THESS

C. H. BLACKALL.

COLOR
Introduction:

This production is partly original and partly produced from standard works upon the subject. The authorities consulted have been Michelon, Von Bezold, "Theory of color," Chevreul, "Laws of contrast of color," Christopher Dresser, "Principles of decorative design," Guimet, "Elements of Physics," and Racinet, "Ornament Polychrome." An attempt has been made, however, to arrive at conclusions independently of any particular authorities, and to present the subject as it is presented to the eye—in its true light.

The pigments used in representing the various colors were the ordinary powdered water colors, with one or two exceptions. Of course it is simply impossible to represent the spectral colors with pigments, but the plates can give a pretty clear idea of what they are intended to represent, and a good imagination can supply the rest.

In this Thesis an attempt has been made to record the theory of some benefits in the practical application of colors so that some of the theories advanced in regards to spectral color, may be realized in the combinations and contrasts of pigments.

Illinois Industrial University
June 6, 1877
1. Spectral Colors.

The most practical men have their theories, and it frequently happens
that the most practical men have theories which agree the least with direct
evidence. Several theories have been advanced to explain the actions
and reactions of color, but only within the last few years has any thing
like a satisfactory theory been proposed. Chevreul, a French Chemist
was one of the first to fix any laws or rules relating to color. Young in 1802
advanced some speculations as to the optic effects of color, assuming
that the retina contained but three sets of color nerves—red, yellow, and blue,
and that other colors are formed by two or all being excited simultaneously.
Chevreul also assumed three fundamental colors, red, yellow, and blue,
and that from these all colors could be produced by mixing in the proper
proportions. When these three are mixed in certain fixed ratios, they will
produce white. These proportions Chevreul assumed to be about Blue 7,
Red 5, Yellow 3. One of the best proofs of the correctness of this assumption
was considered to be the fact that by placing these colors in the above
proportions as sectors of a disc, which was caused to rotate rapidly, the
disc assumed an almost greyish appearance, closely approaching to white.
This experiment was performed in the laboratory, and the color obtained
is represented on Plate I. But there are objections to this theory, the principal
Plate 1.
Color disc.
which is that it is based upon the actions of pigment colors upon each other, and as pigments will always exert some chemical action upon each other, they can not truly represent pure colors. Experimentally, this theory can be shown to be lacking. If the theory were true, the same color should result by mixing two colors, as by viewing them simultaneously. This is shown on Plate 2, where the effects of yellow and blue were combined by ruling blue lines upon the yellow and yellow lines upon the blue; the two pigments were also combined by mixture, with the result as shown. The effect produced by the lining can be seen to be quite different from that produced by mixing. The same was also tried with red and blue. Also according to the common theory, yellow and blue give green, whereas the color obtained is far from being green and closely approaches white, as shown on Plate 3. Other combinations are also shown on the same plate. These results were obtained by the combinations of spectral colors. With spectral colors, these results are actual combinations, whereas when pigment blue and pigment yellow are mixed they produce a green, but as Gouy says, it is a case of subtraction of colors, and not of addition. For in the pigment mixture, the blue absorbs almost entirely the yellow and red light, and the pigment yellow absorbs the blue and violet, so that only the green remains.

Still this theory has many good points, and has been of great use in
PLATE 2.

Mixtures of Pigments.
the mixing and applying of pigment colors, and if laws can be de-
duced relating to the subtractive powers of pigments, it is evident that
they could be as readily used as laws relating to mixtures of pigments.
But pigments as act upon each other that there would always be a great
many exceptions to the rules. Of late years physicists have taken hold
of the subject, and have endeavored to scientifically investigate this
point. At present the best authorities give the primaries as Red,
Green, and Bluish Violet. If white light be slightly decomposed by a
prism these colors will appear quite plainly. The best statement of the
new theory is given in Wilhelm von Bezold's "Theory of Color," and in this
thesis this work has been taken as the best authority upon the subject.

The light of the sun, as we view it, is white, and although we
are accustomed to speak of the golden sunlight, the light from a magne-
slime-lamp, which is undoubtedly white, appears almost yellow when
viewed by strong sunlight. Then light strikes an object, some of the
rays are absorbed by it, and the remainder is sent off to the eye of the
beholder. These reflected or transmitted rays determine the color of
the substance. Thus grass absorbs all but the green parts of light,
whereas we say its color is green. Lampblack absorbs all the rays,
whence it has no color, which condition we express by calling it black,
in opposition to white, which is assumed to be a mixture of all colors.
To prove that white is really a mixture of all colors, if a ray of light be passed through a prism, (Fig. 1.) it will be decomposed on emerging. If now a second prism B, exactly similar to A, be placed so as to catch all of the refracted rays, as shown, the light in traversing it will be recombined, and will emerge a ray of white light, N, parallel to the incident ray AB.

For studying the spectra, the following arrangement was used, (Fig. 2.) The light of the sun, collected by a heliostat, was made to fall through a narrow slit, S, into a darkened room. The light was then passed through a glass prism, was decomposed, and appeared spread out upon the ceiling at R, V.

Examining the spectra thus obtained, the prominent colors are found to be Red, Bluish green, and Bluish violet, but a closer examination showed the presence of the colors red, orange, yellow, yellowish green, green, bluish green, turquoise blue, ultramarine, and violet. These divisions are however purely arbitrary since the colors are so
Plate 4.
Colors of the Spectrum
Complementaries
Blended and run together that it is impossible to say just where one color begins and another ends, whence we have an infinite number of tints ranging from deep red to purple. It is of course impossible to exactly match the colors, but some of them have close analogy to pigment colors. Thus the red may be represented quite accurately by Scarlet Vermillion; the orange approximately by Neutral Orange; Chrome yellow, especially in the powder form, is an excellent representative of the aper- from yellow. The green closely resembles the color of a solution of sulphate of iron, and the turquoise blue is so called from its resemblance to the stone color of the stone of that name which may be matched by sulphate of copper in weak solution. Burnt Carmine will give a good idea of the purple or violet of the spectra, though these colors are best matched by mixtures of Carmine and Ultramarine dispersing colors. The powder Ultramarine gives almost a pure blue. These colors are represented in their order on Plate 4.

The terms primary, secondary, and tertiary can not be employed with propriety in speaking of spectral combinations, as all of the nine colors are primary. Complementary colors can however be very readily determined. Two colors are complementary to each other when by combination of the two, white is produced. The way in which the complementsaries were determined was as follows. (Fig. 3.) The
light enters through a slit at S, passes through a prism P, and is thereby decomposed; the scattered rays are then collected by a double convex lens L which focuses them on the screen N at V, producing a white image of the slit. Now if a prism with a very sharp edge be inserted in the cone of rays, as at P, part of the rays will be deflected, and without sensible dispersion, will be focused at a point R on the screen. Now it is evident that both will appear colored, and that the color of one will be what the other lacks in order to make white, or the two will be exact complementsaries. Proceeding in this way it was found that when R was red, V was blue; green; when R was yellow, V was violet. etc. The complementary colors are represented on Plate 4.

A great many very interesting experiments can be performed by the use of the prism and decomposed light, but most of them are of little value to the practical colorist, and have hence not been treated here. A few other experiments will be referred to furtheron.
2. Pigment Colors.

At the very outset of the study of pigment colors we are met with the question, what are pure colors, what are the best representatives of the colors of the spectrum? It is impossible to answer this conclusively, but there are means of determining whether certain pigments give colors corresponding to similar colors of the spectrum. As previously stated, the color of any thing, is determined by the rays reflected or transmitted to the eye, whence a blue object absorbs all but the blue rays, etc. As most pigments are too opaque to be observed by transmitted light, they must be examined by reflected light. If the solar spectrum be allowed to fall upon a screen painted with the color it is wished to examine, carmine for instance, if it is a pure color, all the spectral colors will be absorbed except the red, which will take its appearance much intensified. This experiment was tried in the laboratory, with the following results. Carmine appeared black under all the spectral colors except red. Ultramarine gave a similar result with regard to the blue, tho not as decided as with the red. Chrome yellow evidently closely corresponded to the spectrum yellow, but was less pure than either of the others in appearance, which fact was probably caused by the delicacy of the color, rendering it easily destroyed.
Hence we may consider Carmine, Ultramarine blue, and chrome yellow to be pure colors, corresponding to the similar ones in the solar spectrum. Other colors were tried, but with no satisfactory results. Emerald green is too yellow for green, and Prussian Blue too green for Turquoise Bleed; etc. These three colors are however sufficient for most experiments, as from these with additions of white or black, almost any hue or tint may be obtained by mixture.

Notwithstanding its numerous defects, the common theory of color is exceedingly useful as it is based upon the action of pigments. Its chief use however is in the mixing of colors, while von Reylé's theories are much more practical for determining harmonies. By an examination of Plate 4, it will be seen that the complementsaries are separated from each other by four colors, whence von Reylé has constructed a color chart, as represented on Plate 5, Figure 1, by arranging the nine colors around a circle, adding purple to connect the two. In this diagram it will be seen that the complementsaries are diametrically opposite to each other. Hence, if we have a color between red and orange, as Vermillion, for instance, we can see that its complementsary should be between greenish blue and Turquoise blue. This would seem to be very useful, but there is one difficulty about it. Ideas of harmony are dependent upon the state of the human mind, and, like taste in art, are influenced by
Plate 5.
Von Bezold's Color Charts.
Jackson to a great extent. Thus combinations of color which to the Assyrian or Egyptians would have seemed perfect to us present anything but harmony, as green and blue which are often found in Assyrian art. Von Gagold also noticed that the color in his ten division diagram were not all separated by the same intervals, that is the difference between red and orange was twice that between orange and yellow – the difference being due to the difference in the number of vibrations of ether which produced the color. He therefore divided red into Carmine and Vermillion, and Violet into Bluish violet and Turkish violet, and arranged the colors in their order around the circle as represented on Plate 5, fig. 2. The colors which give the best harmony are those found diametrically opposite, as before. They are: Purple and Green, Vermillion and Turquoise Blue.; Yellow and Bluish Violet, Carmine and Blush; Purple and Ultramarine, Yellowish green, and Prussian blue.

An examination of historical ornament will show that the above combinations have been and are still extensively used in industrial arts. According to Von Gagold, 7. has been much used in Assyrian, Egyptian, Indian, Roman, Mauresque and Gothic art works. 7 and 8 are found in East India carpets. 2 and 6 are particularly employed for silk.

The twelve division diagram may also be used to determine the color which will be in best harmony. They would be the ones equidistant on the
Plate 6.
von Bezold’s Pairs and T riads.
circumference of the circle, or as nearly near,

1. Carmine, Yellowish green, and Ultramarine.

2. Vermillion, Green and Bluish Violet.

3. Purplish, Yellow Turquoise blue.

4. Orange, Bluish green, Purplish Violet.

Nos. 1 and 3 were used largely by the Italian painters of the Renaissance. No. 4 was used in all the woven fabrics of the Middle ages. These tints and shades are represented on Plate 6.

Now Bezold's theories are exceedingly useful in the determination of harmonies, but he gives very little relating to mixtures. The best he offers upon this point is in regard to colors viewed simultaneously. Thus suppose the disc of the color top to be painted with 3 parts Green, and two

parts Violet. To find the color given by the combination, connect the center of the violet with the center of the green by a line AB, Fig. 4 on a 10 division chart in which the colors are supposed to grade from purity at the circumference to white at the center.

Then the resulting color would be found 7/10 of the way from the green or in a pale turquoise blue. If three colors are to be combined, say
green 6. Violet 4 and red 5—draw the line AB as before, and from X draw the line XC to the centre of the red; the resulting color will be 7/2 of the way from C to X or a very pale purple.

It is unfortunate that the theory and practice of coloring are so different, but so it is, and with the present pigments nothing can be done to make them agree. Accepting the theory of Chevreul as true for mixtures of pigments, colors are divided into primaries, from which all others may be obtained by combination. Secondaries, produced by mixing two primaries, and Tertiaries, produced by mixing three primaries. These are represented on Plate 7. It has been found that the primaries combine to give the best proportions in the relations of Red 5, Yellow 3, Blue 8, whence the following table could be formed.

Red 5 and yellow 3, give Orange 9
Blue 8 and Yellow 3, give green 11
Blue 8 and Red 5, give Purple 3
Red 5 and yellow 3 give Orange 8
Blue 8 and Yellow 3, give green 11
Blue 8 and Red 5, give Purple 3

On Plate 7, in figure 2 the tertiaries are arranged opposite their primaries. Russet— the red tertiary being opposite Red, etc. Fig. 4 shows the relative angular areas or combining powers of the colors.
Figures 5 and 6 are diagrams of harmony. Thus yellow harmonizes with purple, etc. Also Red and Blue produce the intermediate secondary Purple. Similarly purple and orange produce Russet, which harmonizes with green. With these diagrams and the combining equivalents of the colors, much can be done towards determining harmonizing colors. Thus suppose we are using red and orange together in a composition and wish to determine the single color that can be harmoniously used with it. Analyzing the colors according to the primaries, we have

\[
\begin{align*}
\text{Red} & = 1 \text{Red} \\
\text{Orange} & = 1 \text{Red} + 1 \text{Yellow}.
\end{align*}
\]

Now in order to have good harmony the three primaries must be present in relation to form-white, whence there must be added 1 yellow and 2 blue, or a bluish green. And knowing the combining powers of the color and assuming them to be of equal intensity, the relative areas would evidently be:

\[
\begin{align*}
\text{Red} & = 5 \\
\text{Orange} & = 8 \\
\text{Bluish Green} & = 8 + 8 + 3 = 19.
\end{align*}
\]

Suppose the colors are Russet and Red. Analyzing we have

\[
\begin{align*}
\text{Red} & = 1 \text{Red} \\
\text{Russet} & = 2 \text{Red} + 1 \text{Yellow} + 1 \text{Blue}.
\end{align*}
\]
Whereas there is to be added 2 yellow and Blue, and the proportions would be:

Red 5, Russet 21, Green 22.

If the colors are Russet and Citrine, we have:

Russet = 2 Red + yellow + Blue
Citrine = 1 Red + yellow + Blue

whence there is to be added 1 blue, and the proportions would be:

Russet 21, Citrine 19, Blue 8.

These combinations are represented on Plate 8.

By examining Figures 5 and 6 we see that yellow harmonizes with Purpled and purple in its turn harmonizes with Citrine, but it does not follow that Citrine harmonizes with Yellow. Indeed there is one thing that can be said about these and all similar charts for illustrating harmony. If the colorist has not a true idea of harmony in his head, all the charts in the world could never give it to him. The color charts will certainly help a great deal, but since it is impossible to say just what is a perfect Citrine, or just what is a perfect green, a person's judgment will be the only criterion he can safely use, and if his judgement is poor, his harmonies will be poor. As regards the combining equivalents of the colors they are of but little practical account. It may be true that 6, 5 and 8 are the correct proportions but segments vary so widely in effect it would be impossible to exactly or even approximately hit the proportions.
in any object of industrial art. Von Bezold says that he carefully
inspected Bowen Jones' Grammar of Ornament, but could find no instance
in which these proportions were carried out, and the writer has looked
through Racinet's L'Ornement Polychrome with a similar result. Har-
mony of color is like the weather; it can be determined only on general prin-
ciples, aided by experience and judgement.

When two colors are placed side by side, they will exert a certain
influence upon each other. If they are complementary they will tend to
brighten each other, as with Red and Green, and the red will appear redder
and the green greener by contrast, than it actually is. Colors not com-
plementary are variously affected. Thus when Blue and Black are
placed together the black assumes a rusty appearance, due to orange,
the complementary of blue, which is cast upon the black. If we intently
view a bright green object for several moments, and then quickly close
the eyes, the image appears to remain, but its color is the complementary
of green, or red. Similarly if we close view red, or closing the eyes,
green will appear. From these phenomena, it has been concluded
that the eye perceives a color, all the color nerves are set into action,
whence while the color of the object viewed is most intense, its complemen-
tary will be cast upon the surrounding objects. This principle is of
great importance in industrial art, as upon it depends a great deal
Plate 10.
Contrast.
Plate II.

Background
Orange and red warm. Beyond this also some colors appear to advance, and others to retire from the eye. Blue retires, yellow is stationary and red advances. This is illustrated on Plate 10. In Fig. 1 the small square seems raised. In Fig. 3 it seems depressed. In Fig. 4, the black seems to project like a screen or cloud. In Fig. 5 the retiring effect of colors is well represented. It is owing to its retiring effect that the sky appears so distant. Blue also seems to be soothing in its nature, while red excites. A pure yellow has always been suggestive to the writer, of a frail porcelain dish, that would go to pieces if handled much. Dusser says, "By certain combinations color may make glad or depress, convey the idea of purity, richness or poverty, or may affect the mind in any desired manner, as does music." But this would depend upon the person.

It is certain however, that color excites a deep influence upon a person's feelings. Thus a room whose walls are painted a green or light blue, seems cool and pleasant on a warm summer day, and a room whose walls were lit up by the glow of a bright red fire, would seem to perfectly express — on a cold winter day — warmth and cheerfulness.

The effect of colors can be much increased by outlining. Dusser gives some valuable rules as the result of his experience. He says, "When a color is placed on a gold ground, it should be outlined.
with a darker shade of its own color.

"Then a gold ornament falls on a colored ground it should be outlined with black.

"Then an ornament falls upon a ground in direct harmony with it, it must be outlined with a lighter tint of its own color.

"Then the ornament and ground are two tints of the same color. If the ornament is darker than the ground, it will require outlining with a still darker tint of the same color." These are illustrated on Plates 12 and 13.

The study of color is exceedingly interesting and could be carried to a great extent. Indeed experience is the only way in which one can obtain a good knowledge of color. It is difficult to say which is the most practical, the Von Bezold or Chevreul theory. Both give excellent results, and if pigments exerted the same influence as sunbeams, there could be no question but that Von Bezold's was the best. As it is, both are right, and will amply repay any time put upon their study.
3 - Applications.

The use of color is universal. Everything we see is colored, and nearly every object and can be rendered more attractive by a judicious use of color. The branches of color which require special attention are the harmonies and contrast of colors are wall decorations, hangings, tapestries, carpets and woven fabrics. Potters, metal work, tiles, furniture, stained glass. Of these, the most important to the architect are wall decorations, tiles, metal work and stained glass, which will accordingly be the only ones noticed.

The practice of painting and decorating houses and buildings is as old as architecture itself. Picturesque representations are found even upon the walls of the pyramids. With the Greeks color was much used to beautify architecture, as we know from the remains of some of their temples, where surface decorations in color were used with a skill and taste such as belonged to the Greeks alone. The Roman Architecture was characterized in some places, as at Pompeii, by its wall decorations. These were not what we now designate as frescoes, but were simply paintings in oil upon a flat surface. The true frescoes— the Buon frescoes as they are called were first used by Michael Angelo, and the Italian artists of the 15th
Century. The color was applied to freshly laid mortar, whereof its name fresco. It was much used for the decoration of churches and ecclesiastical buildings, and palaces, but did not long survive the death of Michael Angelo who was by far the best master of this medium, and almost the only one, except Raphael, who achieved any success with it. That is now known as fresco, or merely distemper painting. To use this, the plaster is applied to the wall and allowed to thoroughly dry. It is then coated with a size composed principally of water, glue, and alum. The colors employed are ordinary dry mineral or earthy colors, and are mixed with water and glue. Calsamine is the most common form of distemper painting, in which whitewash serves as a body, and tinted with colors to suit the taste. Much better effects are however produced by mixing the colors themselves, rather than any hints of the color.

A nightful application of color will much increase the effect of a room. Thus a room exposed to strong sunlight could be made cozy and retired looking by painting the walls with a dark color with all decorations strong but subdued. A small room whose walls were painted a bluish tint, say a mixture of Ultramarine and a little Umber, would appear much larger than it really is.
while a room painted with a citrine or mace tint would appear smaller. Primary colors should never be used except in small effect bits, and even then, very sparingly. American s are not yet used to strong colors, but will have their walls colored with weak meaningless tints; but there are few who have seen strong colors used in decoration that have not been pleased by their effect. Light tints should seldom be used for backgrounds, and there is one principle that we should always remember in house decoration. The things in the room should be of more importance than the walls, whence dark colors are well suited to set off the furniture. Never to display the lady's dresses etc. The cost of distemper painting is quite small. Only two coats of plaster are required,—the brown and slip coats, and the pigments are themselves very cheap.

Tiles have been used in Europe for many years, but it is only of late that any have appeared in common use in this country. Here they are used principally for public buildings, but they are excellently adapted for use in the halls, libraries and Kitchens of private residences. A library with a large rug on the floor and a tiled border some 2 or 3 feet wide, would certainly present a good appearance, and
would certainly be very appropriate for its purpose. Tiles are to be stepped upon, hence they should not be of such elaborate form design as to draw the attention from the surrounding objects. Indeed it can be said of decorating generally, that its effect should be more harmonious than contrast. In tiles, as in wall decoration, the colors should be subdued - tending colors are the best, with simple geometrical forms. Tiles may also be very appropriately used for wainscotting, fireplaces,rosettes of stairs and many other places.

Ironwork is usually left black or perhaps varnished. Blue andgold, chocolate and gold, or black and silver can be used to good advantage in creating railings, etc., and these colors would contrast well with the brick.

A whole volume might be filled with dissertations upon stained glass, and bit little could be said that has not been said. Its effects are marvellous and nothing can exceed the beauty of a stained glass window. Much that is made and sold in America as stained glass is in reality but stencil work, or is printed on the glass. In fact very little true stained glass is seen here. But even with printed glass, very excellent effects can be obtained.
4. Conclusion.

Color is a life-long study, and none ever has it perfectly, either the theory or practice. Lessons of harmony and contrast can be learned from all around us. The rose leaf, the birds' wings, soap bubbles, sunrises and sunsets, rainbows, the maiden's blush—all these will help us in appreciating and understanding color. It may seem singular that the Indians of the East, and the Chinese peoples, who are at best but half civilized, are far ahead of all Europe in delicacy and refinement of taste as regards coloring, just as it is. The only way we can account for it is on the ground that their coloring is natural and not conventional, and that they are specially gifted in this direction. The works of Christopher Dresser upon color, the based upon a wrong theory, are useful and exceedingly practical, and will help a great deal to a correct understanding of color.