

## SYSTEMS OF COLOR STANDARDS.

BY

A. AMES, JR.

THE principal object of a color standard is to have some means by which the color of any object can be determined. This can be done either by an instrument such as a colorimeter or a standard composed of colored cards. As any instrument is too complicated for general use, only those standards composed of colored cards will be considered in this paper.

The purpose of a color standard and requisites to which it must conform will be first considered, after which the good points and defects of various standards will be taken up.

As was stated, the principal object of a color standard is to have some means by which the color of any object we may happen across can be determined. To do this it is necessary that the cards in the standard be properly arranged so that we can find as easily as possible the card similar to the color in question. As in most instances we wish to record what that particular color is we should have the simplest and best nomenclature. There should moreover be a sufficient number of cards, so that we can find any color. As such a number of cards will tend to make the standard bulky, it should contain the largest possible range of colors with the fewest cards. And last, though very important, every color in the standard should be based on exact measurements, so that people at other times and places will know exactly the color of any card we may designate.

This makes five requisites which a color standard of this kind must satisfy. First, *Arrangement*. It must be such that it is as easy as possible to find any desired color in the standard; that is, such that you know a color's particular position in the standard and its direction from any other color. Second, *Notation or Nomenclature*. The notation of the different cards must be as simple as possible. It should call to mind a particular color and only that color, and should designate its particular position in the standard. Third, *Number*. There should be a sufficient number of cards, so that the color of any object can be closely matched. Fourth, *Spacing*. The spacing between the cards in all parts of

the standard should be the same. With even spacing between all the cards a standard with a given number of cards will have the greatest usefulness. Fifth, *Standardization*. The exact nature of the color in every card should be determined by accurate measurement, so that when a particular card is named its particular color and no other will be designated. Furthermore, such notation and measurements should be universally accepted, so that a particular color will mean the same thing to all peoples at all times.

These five requisites will now be considered in more detail.

#### ARRANGEMENT.

All colors lie in a natural arrangement to each other, due to the three constants which every color possesses. These are, first, Hue (or wave-length); second, Chroma (saturation); third, Value (brightness).

We are indebted to Munsell for the most complete presentation of their mutual arrangement due to these three constants. He shows their arrangement is in the form of a color solid, roughly spherical in shape. Steps around the horizontal equator give differences in hue or wave-length. Planes at different heights along the vertical axis give different steps in value or brightness, white at the top, black at the bottom. Radial distances from this vertical axis give differences in chroma or saturation.

For practical reasons the cards in a color standard must be arranged on a sheet, *i.e.*, on a two-dimensional surface. It therefore becomes necessary to decide what arrangement there exists in a two-dimensional surface of this color solid which is most suitable for our purpose. It would seem without question to be best to use that grouping which would leave one of the color constants unchanged and the other two variable. Three such groupings, however, can be obtained in a two-dimensional surface.

You can get a grouping in which the hue or wave-length remains constant and the value and chroma change, as by taking a vertical plane from the axis outward. Or you can keep the value constant with the color and saturation changing by taking horizontal planes. Or you can keep the chroma constant with varying color and value by taking cylindrical surfaces at different distances from the axis.

The first grouping seems without question the best. Because,

when we see a color we always think first of its hue or wave-length. Value and chroma are qualifying factors.

The best arrangement therefore is to have all the colors of the same hue or wave-length on one chart or page. We would have then a series of such charts, as many as we wished different hues in our standard. On all of these charts the lines of cards which were on the same level from the top would have the same value. Those lines of cards which were the same distance from the sides would have the same chroma. With the three constants of a given color in mind such an arrangement enables one to find it very easily; in fact, leads one directly to it.

#### NOTATIONS OR NOMENCLATURE.

The color names in ordinary use are of practically no help, due to the fact that they are too general and in themselves designate no particular color, except to those who have arbitrarily learned to associate them with some particular color.

Every color has the three constants of hue, chroma and value. If any one of these constants is varied the color is varied. A color therefore can be absolutely specifically designated if its hue, chroma and value are given. Here again we are indebted to Munsell for giving us a most convenient way of doing this. The first constant, hue, he designates by a letter; for example, R for red or B for blue. The second constant, value, he designates by a number above a line to the right of the letter; the third constant, chroma, by a number below this line. For example, R 6/5 gives all three constants and determines the color. When you see such a notation you think first of red, then you notice the figure six and realize it is a little above middle value. The figure five tells you that its chroma is half-way between a neutral gray and a full chroma red. A very definite color is thus brought to your mind.

An improvement that could be made in this notation would be in the matter of the letters used to designate the hue. In a color standard there should be at least thirty or forty different hues. The words in common use to designate hue are yellow, orange, red, purple, blue and green. We can get definite hue notation if we qualify one of these words by another. That will give us all together twelve names: yellow, yellow orange, orange, etc. This, however, is not enough to cover the necessary hues. It

is possible to still further increase the number in two ways. First, by considering the last part of the combined word as the noun and the first part as the qualifying adjective and adding between yellow and yellow orange, for instance, the name "orange yellow," which would be a yellower hue than "yellow orange." After having used this notation for many years in my own system I am convinced it is very poor. When I come across it I always have to stop and think which is yellowest in hue, "yellow orange" or "orange yellow." Moreover, this adds only six more names, which does not give us enough. Second, the name could be repeated as "yellow yellow orange." But such a notation is subject to the criticism made above.

It is believed the best notation would be to use the simple and simple compound names, yellow, yellow orange, orange, etc., followed by the wave-length of the hue. The name or initial would give the general hue, the number the exact hue. The decrease in size of the number would suggest shorter wave-length and a hue slightly towards the blue end of the spectrum.

As there are no wave-lengths covering the purple region, an arbitrary set of numbers covering the least perceptible differences could be used in this region.

There is some question as to whether there is any necessity of using the letters placed before the wave-length number to designate the general hue.

The objections to the use of such letters are: that anyone using a standard would learn to know the hues by the number of their wave-length and that the letters therefore are unnecessary. That as words designating hue designate no particular wave-length, and as there are not enough of them to designate all the necessary hues, it would be better to develop the practise of thinking of hue in terms of wave-length and abandon the old names for hue.

The arguments in favor of the use of letters to designate the general hue are that the majority of persons using a color standard would not learn to know the hues by the number of their wave-length and that general designations by a symbol would be helpful, for although words designating hue do not designate particular wave-lengths, yet they do universally designate regions in the spectrum. That it would be impossible to ever develop a universal practice of thinking of hues in terms of wave-lengths. That the old names for hue are so universally accepted that they

will always be used and that it would be best to assign them to particular regions in the spectrum.

#### NUMBER OF CARDS.

A color standard to be of practical use must have a sufficient number of different cards, so that the color of any object can be closely matched. The degree of closeness of course varies according to what use the system is put. But for all scientific purposes, biological, for instance, and for use in mercantile business, matching textiles, arts, etc., it should be pretty close. The ideal standard set would be one in which the number of cards was such that the difference between any card and the card next to it was two least perceptible differences. The color of any object lying between cards with a separation equal to two least perceptible differences would appear like one or the other of the cards unless it lay half-way between them. Its color would therefore be definitely determined and it could be designated as lying half-way between such cards.

The least perceptible differences in the three constants under the best conditions are roughly such that we can distinguish one hundred and fifty steps in hue, two hundred steps in value, one hundred steps in chroma. The least perceptible difference between small cards such as must be used in a color standard is, however, much greater than those given above. For instance, in the set of grays which the writer made up containing sixty steps, the difference between the cards is just about perceptible. It is these larger, least perceptible, differences which should be used as the basis of the separation of a standard of cards. I should roughly estimate them to be between two and three times as great as that which you can get under the most favorable conditions. This would give from fifty to eighty steps in hue, seventy to one hundred steps in value and thirty-five to fifty steps in chroma. If the cards are separated by two such perceptible differences, we would have from twenty-five to forty steps in hue, thirty-five to fifty steps in value and sixteen to twenty-five steps in chroma. This would give a total number of about thirteen thousand different cards. It would be advisable to furnish sets with separations of three or four, or more least perceptible differences between the cards, the different standards being supplied according to the use to which they would be put.

## SPACING.

Whatever degree of separation is used, it should be the same throughout the entire system. That is, if the difference in value between a card and the next one above or below it was two least perceptible differences, the differences in chroma between that card and the next one to the left, or the right of it, should be the same. Also the difference in hue between the cards on one chart or page from those on the next chart or page should be the same.

The data on least perceptible differences in value or brightness have been worked out by many investigators, which makes this spacing easily determined. The least perceptible difference in hue in the spectrum have been very definitely determined for a limited number of observers by A. L. Jones.<sup>1</sup> It is believed, however, that it should be worked out for a large number of observers before it will be sufficiently definitely determined to use in making up a color standard.

In regard to spacing in chroma, although some data have been collected of the least perceptible differences in that constant, the best by Geissler,<sup>2</sup> it is not sufficient for the purpose. Further measurements would have to be made to determine the average least perceptible differences in this constant. This, however, would not be a difficult or long job, as the path has been blazed and methods established.

## STANDARDIZATION.

The three constants of every card in the standard should be determined by the most accurate measurement. The best way to do this would be to first calculate in the three constants of hue, value and chroma; *i.e.*, wave-length, intensity and saturation or the amount of white light added, just what every card in the standard should be. Then these combinations should be obtained by means of a colorimeter with a standard light source in a standard illumination. Finally the cards should be made to match these predetermined combinations obtained with the colorimeter. The spectral curves of the color patches obtained by the colorimeter should be determined as should those of the various cards. If

<sup>1</sup> JOURNAL OPT. SOC. OF AMER., Vol. 1, Nos. 2 and 3, March-May, 1917.

<sup>2</sup> *Amer. Jour. of Psych.*, 1913, 24, p. 171; see also Luckiesh: *Color and Its Applications* (Van Nostrand), p. 127.

possible those of the cards should be made similar to those obtained by the colorimeter. The determination of the spectral curves of the cards would not be so difficult as might appear. For if, as suggested, all the cards on each page of the standard were various values and chromas of the same hue, they would be obtained by mixing white and black paint with the saturated pigment of that hue. If the spectral curve of the saturated pigment was determined, the curves of all the other cards on that page would be of the same type. This work should preferably be done by some government bureau, as the Bureau of Standards, and the colorimeter kept by them as the standard. A set of measurements of every card in the standard should accompany the standard.

Various color standards will now be considered, bearing in mind the above-mentioned requisites.

#### RIDGWAY'S.

Ridgway's system<sup>3</sup> is probably the most used to-day, and on the whole is believed to be the best system. It is defective, however, in that it satisfies but one of the aforementioned requisites of a perfect color standard.

First, *Arrangement*. It is defective in that he has grouped together in one page the fully saturated red, orange red and orange orange red, of all values from lightest to the darkest. On the next page he has red orange, orange red orange and orange, and so on around the spectrum. On later pages he has the same colors similarly grouped, but one step less in saturation. That is, on any one page he has different hues, chromas, and values; in other words, all three of the color constants are varying.

Further, different vertical lines of cards give differences in hue, but nothing in his arrangement gives differences in chroma or value. The chroma on a single sheet varies, because in mixing white or black with his pure color to get his differences in value he also gets differences in chroma in the same vertical line. And by putting all his fully saturated colors in the same horizontal line, *i.e.*, the fifth from the top, he varies his values because a full chroma yellow, for instance, is much lighter in value than a full chroma red.

Second, *Nomenclature*. The color names he uses are too

---

<sup>3</sup> "Color Standards and Color Nomenclature," Robert Ridgway, Washington, D. C., 1912.

general and do not materially help to designate the exact color. The letters and numbers he uses are subject to the following criticism: He has the hues both lettered and numbered, his lettering being complicated and his numbering arbitrary. He begins with number one for red and goes to seventy-one for violet red red. Accompanying these numbers he has letters. From orange to yellow, for instance, they run as follows: OY-O, Y-O, OY, YO-Y.OYY. This notation is clearly confusing. The different values he designates by small letters, beginning with (a) in middle value he designates the lighter values by (b), (d), (f), and the darker values by (i), (k), (m), differentiating between tints and shades. The different chromas he designates by dashes above the number for hue, one dash (') designating one step from full saturation, two dashes (") two steps, etc. It is evident that this is a very complicated notation.

Third, *Number of Cards*. In all he has one thousand one hundred and fifteen different cards. This number is too small. Defective arrangement and notation can be surmounted, but there is no way to make up for an insufficient number of cards.

Fourth, *Spacing*. His spacing is not even, primarily due to his faulty arrangement of putting all full chromed colors in the middle of his value scale. He gets, for instance, the same number of steps from yellow to white that he does from blue to white, and the yellow is much lighter than the blue. Even the spacing of his hues is not as even as can be determined by present scientific methods, Jones.<sup>4</sup>

Fifth, *Standardization*. We have Ridgway to thank for the best standardization as far as I know up to date. He based his colors on combinations from the Maxwell color disk. His data cover the spacing for all three constants and fulfill all the requirements of standardization. With the means he used it could not be improved upon. It is believed it would be much better, however, to obtain the various combinations of color constants by direct mixtures of light with a colorimeter. In the last analysis he has to base his six fundamental hues on wave-lengths. It would seem best therefore to start with actual wave-lengths, getting the various values and chromas by changing the intensity and adding white light.

---

<sup>4</sup> *Loc. cit.*

## MUNSELL.

Munsell's system,<sup>5</sup> which has been developed since Ridgway's, is in some of the requisites better, some worse, than Ridgway's.

First, *Arrangement*. Its arrangement, which has already been described, cannot be improved upon.

Second, *Nomenclature*. His nomenclature, as far as it goes, is also, it is believed, as good as can be devised. It is wanting only in that it does not give any suggestion as to how the intermediate hues between his eleven standard ones should be designated.

Third, *Number of Cards*. As a complete color system, for which I do not believe he intended it to be, it falls down in that there are not enough different colors in the system. He only has eleven different hues, as compared with Ridgway's thirty-six.

Fourth, *Spacing*. His spacing is not the same throughout the system, that between hues being greater than those between value and chroma. His spacing between values and chromas looks very good indeed. Priest, *et al.*,<sup>6</sup> have shown, however, that his series of values is not in accord with the natural system expressed by Weber's law.

Fifth, *Standardization*. Munsell gives no specific account as to what measurements his colors are based upon. His system, therefore, fails in this requisite, although the examination of his system by Priest *et al.*<sup>7</sup> goes a long way towards meeting this deficiency.

## AMES.

This standard, which is in triplicate and has never been published, was made by the writer and his sister, Mrs. Oakes Ames, before Ridgway's last edition came out and before Munsell completed his work. It was made as an assistance in painting to make exact color reproductions of scenes. The method was to match the color seen by holding up a card, noting the color on the canvas, and after the whole scene had been matched putting in the paints from the color notations. It contains twenty-seven hues, fifteen steps in value and ten steps in chroma for each hue, making in all about thirty-three hundred different cards. It fulfilled

---

<sup>5</sup> "Atlas of the Munsell Color System," Wadsworth, Howland & Co., Boston, Mass.

<sup>6</sup> *Technol. Papers, Bureau of Standards, No. 167, Sept., 1920.*

<sup>7</sup> *Loc. cit.*

every requirement expected of it. It has, however, marked defects and can be much improved upon. It will be considered in view of the five requisites of a perfect color standard.

First, *Arrangement*. The arrangement, which was in general after Munsell, cannot be improved upon, except in so far as it does not follow Munsell. That is, in the following particulars: First, all the fully saturated colors are put ten steps out from gray. For example, there are ten steps from a fully saturated red to gray and the same number from a fully saturated green to gray. Now a fully saturated red is much stronger in chroma than a fully saturated green. The arrangement, therefore, is wrong. Second, vertical lines at an equal distance from the side of the page do not designate the same chroma. This is due to the fact that in making lighter values of a saturated color we mixed white with them and kept them in the same vertical line as the saturated color, although of course their saturation was reduced by the added mixture of white.

Second, *Notation*. The notation which followed Munsell is very good, except in the designation of the hues. Names as orange yellow and yellow orange were used which, as has been said before, are confusing. The use to which the standard has been put most thoroughly tested and proved the value of Munsell's method of notation, *i.e.*, a designation for each color constant.

Third, *Number of Cards*. The total number of cards in the standard is about thirty-three hundred. In this particular it is markedly superior to the other standards. From all my experience, however, it is believed the number should be increased.

Fourth, *Spacing*. The spacing between values and chromas is about right, but there should be more hues in certain sections of the spectrum. The spacing, however, is not the same throughout the system. This is due to the poor arrangement above spoken of. The spacing in the green chart is not as great as that in the red, and the spacing in the lighter values of the red chart is not as great as it is in the lower part. If the spacings were the same throughout the system would have its same usefulness with about one-third less cards.

The spacing in value was carefully worked out with Maxwell disks, taking into account Fechner's law, and though it has not been measured, gives, it is believed, substantially even steps in sensation. The spacing in hue and chroma was done only by eye.

Fifth, *Standardization*. In this requisite the system falls down entirely. Every card can be duplicated from a tube of color which matches it, but this in no way fulfills the demands of this requisite.

The arrangement of the colors on separate cards that can be taken out of the sheets has proved to be of the greatest convenience, as it makes it possible to match surfaces that cannot be brought into juxtaposition with the different parts of the sheet.

#### JORGENSEN.

Jorgensen's work<sup>8</sup> cannot really be considered a standard for the purposes above described. He gives, however, a suggestion that might be of value in making up a color standard. That is to have the different values and chromas of each hue gradually blend into one another, the value and chroma being designated by a scale at the top and side of each chart. I imagine this would have to be done by some printing process, and I am not sufficiently conversant with the technique of color printing to know whether or not it would be possible. The great advantages of such a method, in that it would give all of the colors and in the smallest possible space and at an enormously reduced cost, seem to make it at least worth considering.

#### CONCLUSION.

The demand for a perfect standard color system is very great and from innumerable branches of activity, art, sciences, manufacturers, retailers.

The lines of procedure and work necessary to produce a standard system have been pretty definitely laid out.

The only reason for delay is the lack of sufficient number of individual determinations of the least perceptible differences in hue and chroma. It is most earnestly advised that these determinations be made by various laboratories and as soon as possible, in order that the great need for a proper color standard can be met.

WILDER LABORATORY,  
DARTMOUTH COLLEGE,  
HANOVER, N. H.

---

<sup>8</sup> "The Mastery of Color," C. J. Jorgensen, Milwaukee, 1906.