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COLOR for the Amateur Photographer

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Recent developments in the manufacture of color films have brought natural-color photography within the easy reach of all. With the latest single-exposure film, the taking of such pictures is as easy and as simple as the taking of ordinary black-and-white pictures, and very slightly more expensive. Furthermore, for some of the methods, development is as easy as the development of the regular films.

The purpose of this article is to discuss the modern methods of color work, consisting of the additive and the subtractive processes which will be analyzed simply and briefly.

Light and Color

Light—and we must remember that color is a property of light—travels in a straight line from its source so long as it moves through the same medium. If it strikes a medium of different density, three things may happen to it. First of all, it may be "absorbed". If it is completely absorbed, the object upon which it falls will appear black. All light is gone, and hence there is no color. If it is partially absorbed, the color of the illuminated object will depend upon which of the light wave lengths are absorbed. Secondly, the light may be "reflected," that is, sent back in the direction from which it came. Finally, it may be "refracted," or bent, in which case it will travel in a different direction. When a beam of light travelling through the air from the sun strikes a lens, for instance, it enters a medium in which the speed of transmission is less than this speed is in the air. The ray, then, is bent or refracted. At the same time, some of it may be absorbed and some of it may be reflected so that the total amount of light leaving the lens may be much less than the total amount of light entering it.

Light, therefore, may be transmitted, reflected, refracted, or absorbed. It is with the absorption that we are most concerned, for it is through absorption that colors are registered on the human brain.

Primary and Secondary Colors

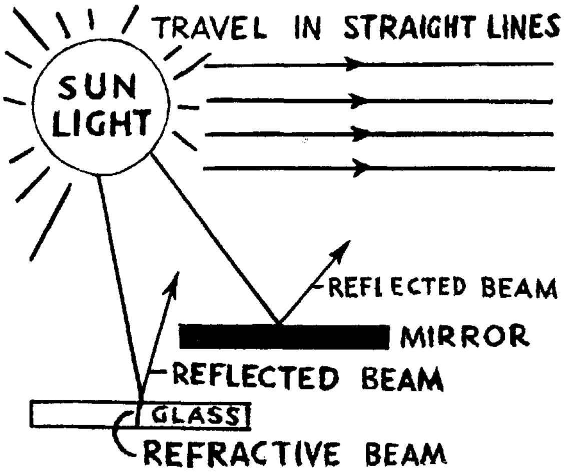
In spite of all the different colors of which one is aware, all color consciousness appears to be due to the excitation of one or more of the three color sensations of which the human eye is capable. This fact was first stated as a theory by Wunch, and later by Young, but it was established experimentally by Clerk Maxwell in 1860. These three color sensations are the so-called "primary" colors. Any other color combination is caused by a combination of two or more of these primary colors. The other colors comprise the "complementary" colors.

If the three primary colors of pure red, pure green, and pure blue were to combine in equal quantities, the resulting color sensation would be white. If only two are combined in equal amounts, the sensation is that color, which, if added to the third in the right proportions, would produce white. This sensation is, therefore, called the "complementary" color of the third. For example, if red and green sensations were combined equally, the resulting sensation would be yellow. Yellow (light) added to blue (light) in the proper proportions will produce the sensation of white, hence yellow and blue are called complementary colors. Red and blue light added in the same amounts will produce magenta, a reddish purple, which is the complement of green. Green and blue sensations together result in a color sensation of blue-green, which is the complement of red. These complementary colors are sometimes called "secondary" colors.

A knowledge of these colors is necessary to understand the production of color films and pictures.

Addition and Subtraction of Colors

There are ways in which any color may be produced. One is that mentioned in the preceding topic: the adding of light of two or more colors. For example, the combination of red and green light will produce yellow. Red, green, and blue together will produce white; therefore, if blue is subtracted from white, it



Transmission of Light

will leave yellow. If red is removed from white, blue-green is produced, and green is found by eliminating both red and blue from white. This subtracting process explains how the mixing of pigments of various colors, as in paints, results in other colors. Blue paint is blue because it absorbs the red and some of the green, but reflects the blue and some of the green. Yellow paint is yellow because it absorbs the blue, reflecting the red and some of the green. If these two pigments are mixed, they will absorb the blue (absorbed by the yellow pigment), and the red (absorbed by the blue pigment). The mixture will reflect only the green which is reflected by both the blue and the yellow. Hence the paint is green.

It will be seen then, that any color sensation can be produced by adding the lights of the primary colors in the proper proportions or by subtracting from white light the complement of these colors in the proper proportions. The former operation is employed in the additive method of color photography, and the latter is used in the subtractive method. Of these methods, the Dufaycolor and Agfacolor processes belong to the additive class, while the Kodachrome process is a member of the subtractive class.

Additive Process

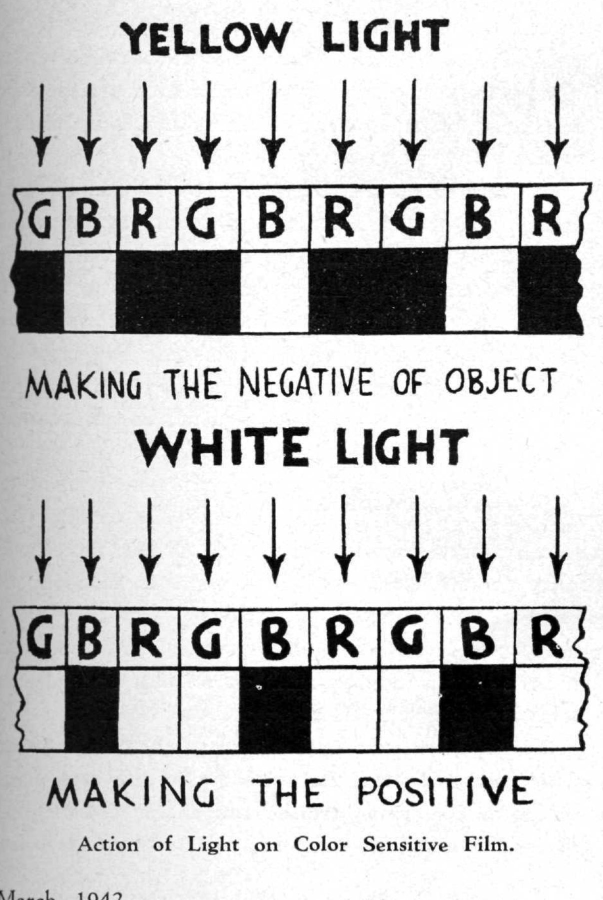
The additive process depends upon the fact that if an image consists of a number of sufficiently fine lines or dots, it will appear solid (the principle of photo-engraving). If these lines or dots are of different colors, the image will appear to be the color that would result from the addition of lights of the various colors in proportions equal to those proportions of the colored lines or dots. The principle involved is that of the "screen plate." The screen plate consists of a series of fine lines or dots, which are individually colored red, and green, and blue, the proportion of each color being such that, since the lines are so small, the resulting screen has no color at all. In Duraycolor films and Agfacolor plates, the emulsion is coated directly upon the screen plate. In other words, the screen plate is entirely separate. Very simply explained, it can be said that the screen plate is nothing more than three color filters, all in one. So from here on the word "filter" will be used interchangeably with "screen plate." The emulsion of the film is exposed behind the filter, the red lines permitting red light to pass as it comes from the subject, but stopping the blue and the green; the green lines passing green light but stopping the red and the blue light; and, likewise, the blue lines passing the blue light but stopping the others.

In photographing a yellow object, red light and green light are reflected by the object. The red light gets through and darkens the emulsion behind the red lines of the filter. The green light gets through and darkens the emulsion behind the green lines, but the emulsion behind the blue lines (which stop both red and green light) will not be affected. If a positive is now made by reversal, and some white light is passed through the filter, light will be passed by the emulsion that was originally affected by the red light, and owing to the red lines of the filter, only red light will get through this part of the film. Likewise, green light will get through the portion that was originally affected by the green light. As this portion was dark on the negative, it will be light on the positive, and it will also be behind the green lines on the filter. However, no light will get through the blue lines of the filter because the emulsion behind them was not originally affected. When a reversal is made, the emulsion of the film behind the blue lines will be dark. The result will be that the red light will pass through the part originally affected by the red, and green light will pass through the part originally affected by the green light, and, for a yellow object, no blue light will pass through the screen. Therefore, coming through the image of the yellow object will be both red light and green light, but no blue light. Since a yellow object will reflect red light and green light, the image will appear yellow. So it is with other colors, every part of the image appearing to have the color of the corresponding of the object or subject. The uniformity of the colors produced by this method will depend upon the fineness of the lines or dots of the screen plate or filter, just as the uniformity of the tones of an ordinary print depends upon the fineness of the grain of the negative.

Additive processes, in general, have three major disadvantages. In the first place, the three color filters, whether over the lens or in the film, transmit not more than one-quarter to one-sixth of the light that falls on them. In the second place, each color filter or group of filters, covers only one-third, or so, of the total area of the lens of the camera, or of the film area. This is, of course, referring to the use of the color films or the special color filters that fit on the camera, over the lens. Because of these two conditions, the light used for projections of the color transparencies on a viewing screen has to be very much brighter than under ordinary conditions, in order to maintain sufficient viewing-screen brightness of the image. The third great disadvantage is that the discrete color areas in the screen pattern or plate, while microscopically small in the film or plate, are seldom invisible on the viewing screen. The definition and sharpness are poor.

The Subtractive Method

Also a three-color process, the subtractive method produces its colors by the subtraction of other colors from white light. Most of these processes require the making of three separate negatives, one for each of the primary colors. However, there are few processes in which the record of all three colors is made on a single exposure. The only method of producing three-color prints embodies a subtractive process, and it requires three separate negatives for the printing. In the subtractive processes, the three negatives may be made separately by the use of three individual color filters in three individually taken pictures. Or the negative may be made all at once in a specially-made camera, or all at once on three separate layers of one film, as in the Kodachrome film. From each of the three negatives, a positive is made and colored with



Action of Light on Color Sensitive Film.

One of the Color Films.—Courtesy of Eastman Kodak, Company.

A cross-section of Kodachrome Film showing the extreme thinness of the three color-sensitized coatings separated by plain gelatin layers.

the color complementary to that with which the negative was made. Then the three positives so made are superimposed in register to form a positive transparency, or the color is transferred (by emulsion stripping, by dye imbibition, or by the use of other materials) to a paper support giving a positive paper print. In order to understand better the principles of this method, let us again consider the yellow object.

The positives from the negatives made with the red light and the green light will be light where there was yellow light in the subject, whereas the positive from the blue light negative will be dark where there was yellow in the subject. In coloring the images, the dark portions are colored so that the red and green filter positives are left clear in the portions corresponding to the yellow of the object. When the three are superimposed in register, the clear part of the first two will permit all three colors to come through. The yellow image of the blue-filter positive will subtract the blue light, letting only the red and the green pass through. Since these two lights are reflected by a yellow object, this part of the combination image will appear yellow. The image of each positive is colored with the color complementary to that of the light with which its negative is made. The image through the blue-filter is dark where there was no blue light from the subject. It is therefore colored yellow to represent the absence of blue. Likewise, the red-filter positive (from the negative made with the red light) is colored blue-green to represent the absence of red, and the green-filter positive is colored magenta to represent the absence of green. The "positive" referred to throughout the treatment of the subtractive process, is a reversal made of each particular color negative.

With the subtractive method it is possible to get a natural-color transparency with a single exposure. The film consists of five layers of emulsion coated on one film base and so arranged that each is affected by only one of the three primary colors. There are two gelatin emulsions which separate the three photographic emulsions. The outer layer of emulsion is sensitive to blue and violet alone and is separated from the next layer by a coating of gelatin, dyed yellow to absorb the blue but to transmit both the red and the green. The second layer of the emulsion, which is

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reached by the red light and the green light, is sensitive to the green but not to the red, and is therefore affected only by the green. The third layer is sensitive to the red light, but not to the green. So the first layer will be affected by the blue light only, the second by the green light only, and the third by the red only.

By a complicated process, the images on the three films or emulsions are developed, reversed, and colored so that each resulting positive is of the color complementary to that with which that layer of emulsion was first exposed. Hence, the image on the first layer is colored yellow, that on the second layer is colored magenta, and that on the third layer is colored blue-green. When viewed by transmitted light, the image appears in the colors of the original subject.

The future has much in store for the users of color film. Color photography has a long way to go and few know just what developments are being made in the laboratories of the great film manufacturers. Tomorrow, something new may be placed on the market to revolutionize the whole science of color photography.

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Freshman Engineers on hunting trip:

"What are you gonna' do with that skunk you caught?"

"I'm going to put him in my room."

"What about the smell?"

"Oh, he'll get used to it."