis on the 7th level of YR may represent the 9th step in the scale of chroma, such as the buttercup, while the “modest” violet with a chroma of only 4, is shown by its position to be nearer the neutral axis than the brilliant buttercup by five steps of chroma. This is the third dimension of color, and must be included in our notation. 44So we write the buttercup $YR^{7/9}$ and the violet $B^{3/4}$,—chroma always being written below to the right of hue, and value always above.

VALUE
(This is the invariable order: HUE .)
CHROMA

(74) A line joining the head of the pin mentioned above with $B^{3/4}$ does not pass through the centre of the sphere, and its middle point is nearer the buttercup than the neutral axis, showing that the hues of the buttercup and violet *do not balance in gray*.

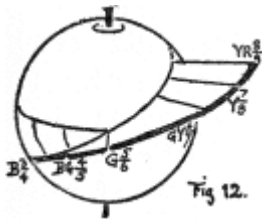
The neutral centre is a balancing point for colors.

(75) This raises the question, What is balance of color? Artists criticise the color schemes of paintings as being “too light or too dark” (unbalanced in value), “too weak or too strong” (unbalanced in chroma), and “too hot or too cold” (unbalanced in hue), showing that this is a fundamental idea underlying all color arrangements.

(76) Let us assume that the centre of the sphere is the natural balancing point for all colors (which will be best shown by Maxwell discs in Chapter V., paragraphs [106–112](#)), then color points equally removed from the centre must balance one another. Thus white balances black. Lighter red balances darker blue-green. Middle red balances middle blue-green. In short, every straight line through this centre indicates opposite qualities that balance one another. The color points so found are said to be “*complementary*,” for each supplies what is needed to complement or balance the other in hue, value, and chroma.

(77) The true complement of the buttercup, then, is not the violet, which is too weak in chroma to balance its strong opposite. We have no blue flower that can equal the chroma of the buttercup. Some other means must be found to produce a balance. One way is to use more of the weaker color. Thus we can make 45a bunch of buttercups and violets, using twice as many of the latter, so that the eye sees an *area* of blue twice as great as the *area* of yellow-red. Area as a compensation for inequalities of hue, value, and chroma will be further described under the harmony of color in [Chapter VII.](#)

(78) But, before leaving this illustration of the buttercup and violet, it is well to consider another color path connecting them which does not pass through the sphere, *but around it* (Fig. 12). Such a path swinging around from yellow-red to blue slants downward in value, and passes through yellow, green-yellow, green, and blue-green, tracing a *sequence of hue*, of which each step is less chromatic than its predecessor.



This diminishing sequence is easily written thus,—YR⁸/₉, Y⁷/₈, GY⁶/₇, G⁵/₆, BG⁴/₅, B³/₄,—and is shown graphically in Fig. 12. Its hue sequence is described by the initials YR, Y, GY, G, BG, and B. Its value-sequence appears in the upper numerals, 8, 7, 6, 5, 4, and 3, while the chroma-sequence is included in the lower numerals, 9, 8, 7, 6, 5, and 4. This gives a complete statement of the sequence, defining its peculiarity, that at each change of hue there is a regular decrease of value and chroma. Nature seems to be partial to this sequence, constantly reiterating it in yellow flowers with their darker green leaves and underlying shadows. In spring time she may contract its range,

making the blue more green and the yellow less red, but in autumn she seems to widen the range, presenting strong contrasts of yellow-red and purple-blue.

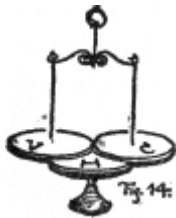
(79) Every day she plays upon the values of this sequence, 46 from the strong contrasts of light and shadow at noon to the hardly perceptible differences at twilight. The chroma of this sequence expands during the summer to strong colors, and contracts in winter to grays. Indeed, Nature, who would seem to be the source of our notions of color harmony, rarely repeats herself, yet is endlessly balancing inequalities of hue, value, and chroma by compensations of quantity.

(80) So subtle is this equilibrium that it is taken for granted and forgotten, except when some violent disturbance disarranges it, such as an earthquake or a thunder-storm.

The triple nature of color balance illustrated.

(81) The simplest idea of balance is the equilibrium of two halves of a stick supported at its middle point. If one end is heavier than the other, the support must be moved nearer to that end.

But, since color unites three qualities, we must seek some type of *triple balance*. The game of jackstraws illustrates this, when the disturbance of one piece involves the displacement of two others. The action of three children on a floating plank or the equilibrium of two acrobats carried on the shoulders of a third may also serve as examples.



(82) Triple balance may be graphically shown by three discs in contact. Two of them are suspended by their centres, while they remain in touch with a third supported on a pivot, as in Fig. 14. Let us call the lowest disc Hue (H), and the lateral discs Value (V) and Chroma (C). Any dip or rotation of the lower disc H will induce sympathetic action in the two lateral discs V and C. When H is inclined, both V 47 and C change their relations to it. If H is raised vertically, both V and C dip outward. If H is rotated, both V and C rotate, but in opposite directions. Indeed, any disturbance of V affects H and C, while H and V respond to any movement of C. So we must be prepared to realize that any change of one color quality involves readjustment of the other two.

(83) Color balance soon leads to a study of optics in one direction, to æsthetics in another, and to mathematical proportions in a third, and any attempt at an easy

solution of its problems is not likely to succeed. It is a very complicated question, whose closest counterpart is to be sought in musical rhythms. The fall of musical impulses upon the ear can make us gay or sad, and there are color groups which, acting through the eye, can convey pleasure or pain to the mind.

(84) A colorist is keenly alive to these feelings of satisfaction or annoyance, and consciously or unconsciously he rejects certain combinations of color and accepts others. Successful pictures and decorative schemes are due to some sort of balance uniting “light and shade” (value), “warmth and coolness” (hue), with “brilliancy and grayness” (chroma); for, when they fail to please, the mind at once begins to search for the unbalanced quality, and complains that the color is “too hot,” “too dark,” or “too crude.” This effort to establish pleasing proportions may be unconscious in one temperament, while it becomes a matter of definite analysis in another. Emerson claimed that the unconscious only is complete. We gladly permit those whose color instinct is unerring—and how few they are!—to neglect all rules and set formulas. But education is concerned with the many who have not this gift.

(85) Any real progress in color education must come not from a blind imitation of past successes, but by a study into the laws which they exemplify. To exactly copy fine Japanese prints or Persian rugs or Renaissance tapestries, while it cultivates an appreciation of their refinements, does not give one the power to create things equally beautiful. The masterpieces of music correctly rendered do not of necessity make a composer. The musician, besides the study of masterpieces, absorbs the science of counterpoint, and records by an unmistakable notation the exact character of any new combination of musical intervals which he conceives.

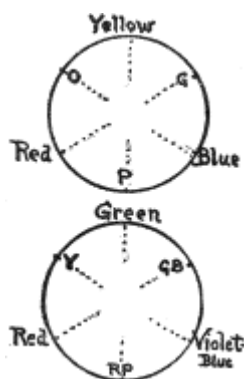
(86) So must the art of the colorist be furnished with a scientific basis and a clear form of color notation. This will record the successes and failures of the past, and aid in a search, by contrast and analysis, for the fundamentals of color balance. Without a measured and systematic notation, attempts to describe color harmony only produce hazy generalities of little value in describing our sensations, and fail to express the essential differences between “good” and “bad” color.

[17.](#) Orange is a variable union of yellow and red. See Appendix.

[18.](#) Green is often wrongly assigned as the opposite of red. See Appendix, on False Color Balance.

[19.](#) Adopted in Course on Optical Measurements at the Massachusetts Institute of Technology. Instruments have also been made for the Harvard Medical School, the Treasury Department in Washington, and various private laboratories.

Appendix to Chapter III.



False Color Balance. There is a widely accepted error that red, yellow, and blue are “primary,” although Brewster’s theory was long ago dropped when the elements of color vision proved to be RED, GREEN, and VIOLET-BLUE. The late Professor Rood called attention to this in Chapters VIII.–XI. of his book, “Modern Chromatics,” which appeared in 1879. Yet we find it very generally taught in school. Nor does the harm end there, for placing red, yellow, and blue equidistant in a circle, with orange, green, and purple as intermediates, the teacher goes on to state that opposite hues are complementary.

Red is thus made the complement of Green,

Yellow „ „ Purple, and

Blue „ „ Orange.

Unfortunately, each of these statements is wrong, and, if tested by the mixture of colored lights or with Maxwell’s rotating discs, their falsity is evident.

There can be no doubt that green is not the complement of red, nor purple of yellow, nor orange of blue, for neither one of these pairs unites as it should in a balanced neutrality, and a total test of the circle gives great excess of orange, showing that red and yellow usurp too great a portion of the circumference. Starting from a false basis, the Brewster theory can only lead to unbalanced and inharmonious effects of color.

The fundamental color sensations are RED, GREEN, and VIOLET-BLUE.

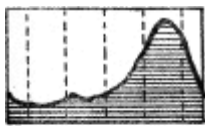
Red has for its true complement BLUE-GREEN,

Green	””	RED-PURPLE, and
Violet-blue	””	YELLOW,

all of the hues in the right-hand column being compound sensations. The sensation of green is not due to a mixture of yellow and blue, as the absorptive action of pigments might lead one to think: GREEN IS FUNDAMENTAL, and not made by mixing any hues of the spectrum, while YELLOW IS NOT FUNDAMENTAL, but caused by the mingled sensations of red and green. This is easily proved by a controlled spectrum, for all yellow-reds, yellows, and green-yellows can be matched by certain proportions of red and green light, all blue-greens, blues, and purple-blues can be obtained by the union of green and violet light, while purple-blue, purple, and red-purple result from the union of violet and red light. But there is no point where a mixture gives red, green, or violet-blue. They are the true primaries, whose mixtures produce all other hues.

Studio and school-room practice still cling to the discredited theory, claiming that, if it fails to describe our color sensations, yet it may be called practically true of pigments, because a red, yellow, and blue pigment suffice to imitate most natural colors. This discrepancy between pigment mixture and retinal mixture becomes clear as soon as one learns the physical make-up and behavior of paints.

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Spectra { Vermilion
Em. Green



Spectral analysis shows that no pigment is a pure example of the dominant hue which it sends to the eye. Take, for example, the very chromatic pigments representing red and green, such as vermilion and emerald green. If each emitted a single pure hue free from trace of any other hue, then their mixture would appear yellow, as when spectral red and green unite. But, instead of yellow, their mixture produces a warm gray, called brown or “dull salmon,” and this is to be inferred from their spectra, where it is seen that vermilion emits some green and purple as well as its dominant color, while the green also sends some blue and red light to the eye. [20](#)

Thus stray hues from other parts of the spectrum tend to neutralize the yellow sensation, which would be strong if each of the pigments were pure in the spectral

sense. Pigment absorption affects all palette mixtures, and, failing to obtain a satisfactory yellow by mixture of red and green, painters use original yellow pigments,—such as aureolin, cadmium, and lead chromate,—each of them also impure but giving a dominant sensation of yellow. Did the eye discriminate, as does the ear when it analyzes the separate tones of a chord, then we should recognize that yellow pigments emit both red and green rays.

White light dispersed into a colored band by one prism, may have the process reversed by a second prism, so that the eye sees again only white light. But this would not be so, did not the balance of red, green, and violet-blue sensations remain undisturbed. All our ideas of color harmony are based upon this fundamental relation, and, if pigments are to render harmonious effects, 52 we must learn to control their impurities so as to preserve a balance of red, green, and violet-blue.

Otherwise, the excessive chroma and value of red and yellow pigments so overwhelm the lesser degrees of green and blue pigments that no balance is possible, and the colorist of fine perception must reject not alone the theoretical, but also the practical outcome of a “red-yellow-blue” theory.

Some of the points raised in this discussion are rather subtle for students, and may well be left until they arise in a study of optics, but the teacher should grasp them clearly, so as not to be led into false statements about primary and complementary hues.

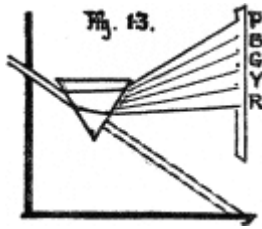
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Chapter IV.

PRISMATIC COLOR.

Pure color is seen in the spectrum of sunlight.

(87) The strongest sensation of color is gained in a darkened room, with a prism used to split a beam of sunlight into its various wave lengths. Through a narrow slit there enters a straight pencil of light which we are accustomed to think of as *white*, although it is a bundle of variously colored rays (or waves of ether) whose union and balance is so perfect that no single ray predominates.



(88) Cover the narrow slit, and we are plunged in darkness. Admit the beam, and the eye feels a powerful contrast between the spot of light on the floor and its surrounding darkness. Place a triangular glass prism near the slit to intercept the beam of white light, and suddenly there appears on the opposite wall a band of brilliant colors. This delightful experiment rivets the eye by the beauty and purity of its hues. All other colors seem weak by comparison.

Their weakness is due to impurity, for all pigments and dyes reflect portions of hues other than their dominant one, which tend to “gray” and diminish their chroma.

(89) But prismatic color is pure, or very nearly so, because the shape of the glass refracts each hue, and separates it by the length of its ether wave. These waves have been measured, and science can name each hue by its wave length. Thus a certain red is known as M. 6867, and a certain green sensation is M. 5269.²¹ Without attempting any scientific analysis of color, let it be said that Sir Isaac Newton made his series of experiments in 1687, and was privileged to name this color sequence by seven steps which he called red, orange, yellow, green, blue, violet, and indigo. Later a scientist named Fraunhofer discovered fine black lines crossing the solar spectrum, and marked them with letters of the alphabet from a to h. These with the wave length serve to locate every hue and define every step in the sequence. Since Newton’s time it has been proved that only three of the spectral hues are *primary*; viz., a red, a green, and a violet-blue, while their mixture produces all other gradations. By receiving the spectrum on an opaque screen with fine slits that fit the red and green waves, so that they alone pass through, these two primary hues can be received on mirrors inclined at such an angle as to unite on another screen, where, instead of red or green, the eye sees only yellow.²²

(90) A similar arrangement of slits and mirrors for the green and violet-blue proves that they unite to make blue, while a third experiment shows that the red and violet-blue can unite to make purple. So yellow, blue-green, and purple are called secondary hues because they result from the mixture of the three primaries, red, green, and violet-blue.

In comparing these two color lists, we see that the “indigo” and “orange” of Sir Isaac Newton have been discarded. Both are indefinite, and refer to variable products of the vegetable kingdom. Violet is also borrowed from the same kingdom; and, in order to

describe a violet, we say it is a purple violet or blue violet, as the case may be, just as we describe an orange as a red orange or a yellow orange. Their color difference is not expressed by the terms “orange” or “violet,” but by the words “red,” “yellow,” “blue,” or “purple,” all of which are true color names and arouse an unmixed color image.

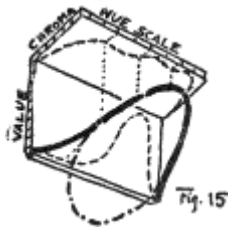
(91) In the nursery a child learns to use the simple color names red, yellow, green, blue, and purple. When familiarity with the color sphere makes him relate them to each other and place them between black and white by their degree of light and strength, there will be no occasion to revert to vegetables, animals, minerals, or the ever-varying hues of sea and sky to express his color sensations.

(92) Another experiment accentuates the difference between spectral and pigment color. When the spectrum is spread on the screen by the use of a prism, and a second prism is placed inverted beyond the first, it regathers the dispersed rays back into their original beam, making a white spot on the floor. This proves that all the colored rays of light combine to balance each other in whiteness. But if pigments which are the closest possible imitation of these hues are united on a painter’s palette, either by the brush or the knife, they *make gray, and not white*.

(93) This is another illustration of the behavior of pigments, for, instead of uniting to form white, they form gray, which is a 56darkened or impure form of white; and, lest this should be attributed to a chemical reaction between the various matters that serve as pigments, the experiment can be carried out without allowing one pigment to touch another by using Maxwell discs, as will be shown in the next chapter.

(94) Before leaving these prismatic colors, let us study them in the light of what has already been learned of color dimensions. Not only do they present different values, but also different chromas. Their values range from darkness at each end, where red and purple become visible, to a brightness in the greenish yellow, which is almost white. So on the color tree described in Chapter II., paragraph [34](#), yellow has the highest branch, green is lower, red is below the middle, with blue and purple lower down, near black.

(95) Then in chroma they range from the powerful stimulation of the red to the soothing purple, with green occupying an intermediate step. This is also given on the color tree by the length of its branches.



(96) In Fig. 15 the vertical curve describes the values of the spectrum as they grade from red through yellow, green, blue, and purple. The horizontal curve describes the chromas of the spectrum in the same sequence; while the third curve leaning outward is obtained by uniting the first two by two planes at right angles to one another, and sums up the three qualities by a single descriptive line. Now the red and purple ends are far apart, and science forbids their junction because of their great difference in wave length. But the mind is prone to unite them in order to produce the red-purples which we see in clouds at sunset, in flowers and 57grapes and the amethyst. Indeed, it has been done unhesitatingly in most color schemes in order to supply the opposite of green.

(97) This gives a slanting circuit joining all the branch ends of the color tree, and has been likened to the rings of Saturn in Chapter I., paragraph [17](#).

A prismatic color sphere.

(98) With a little effort of the imagination we can picture a prismatic color sphere, using only the colors of light. In a cylindrical chamber is hung a diaphanous ball similar to a huge soap bubble, which can display color on its surface without obscuring its interior. Then, at the proper points of the surrounding wall, three pure beams of colored light are admitted,—one red, another green, and the third violet-blue.

(99) They fall at proper levels on three sides of the sphere, while their intermediate gradations encircle the sphere with a complete spectrum plus the needed purple. As they penetrate the sphere, they unite to balance each other in neutrality. Pure whiteness is at the top, and, by some imaginary means their light gradually diminishes until they disappear in darkness below.

(100) This ideal color system is impossible in the present state of our knowledge and implements. Even were it possible, its immaterial hues could not serve to dye materials or paint pictures. Pigments are, and will in all probability continue to be, the practical agents of coloristic productions, however reluctant the scientist may be to accept them as the basis of a color system. It is true that they are chemically impure and imperfectly represent the colors of light. Some of them fade rapidly and undergo chemical change, as in the notable case of a green pigment tested 58by this

measured system, which in a few weeks lost four steps of chroma, gained two steps of value, and swung into a bluer hue.

(101) But the color sphere to be next described is worked out with a few reliable pigments, mostly natural earths, whose fading is a matter of years and so slight as to be almost imperceptible. Besides, its principal hues are preserved in safe keeping by imperishable enamels, which can be used to correct any tendency of the pigments to distort the measured intervals of the color sphere.

This meets the most serious objection to a pigment system. Without it a child has nothing tangible which he can keep in constant view to imitate and memorize. With it he builds up a mental image of measured relations that describe every color in nature, including the fleeting hues of the rainbow, although they appear but for a moment at rare intervals. Finally, it furnishes a simple notation which records every color sensation by a letter and two numerals. With the enlargement of his mental power he will unite these in a comprehensive grasp of the larger relations of color.

[20.](#) See Rood, Chapter VII., on Color by Absorption.

[21.](#) See Micron in Glossary.

[22.](#) The fact that the spectral union of red and green makes yellow is a matter of surprise to practical workers in color who are familiar with the action of pigments, but unfamiliar with spectrum analysis. Yellow seems to them a primary and indispensable color, because it cannot be made by the union of red and green pigments. Another surprise is awaiting them when they hear that the yellow and blue of the spectrum make *white*, for all their experience with paints goes to prove that yellow and blue unite to form green. Attention is called to this difference between the mixture of colored light and of colored pigments, not with the idea of explaining it here, but to emphasize their difference; for in the next chapter we shall describe the practical making of a color sphere with pigments, which would be quite impractical, could we have only the colors of the spectrum to work with. See Appendix to preceding chapter.

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Appendix to Chapter IV.

Children's Color Studies.

These reproductions of children's work are given as proof that color charm and good taste may be cultivated from the start.

Five Middle Hues are first taught by the use of special crayons, and later with water colors. They represent the equator of the color sphere (see [Plate I.](#)),—a circle midway between the extremes of color-light and color-strength,—and are known as Middle Red, Middle Yellow, Middle Green, Middle Blue, and Middle Purple.

These are starting-points for training the eye to measure regular scales of Value and Chroma.[23](#) Only with such a trained judgment is it safe to undertake the use of strong colors.[24](#)

Beginners should avoid Strong Color. Extreme red, yellow, and blue are discordant. (They “shriek” and “swear.” Mark Twain calls Roxana’s gown “a volcanic eruption of infernal splendors.”) Yet there are some who claim that the child craves them, and must have them to produce a thrill. So also does he crave candies, matches, and the carving-knife. He covets the trumpet, fire-gong, and bass-drum for their “thrill”; but who would think them necessary to the musical training of the ear? Like the blazing bill-board and the circus wagon, they may be suffered out-of-doors; but such boisterous sounds and color sprees are unfit for the school-room.

Quiet Color is the Mark of Good Taste. Refinement in dress and the furnishings of the home is attractive, but we shrink from those who are “loud” in their speech or their clothing. If we wish our children to become well-bred, is it logical to begin by encouraging barbarous tastes? Their young minds are very open to suggestion. They quickly adopt our standards, and the blame must fall upon us if they acquire crude color habits. Yellow journalism and rag-time tunes will not help their taste in speech or song, nor will violent hues improve their taste in matters of color.

Balance of Color is to be sought. Artists and decorators are well aware of a fact that slowly dawns upon the student; namely, that color harmony is due to the preservation of a subtle balance and impossible by the use of extremes. This balance of color resides more *within* the spherical surface of this system than in the excessive chromas which project beyond. It is futile to encourage children in efforts to rival the poppy or buttercup, even with the strongest pigments obtainable. Their sunlit points give pleasure because they are surrounded and balanced by blue ether and wide green fields. Were these conditions reversed, so that the flowers appeared as little spots of blue or green in great fields of blazing red, orange, and yellow, our pained eyes would be shut in disgust.

The painter knows that pigments *cannot* rival the brilliancy of the buttercup and poppy, enhanced by their surroundings. What is more, he does not care to attempt it. Nor does the musician wish to imitate the screech of a siren or the explosion of a gun. These are not subjects for art. Harmonious sounds are the study of the musician, and

tuned colors are the materials of the colorist. Corot 61 in landscape, and Titian, Velasquez, and Whistler in figure painting, show us that Nature's richest effects and most beautiful color are enveloped in an atmosphere of gray.

Beauty of Color lies in Tempered Relations. Music rarely touches the extreme range of sound, and harmonious color rarely uses the extremes of color-light or color-strength. Regular scales in the middle register are first given to train the ear, and so should the eye be first familiarized with medium degrees of color.

This system provides measured scales, established by special instruments, and is able to select the middle points of red, yellow, green, blue, and purple as a basis for comparing and relating all colors. These five middle colors form a Chromatic Tuning Fork. (See page 70.) It is far better that children should first become familiar with these tuned color intervals which are harmonious in themselves rather than begin by blundering among unrelated degrees of harsh and violent color. Who would think of teaching the musical scale with a piano out of tune?

The Tuning of Color cannot be left to Personal Whim. The wide discrepancies of red, yellow, and blue, which have been falsely taught as primary colors, can no more be tuned by a child than the musical novice can tune his instrument. Each of these hues has three variable factors (see page 14, paragraph [14](#)), and scientific tests are necessary to measure and relate their uneven degrees of Hue, Value, and Chroma.

Visual estimates of color, without the help of any standard for comparison, are continually distorted by doubt, guess-work, and the fatigue of the eye. Hardly two persons can agree in the intelligible description of color. Not only do individuals differ, but the same eye will vary in its estimates from day to day. A frequent assumption that all strong pigments are equal in chroma, is 62 far from the truth, and involves beginners in many mishaps. Thus the strongest blue-green, chromium sesquioxide, is but half the chroma of its red complement, the sulphuret of mercury. Yet ignorance is constantly leading to their unbalanced use. Indeed, some are still unaware that they are the complements of each other. [25](#)

It is evident that the fundamental scales of Hue, Value, and Chroma must be established by scientific measures, not by personal bias. This system is unique in the possession of such scales, made possible by the devising of special instruments for the measurement of color, and can therefore be trusted as a permanent basis for training the color sense.

The examples in Plates II. and III. show how successfully the tuned crayons, cards, and water colors of this system lead a child to fine appreciations of color harmony.



PLATE II.

Color Studies with TUNED CRAYONS in the Lower Grades.

Children have made every example on this plate, with no other material than the five crayons of middle hue, tempered with gray and black. A Color Sphere is always kept in the room for reference, and five color balls to match the five middle hues are placed in the hands of the youngest pupils. Starting with these middle points in the scales of Value and Chroma, they learn to estimate rightly all lighter and darker values, all weaker and stronger chromas, and gradually build up a disciplined judgment of color.

Each study can be made the basis of many variations by a simple change of one color element, as suggested in the text.

1. Butterfly. Yellow and black crayon. Vary by using any single crayon with black.
2. Dish. Red crayon, blue and green crayons for back and foreground. Vary by using the two opposites of any color chosen for the dish and omitting the two neighboring colors. See No. 4.
3. Hiawatha's canoe. Yellow crayon, with rim and name in green. Vary color of canoe, keeping the rim a neighboring color. See No. 4.
4. Color-circle. Gray crayon for centre, and five crayons spaced equidistant. This gives the invariable order, red, yellow, green, blue, purple. *Never use all five in a single design.* Either use a color and its two neighbors or a color and its two opposites. By mingling touches of any two neighbors, the intermediates are made and named yellow-red (orange), green-yellow, blue-green, purple-blue (violet), and red-purple. Abbreviated, the circle reads R, YR, Y, GY, G, BG, B, PB, P, RP.
5. Rosette. Red cross in centre, green leaves: blue field, black outline. Vary as in No. 2.
6. Rosette. Green centre and edge of leaves, purple field and black accents. Vary color of centre, keeping field two colors distant.
7. Plaid. Use any three crayons with black. Vary the trio.
8. Folding screen. Yellow field (lightly applied), green and black edge. Make lighter and darker values of each color, and arrange in scales graded from black to white.
9. Rug. Light red field with solid red centre, border pattern and edges of gray. This is called self-color. Change to each of the crayons.

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10. Rug. Light yellow field and solid centre, with purple and black in border design. Vary by change of ground, keeping design two colors distant and darkened with black.
11. Lattice. Yellow with black: alternate green and blue lozenges. Vary by keeping the lozenges of two neighboring colors, but one color removed from that of the lattice.

For principles involved in these color groups, see [Chapter III](#).

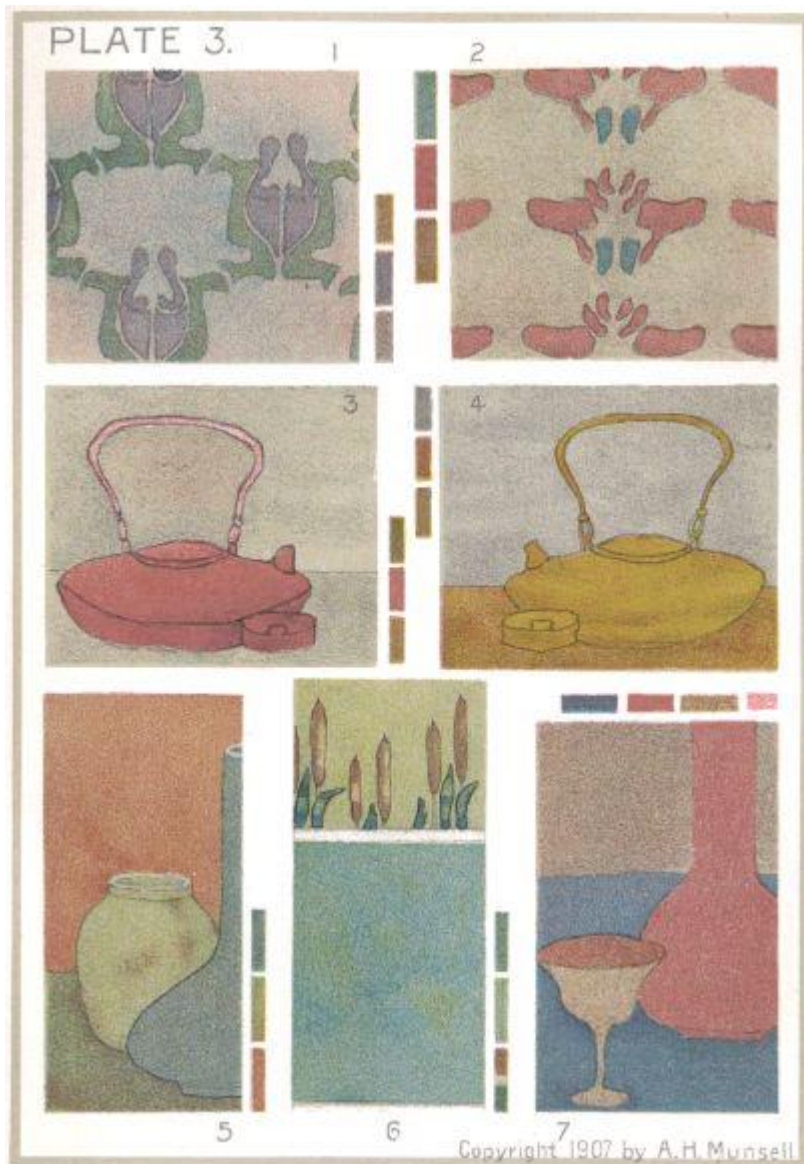


PLATE III.

Color Studies with TUNED WATER COLORS in the Upper Grades.

Previous work with measured scales, made by the tuned crayons and tested by reference to the color sphere, have so trained the color judgment that children may now be trusted with more flexible material. They have memorized the equable degrees of color on the equator of the sphere, and found how lighter colors may balance darker colors, how small areas of stronger chroma may be balanced by larger masses of weaker chroma, and in general gained a disciplined color sense. Definite impressions and clear thinking have taken the place of guess-work and blundering.

Thus, before reaching the secondary school, they are put in possession of the color faculty by a system and notation similar to that which was devised centuries ago for the musical sense. No system, however logical, will produce the artist, but every artist needs some systematic training at the outset, and this simple method by measured scales is believed to be the best yet devised.

Each example on this plate may be made the basis of many variants, by small changes in the color steps, as suggested in the 65text, and further elaborated in [Chapter VI](#). Indeed, the studies reproduced on Plates II. and III. are but a handful among hundreds of pleasing results produced in a single school. [26](#)

1. Pattern. Purple and green: the two united and thinned with water will give the ground. Vary with any other color pair.
2. Pattern. Figure in middle red, with darker blue-green accent. Ground of middle yellow, grayed with slight addition of the red and green. Vary with purple in place of blue-green.
3. Japanese teapot. Middle red, with background of lighter yellow and foreground of grayed middle yellow.
4. Variant on No. 3. Middle yellow, with slight addition of green. Foreground the same, with more red, and background of middle gray.
5. Group. Background of yellow-red, lighter vase in yellow-green, and darker vase of green, with slight addition of black. Vary by inversion of the colors in ground and darker vase.
6. Wall decoration. Frieze pattern made of cat-tails and leaves,—the leaves of blue-green with black, tails of yellow-red with black, and ground of the two colors united and thinned with water. Wall of blue-green, slightly grayed by additions of the two colors in the frieze. Dado could be a match of the cat-tails slightly grayer. See [Fig. 23](#), *page 82*.
7. Group. Foreground in purple-blue, grayed with black. Vase of purple-red, and background in lighter yellow-red, grayed.

For analysis of the groups and means of recording them, see [Chapter III](#).

[23](#). See Century Dictionary for definition of chroma. Under the word “color” will be found definitions of Primary, Complementary, Constants (chroma, luminosity, and hue), and the Young-Helmholtz theory of color-sensation.

[24.](#) It must not be assumed because so much stress is laid upon quiet and harmonious color that this system excludes the more powerful degrees. To do so would forfeit its claim to completeness. A Color Atlas in preparation displays all known degrees of pigment color arranged in measured scales of Hue, Value, and Chroma.

[25.](#) See [Appendix to Chapter III.](#)

[26.](#) The Pope School, Somerville, Mass.

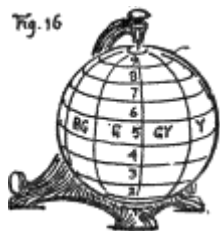
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Chapter V.

A PIGMENT COLOR SPHERE.[27](#)

How to make a color sphere with pigments.

(102) The preceding chapters have built up an ideal color solid, in which every sensation of color finds its place and is clearly named by its degree of hue, value, and chroma.



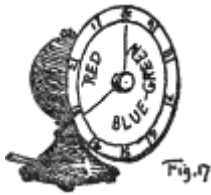
It has been shown that the neutral centre of the system is a balancing point for all colors, that a line through this centre finds opposite colors which balance and complement each other; and we are now ready to make a practical application, carrying out these ideal relations of color as far as pigments will permit in a color sphere[27](#) (Fig. 16).

(103) The materials are quite simple. First a colorless globe, mounted so as to spin freely on its axis. Then a measured scale of value, specially devised for this purpose, obtained by the daylight photometer.[28](#) Next a set of carefully chosen pigments, whose reasonable permanence has been tested by long use, and which are prepared so that they will not glisten when spread on the surface of the globe, but give a uniformly mat surface. A glass palette, palette knife, and some fine brushes complete the list.

(104) Here is a list of the paints arranged in pairs to represent 67the five sets of opposite hues described in Chapter III., paragraphs [61–63](#):—

<i>Color Pairs.</i>	<i>Pigments Used.</i>	<i>Chemical Nature.</i>
Red and Blue-green.	Venetian red.	Calcined native earth.
Yellow and Purple-blue.	Viridian and Cobalt.	Chromium sesquioxide.
Green and Red-purple.	Raw Sienna.	Native earth.
Blue and Yellow-red.	Ultramarine.	Artificial product.
Purple and Green-yellow.	Emerald green.	Arsenate of copper.
	Purple madder.	Extract of the madder plant.
	Cobalt.	Oxide of cobalt with alumina.
	Orange cadmium.	Sulphide of cadmium.
	Madder and cobalt.	See each pigment above.
	Emerald green and Sienna.	See each pigment above.

(105) These paints have various degrees of hue, value, and chroma, but can be tempered by additions of the neutrals, zinc white and ivory black, until each is brought to a middle value and tested on the value scale. After each pair has been thus balanced, they are painted in their appropriate spaces on the globe, forming an equator of balanced hues.



(106) The method of proving this balance has already been suggested in Chapter IV., paragraph [93](#). It consists of an ingenious implement devised by Clerk-Maxwell, which gives us a result of mixing colors without the chemical risks of letting them come in contact, and also measures accurately the quantity of each which is used (Fig. 17).

(107) This is called a Maxwell disc, and is nothing more than a circle of firm cardboard, pierced with a central hole to fit the spindle of a rotary motor, and with a radial slit from rim to centre, so that another disc may be slid over the first to cover any desired fraction of its surface. Let us paint one of these discs with Venetian red and the other with viridian and cobalt, the first pair in the list of pigments to be used on the globe.

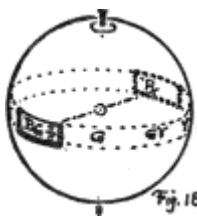
(108) Having dried these two discs, one is combined with the other on the motor shaft so that each color occupies half the circle. As soon as the motor starts, the two colors are no longer distinguished, and rapid rotation melts them so perfectly that the eye sees a new color, due to their mixture on the retina. This new color is a reddish gray, showing that the red is more chromatic than the blue-green. But by stopping the motor and sliding the green disc to cover more of the red one, there comes a point where rotation melts them into a perfectly neutral gray. No hint of either hue remains, and the pair is said to balance.

(109) Since this balance has been obtained by *unequal areas* of the two pigments, it must compensate for a lack of equal chroma in the hues (see paragraphs [76, 77](#)); and, to measure this inequality, a slightly larger disc, with decimal divisions on its rim, is placed back of the two painted ones. If this scale shows the red as occupying $3\frac{1}{3}$ parts of the area, while blue-green occupies $6\frac{2}{3}$ parts, then the blue-green must be only half as chromatic as the red, since it takes twice as much to produce the balance.

(110) The red is then grayed (diminished in chroma by additions of a middle gray) until it can occupy half the circle, with blue-green on the remaining half, and still produce neutrality when mixed by rotation. Each disc now reads 5 on the decimal scale. Lest the graying of red should have disturbed its value, it is again tested on the photometric scale, and reads 4.7, showing it has been slightly darkened by the graying process. A little white is therefore added until its value is restored to 5.

(111) The two opposites are now completely balanced, for they are equal in value (5), equal in chroma (5), and have proved their equality as complements by uniting in equal areas to form a neutral mixture. It only remains to apply them in their proper position on the sphere.

(112) A band is traced around the equator, divided in ten equal spaces, and lettered R, YR, Y, GY, G, BG, B, PB, P, and RP (see Fig. 18). This balanced red and blue-green are applied with the brush to spaces marked R and BG, care being taken to fill, but not to overstep the bounds, and the color laid absolutely flat, that no unevenness of value or chroma may disturb the balance.



(113) The next pair, represented by Raw Sienna and Ultramarine, is similarly brought to middle value, balanced by equal areas on the Maxwell discs, and, when correct in each quality, is painted in the spaces Y and PB. Emerald Green and Purple Madder, which form the next pigment pair, are similarly tempered, proved, and applied, followed by the two remaining pairs, until the equator of the globe presents its ten equal steps of middle hues.

An equator of ten balanced hues.

(114) Ahora viene la prueba total de este circuito de tonos equilibrados por rotación de la esfera. A medida que gana velocidad, los colores parpadean cada vez menos, y finalmente se funden en un gris medio de neutralidad perfecta. Si hubiera fallado produciendo este gris y mostrando un matiz de cualquier tono que aún persista, nosotros debería decir que el tono persistente estaba en exceso o, por el contrario, que su tono opuesto carecía de croma y no preservaba su Comparte el resto.

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(115) Por ejemplo, si la rotación hubiera descubierto la persistencia del gris rojizo, habría demostrado que el rojo era demasiado fuerte, o su opuesto, azul-verde, demasiado débiles, y deberíamos habernos visto obligados a retroceder, aplicando una corrección hasta que se estableciera la neutralidad mediante la prueba de rotación.

(116) Esta es la demostración práctica de la afirmación (Capítulo I., párrafo [8](#)) que *un color tiene tres dimensiones que pueden medirse*. Cada uno de estos diez tonos medios tiene demostró su derecho a un lugar definido en el globo de color por su Medidas de valor y croma. Siendo de crominancia igual, todos son equidistantes del centro neutral y, siendo iguales en valor, todas son igualmente alejados de los polos. Si los tonos cálidos (rojo y amarillo) o el Los tonos fríos (azul y verde) estaban en exceso, la prueba de rotación del la esfera no produciría grises, y por tanto detectaría su falta de Equilibrio. [29](#)

Un diapasón cromático.

(117) Los cinco pasos principales en este ecuador de color se realizan en permanentes esmalte y cuidadosamente protegido, para que, si los pigmentos se pintaban Si el globo cambia o se ensucia, podría detectarse de inmediato y bien

colocado. Estos cinco son rojos medios (llamados así porque midway entre blanco y negro, así como a medio camino entre nuestro rojo más fuerte y el centro neutro), amarillo medio, verde medio, azul medio, y morado medio. Pueden llamarse el DIAPASÓN CROMATICO, ya que sirven para establecer el tono de colores, ya que el diapasón musical preserva la afinación de sonidos.