MOTION PICTURE

COLOR THEORY

COLOR THEORY

This self-study workbook includes general material about color that you should know if you are involved in photography or photofinishing.

You might ask, “Can someone involved at a beginning level understand color theory? Isn’t is a pretty complicated thing?”

The answer is YES, IT’S COMPLICATED BUT, BEGINNERS CAN UNDERSTAND THE BASIC CONCEPTS OF COLOR THEORY AND MAKE USE OF THEM.

It is true that some discussions of color theory are very advanced and can be highly technical and complex. However, the central concepts … those things you need most as a beginner … involve a few simple basic ideas about **light**.

You might also ask, “Do I really **need** color theory … or is it just something that’s nice to know, but not too practical?

The answer is YES, YOU NEED TO KNOW COLOR THEORY AND YOU WILL FIND PRACTICAL APPLICATION OF IT.

Photographic techniques for both picture-taking and photofinishing center around light and its controlled use. The basis of all color theory is **light**. You will find color theory helps you to achieve proper color balance for color photography and for the lab. In photofinishing, you would use it in process monitoring techniques and for corrective action in printing. And one more thing … color theory can help you with reasoning and problem-solving in many, many situations both in picture-taking and in photofinishing.

Even if you are already familiar with color theory, go through the material, It can serve as a review for you. (Besides, there may be something you’ve overlooked.)

Now, let’s begin to look at color.

COLOR

The basis of color theory is **light.**

If you take this workbook into a dark room, you will not be able to see the colors. . . in fact, you will not be able to see the workbook either. . .

That's because you need **light** to make things **visible.**

REVIEW (Check your answers on page 3):

Your eyes need __________ to see shapes and colors.

It is important for you to understand that color depends on __________

Now that we know that light is basic to color theory, we need to know that light is a form of **radiant energy.**

Radiant energy travels through space with a wave-like motion. This wave-like motion travels in straight paths called **rays.** Some **rays** have long waves and some have short waves.

A **wavelength** is the measurement of the distance from wave crest to wave crest. The number of wavelengths (crests) that pass a given point in a given time is called **frequency.**

ANSWERS:
light, light

REVIEW (Check your answers on page 4):

Light (a form of radiant energy) moves in patterns called __________

The straight path of light is called __________

Now try matching the columns:

______ Rays

______ Light

______ Wavelength

______ Frequency

______ Wave

A. Radiant energy that travels through space with a wave-like motion.

B. Measurement of the distance from wave crest to wave crest.

C. The number of wavelengths (crests) to pass a given point in a given time.

D. Straight path of wave-like motion.

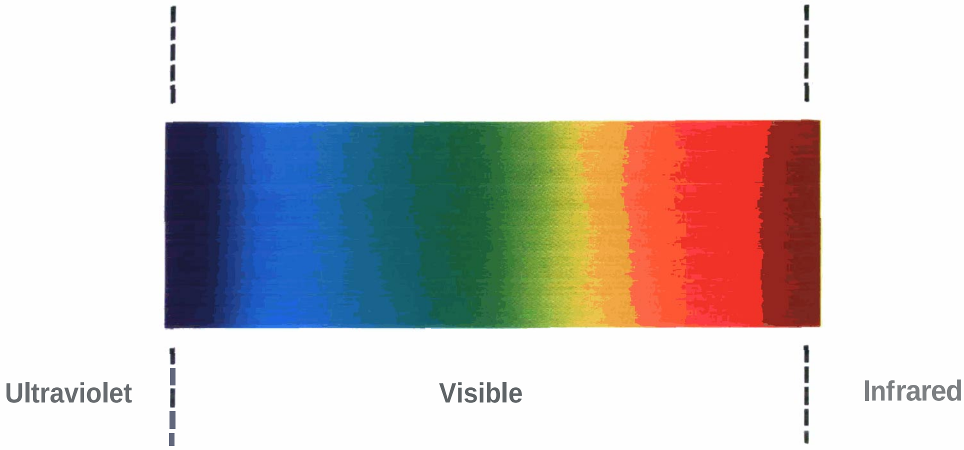
E. The motion pattern of light.

ANSWERS:
waves, rays
D, A, B, C, E

The Electromagnetic Spectrum

If we make a chart where all the rays are arranged according to wavelength or frequency, we have a picture of the electromagnetic spectrum.

The rays in the spectrum differ in length of waves, frequency, and in what these rays do.



The electromagnetic spectrum is made up of both visible and invisible rays. Only the visible rays in the middle of the spectrum are called light.

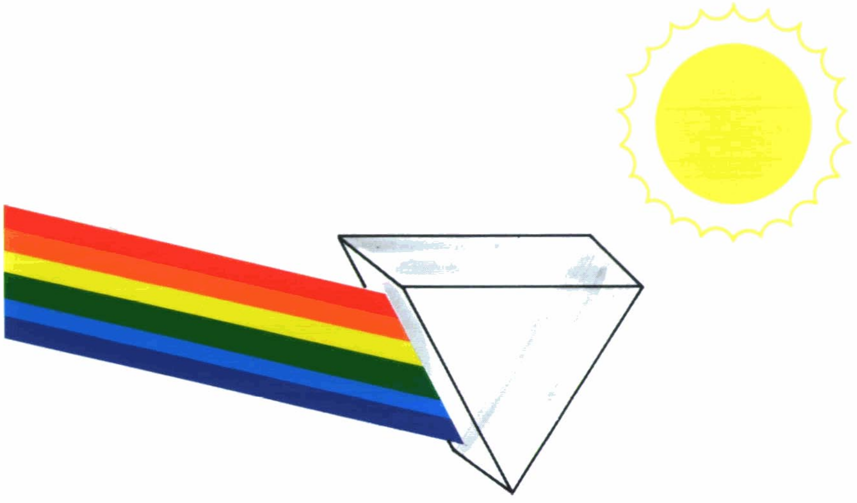
Light can be defined as:

The form of radiant energy which is visible.

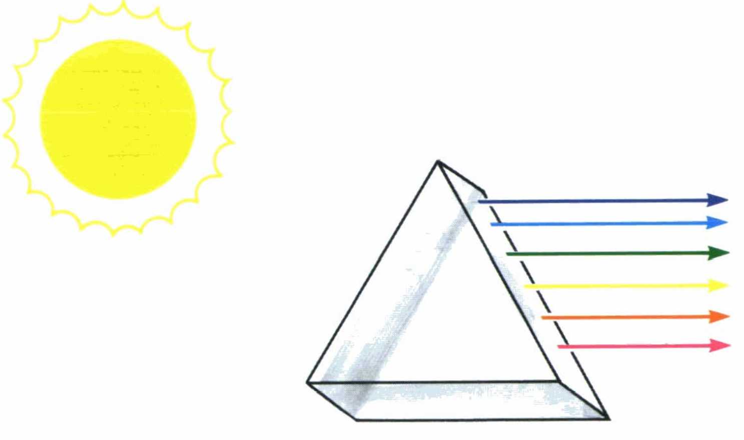
In other words, the eye and how it sees light is basic to our discussion of color.

White Light

The visible part of the electromagnetic spectrum is made up of colors.



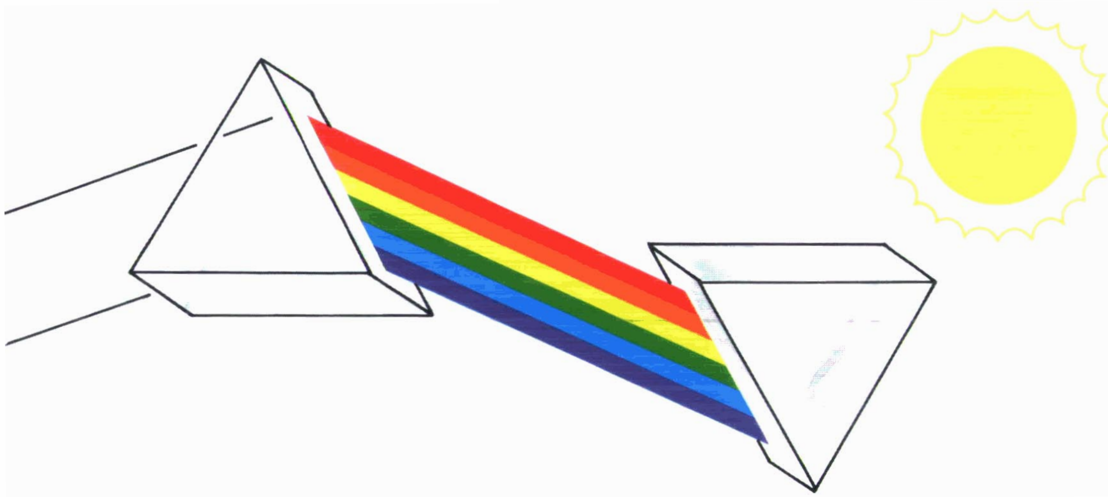
The easiest way to see this is to watch what happens when a beam of white light passes through a triangular lens called a prism.



The prism bends the rays of white light at different angles, so the white light is separated into rays of different wavelengths. Each wavelength gives your eye a sensation of different color—a color pattern like a rainbow.

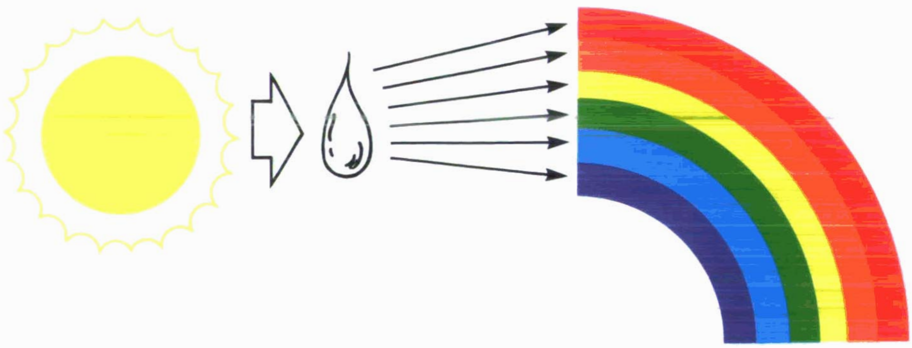
The colors in this pattern are always arranged with red at one end, orange, yellow, and green in the center, and blue and violet at the other end.

If we had a second prism to pass the light through, the colors would be combined again into white light.



A prism does not make or destroy colors. It simply bends the light and spreads the colors apart so we can see them next to each other.

For example, when the sun shines on the rain, or after a shower, raindrops act as tiny prisms to bend sunlight into its separate colored parts.



You can create the same effect yourself with a garden hose. Stand with your back to the sun and shoot a fine spray in front of you. When the spray is in just the right position with respect to the sun, you will see a rainbow.

REVIEW (Check your answers on page 8):

Only visible rays are called __________

White light is a mixture of __________

A __________ bends the rays at different angles, so white light is separated into rays of different wavelengths.

Raindrops may act as tiny prisms to bend light into a color pattern in nature called a __________

White Light Sources

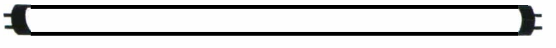
The most common source of white light is the sun. Other sources are fire, candles, and artificial light we make ourselves, such as electricity, etc.

Light from any of these sources does not appear to us to be any particular color. We are not aware of the colors mixed in it, because it is a mixture of many of the colors (all wavelengths) in the visible spectrum.

The Sun

Candles and Other Sources of Fire

Tungsten-Filament Bulbs

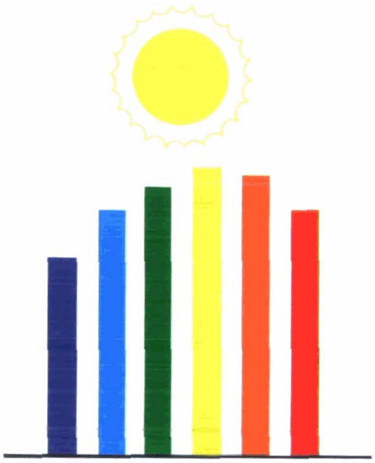


Fluorescent-Tube Lamp

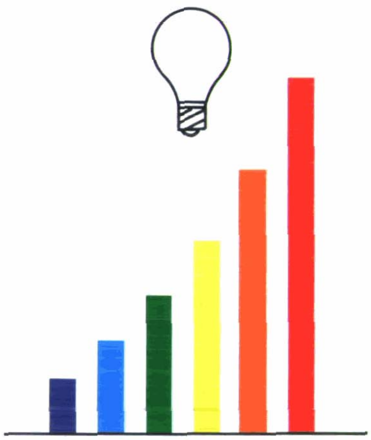
ANSWERS:
light, colors,
prism, rainbow

Different Types of Light Sources

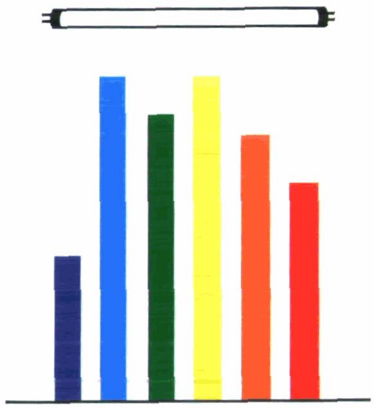
Colored objects will look different under different light sources. This is because each light source has a slightly different mixture of the colored rays. This is particularly important to photographers who use this information daily in adjusting to different lighting situations.



The sun is a balanced mix of rays in the visible spectrum.



Light from a tungsten bulb has more red rays than blue rays.



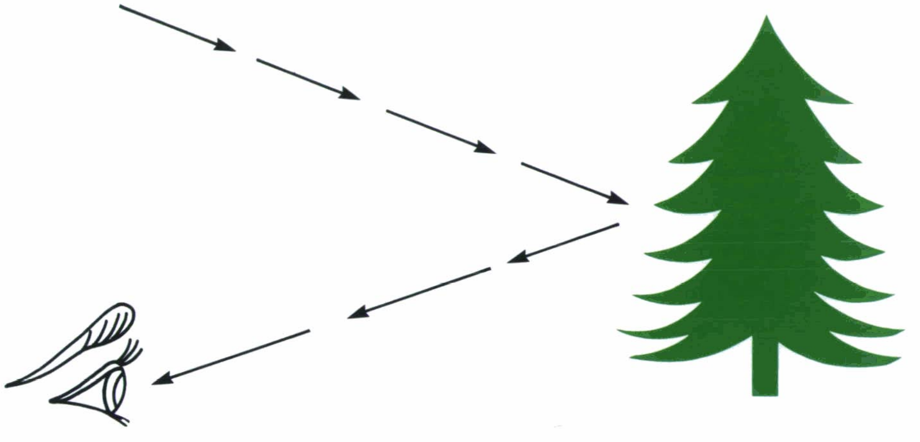
Light from a daylight, **fluorescent-**tube lamp has more blue and yellow than red or violet rays.

How We See Objects

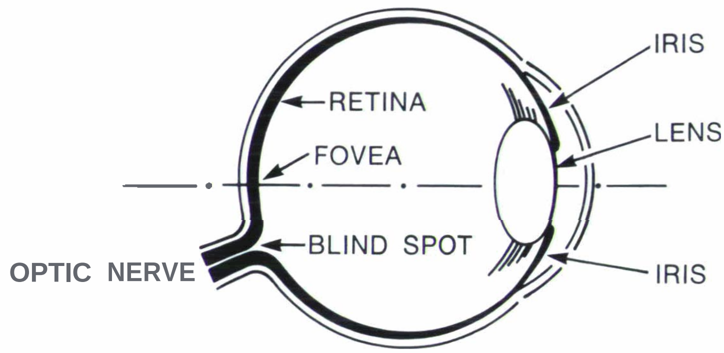
Light rays from any source travel in all directions. Some of these rays hit the object we are looking at.

Some of these rays bounce off the object and are reflected back to our eyes, and still others are absorbed by the object itself.

Only the light that reaches our eyes enters the light-sensitive cells there, and sends messages to the brain.



How the Eye Sees Color



The human eye is much like a camera. It has a **lens,** a light-sensitive layer called a **retina,** and an **eyelid** that acts as a shutter.

Although we don't know everything about how the eye sees color, we do know that human vision **relates** to three colors:

- Red
- Green
- Blue

Research indicates that the brain translates wavelengths of light into color sensation, as a function of nerve connections and of the brain.

Now, let's look at two systems for creating **color.**

ADDITIVE AND SUBTRACTIVE SYSTEMS OF COLOR

*There are two different and quite separate systems for creating color. Both systems can create all colors of the spectrum, but the method of arriving at these colors is different and exactly opposite. One creates by **adding** light and the other by **subtracting** (taking light away).*

Additive System of Color

Starting with BLACK (the absence of light), appropriate mixtures of the additive primaries of red, green, and blue light are **ADDED** to create the colors of the spectrum. If equal amounts of red, green, and blue light are added, the result is WHITE light.

RED + GREEN + BLUE = WHITE

The additive system is used in some color printers and for some advanced photographic techniques. Probably the most common application of additive color we encounter is its use in creating television images.

Subtractive System of Color

Starting with WHITE light, proper proportions of light are **SUBTRACTED** to form any color of the spectrum. This is done by absorption through filters, or by absorption and reflection from paint, pigment, or dyes. If equal amounts of the subtractive primaries of cyan, magenta, and yellow are subtracted, the result is BLACK.

CYAN – MAGENTA – YELLOW = BLACK

Most situations we encounter on a day-to-day basis involve creation of color by subtraction. For example, most things we see involve looking at objects or scenes that absorb and reflect light (subtraction). Painters and printers use pigments and dyes to create desired effects by absorption and reflection (subtraction). A photographic print is created by the absorption and reflection of the dyes and the photographic paper.

How These Systems Work Together

It is very important that you understand how color is created ***both*** by addition and subtraction so you can see how these two systems relate to each other. Then, you will be able to better understand the concepts of complementary colors and reversals and how to make these work for you in photography.

The red created by adding light will be the same color (wavelength) as the red created by subtracting or blocking out color by a filter. Red is still red.

Magenta, cyan, and yellow can create red, green, and blue in the subtractive system, just as cyan, magenta, and yellow can be created by red, green, and blue in the additive system.

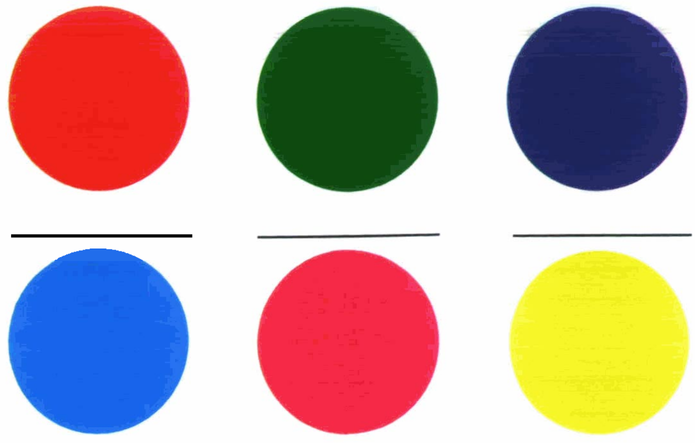
> Remember, both systems can create all colors of the spectrum. It is the ***method*** of creating these colors that makes the difference.
>
> —The SUBTRACTIVE SYSTEM creates color by ***taking light away.***
>
> —The ADDITIVE SYSTEM creates color by ***adding and mixing light.***

This may seem confusing, but as you use the filters and light in exercises that follow, you will learn to make this work for you.

REVIEW. Now, label the following colors of light (Check your answers on page 14):

ADDITIVE PRIMARIES

SUBTRACTIVE PRIMARIES



a. ______ ______ ______

b. ______ ______ ______

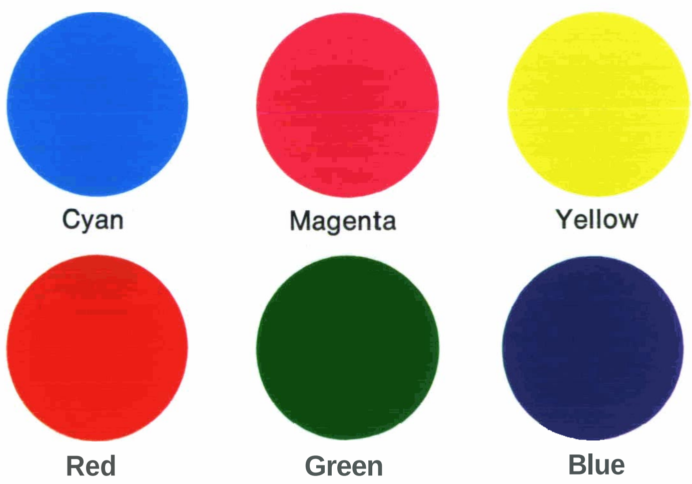
Looking at the chart below:

c. Which are the **subtractive primary colors?**

____

d. Which are the **additive primary colors?**

____



If you subtract light in proper proportions through absorption, can **you:**

e. Create red, green, and blue? ______

f. Or any other color of the spectrum? ______

If you add proper proportions of red, green, and blue light, can you:

g. Create cyan, magenta, and yellow? ______

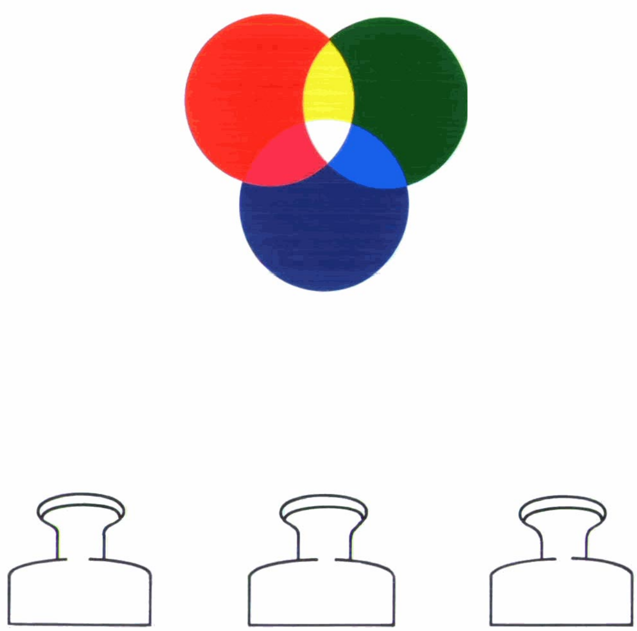
h. Or any other color of the spectrum? ______

ANSWERS:

a. red, green, blue	e. yes
b. cyan, magenta, yellow	f. yes
c. cyan, magenta, yellow	g. yes
d. red, green, blue	h. yes

ADDITIVE SYSTEM OF COLOR

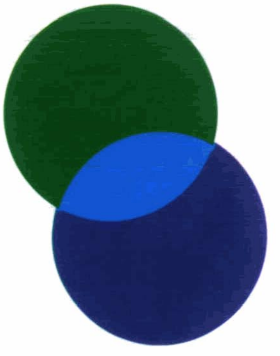
If we take the three additive primary beams of light—red, green, and blue—and overlap them, we can see how they combine.



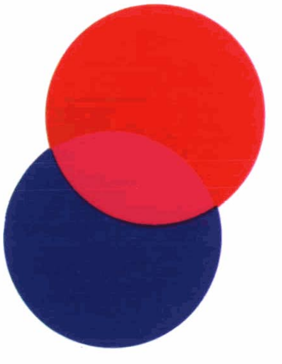
As you can see, the center of the overlapping three beams is white.

You also will notice that where only two colors overlap, different colors are formed.

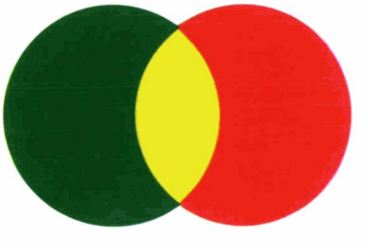
Where the green and blue lights overlap, we see a greenish-blue color that is called **cyan.**



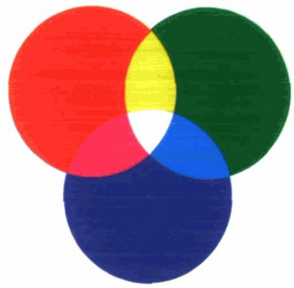
Where the red and blue lights overlap, the reddish-blue color **magenta** is formed.

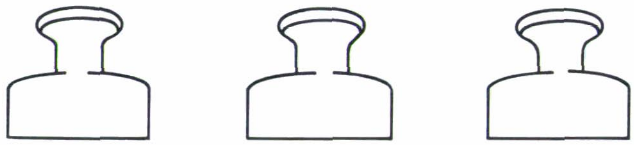


Where the red and green overlap, **yellow** is formed.



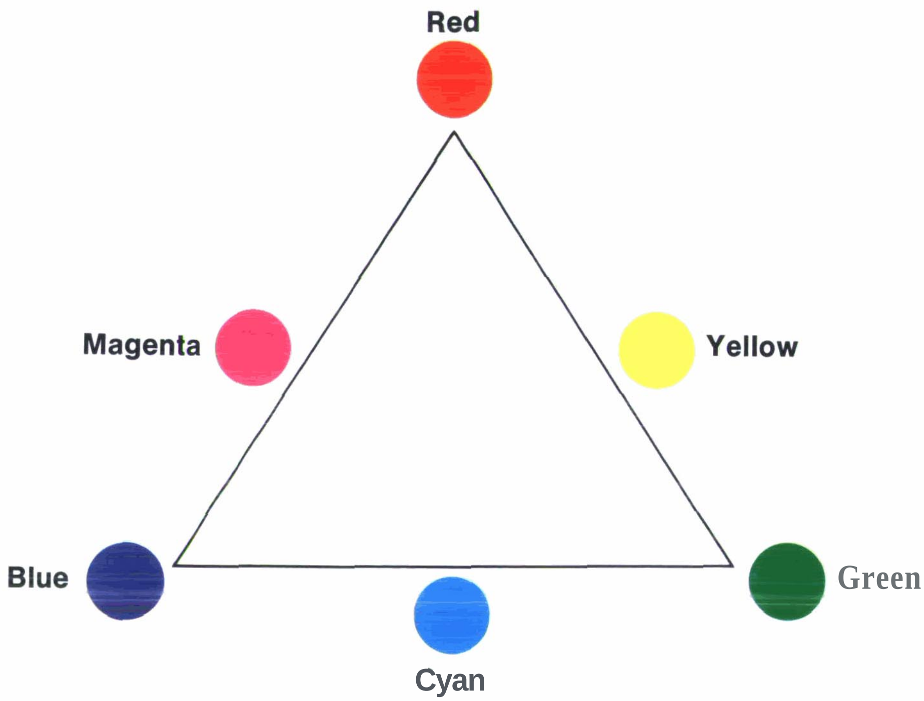
(Remember: We're talking about adding light directly, not about reflected light or paint or pigment.)





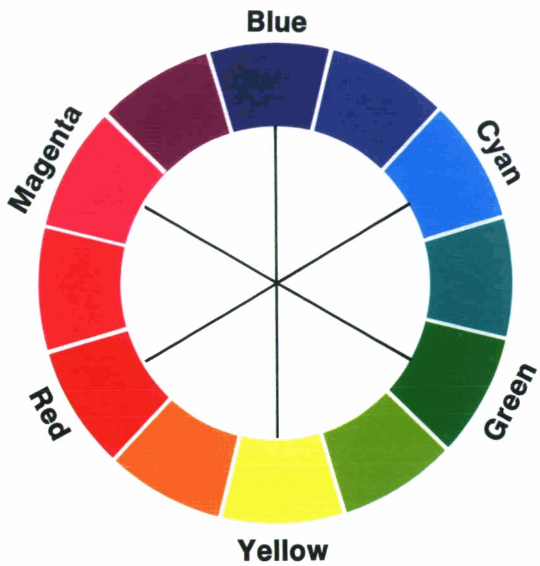
To review—We're using a mixture of colored light from projectors which are covered by red, green, and blue filters. Combined in pairs, the beams form cyan, magenta, and yellow. Where all three beams overlap, the screen appears white.

These relationships can also be seen on this color triangle.



The **additive primary colors** of red, green, and blue are on the points of the triangle. The subtractive primary colors of **cyan, magenta,** and **yellow** are on the sides of the triangle. On this triangle, any two adjacent colors form the one in the middle.

- Red and green form the color in the middle (yellow).
- Blue and red form reddish-blue (magenta).
- Blue and green form bluish-green (cyan).



A color wheel is another way to show the relationships among the various colors.

REVIEW (Check your answers on page 19):

1. Name four different light sources.
   - ____________________
   - ____________________
   - ____________________
   - ____________________

2. The three additive primary colors of light are:
   - ____________________
   - ____________________
   - ____________________

3. Red, green, and blue are the primary colors in the __________ system of color.

4. If you overlap all three additive primary colors of light (red, green, and blue), the result is __________ light.

5. Where only two colors overlap, different colors are formed. Where green and blue light overlap, the color formed is called __________

6. Where red and __________ light overlap, the reddish-blue color called __________ is formed.

7. Where __________ and __________ light overlap, yellow is formed.

ANSWERS:

1. • the sun
   • tungsten-filament bulbs
   • fire, candles, etc
   • fluorescent-tube lamps
2. • red
   • green
   • blue
3. additive
4. white
5. cyan
6. blue, magenta
7. red, green

SUBTRACTIVE SYSTEM OF COLOR

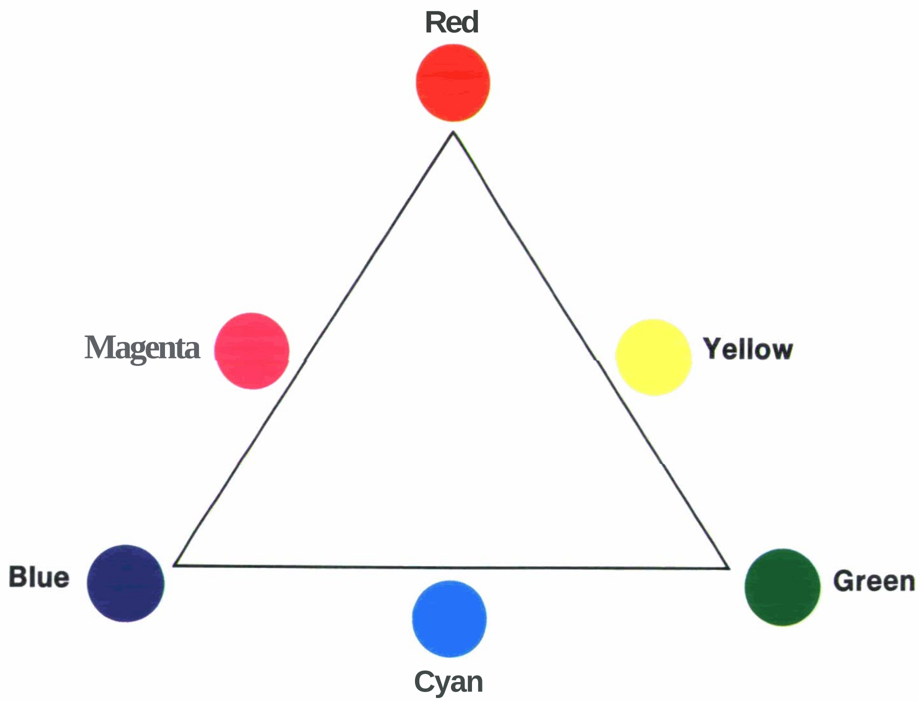
Let's stop here for a minute. You may have thought, "Wait a minute. . . I was taught in school that red, blue, and yellow were the primary colors. How come red, blue, and green are the primary colors in this book?"

Let's remember that we have been talking about adding light. . . not about absorbing and reflecting light off pigments or paints (subtracting light).

In school, when you were taught red, blue, and yellow as the primary colors, it was probably for painting. However, if you actually tried to use red, blue, and yellow as primaries to create all the other colors, you would find it wouldn't work. In order to get the desired results, you would have to use the color of bluish-red called MAGENTA, the color of greenish-blue called CYAN, with YELLOW as the other basic color. So you see, you would actually have to use the primaries of the subtractive system . . . magenta, cyan, and yellow.

Most people are unaware of the technically correct names for these color systems. Painters do, in fact, use a system of absorbing (subtracting) and reflecting (transmitting) light from the surface of the pigment or paint. They use the subtractive system of color.

This subtractive system is also used in photography and in photofinishing. One important photographic use of subtractive color is in the use of filters. For example, in making a color print, filters are used in the printer to absorb some light (subtract it out) and to allow the rest to pass through (transmit) in order to expose the photographic paper.



Looking at this color triangle, you can see that opposite each additive primary color is a subtractive primary color.

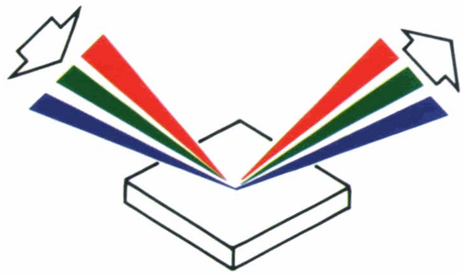
This should help you remember that **subtractive colors subtract** the color **opposite** them from white light.

Different Colors Are Made by Reflecting (Transmission) and Absorbing (Subtraction)

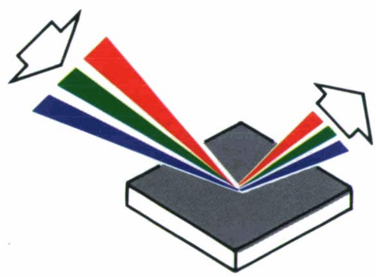
Some of the rays that fall on an object are **reflected,** and some are **absorbed,** or trapped.

Surface color (like that in color prints) depends on pigments in the surface.

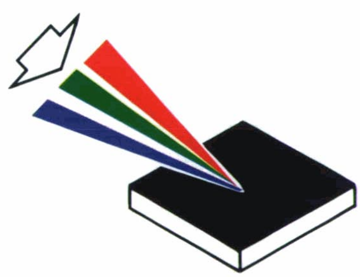
A white surface (like that of photographic paper) will reflect almost all the rays of white light and absorb almost none.



A gray surface absorbs more of the rays and will look darker than a white object.



A black object absorbs almost all the rays. It will be even darker than either gray or white.

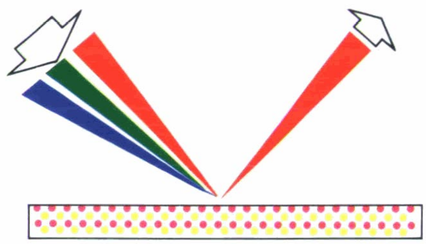


All of these objects (white, gray, and black) differ only in how bright they look. This depends on how much light is reflected and how much is absorbed by each. All of them are colorless or give a **neutral** sensation to the eye.

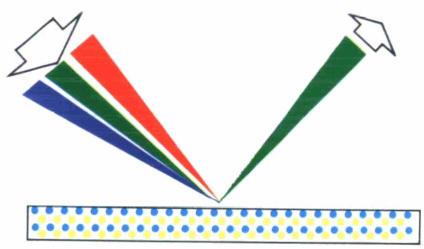
Two Colors Create a Third Color by Reflection (Transmission) and Absorption (Subtraction)

Surface colorants (coloring matter) such as paints, inks, and dyes use cyan, magenta, and yellow as the primary colors. Remember, we are now using the **subtractive** system of color. Cyan, magenta, and yellow are called subtractive **primary** colors because they are the colors used to produce all other colors in this system.

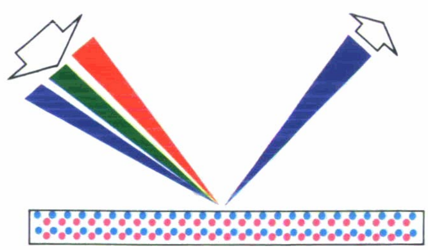
Although we can mix paints together to make a new color, we are creating that new color by absorbing (subtracting) **light.**



A surface with equal amounts of magenta and yellow pigments appears red when we look at it. When white light (red, green, blue) falls on this red surface. the magenta absorbs (subtracts) green rays from the light, and the yellow absorbs the blue rays. Both magenta and yellow **reflect** all red rays, so the surface appears red.



Cyan and yellow pigments form green because the cyan absorbs (subtracts) the red rays, and the yellow subtracts the blue rays. Both of them reflect the green rays.

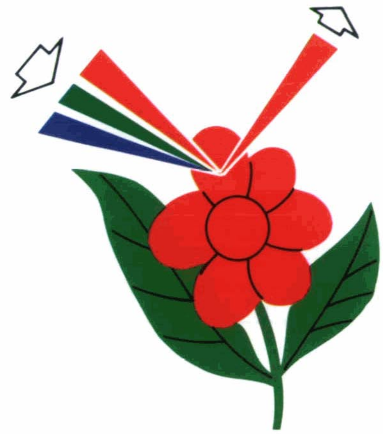


Magenta pigment absorbs (subtracts) the green light and cyan pigment absorbs the red. So, the object will reflect the blue rays and appear blue.

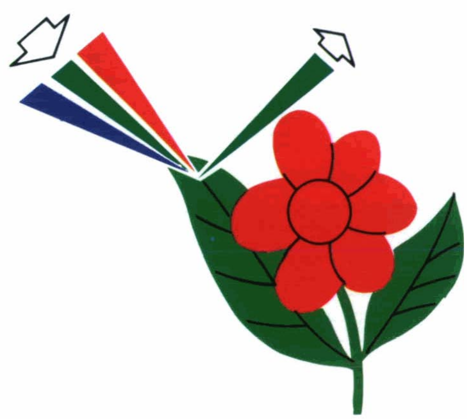
Why a Leaf Looks Green and a Red Flower Looks Red

Objects take on the color of the light they reflect. Light reflected from an object with a neutral (white, gray, or black) colored surface only looks different in **brightness.**

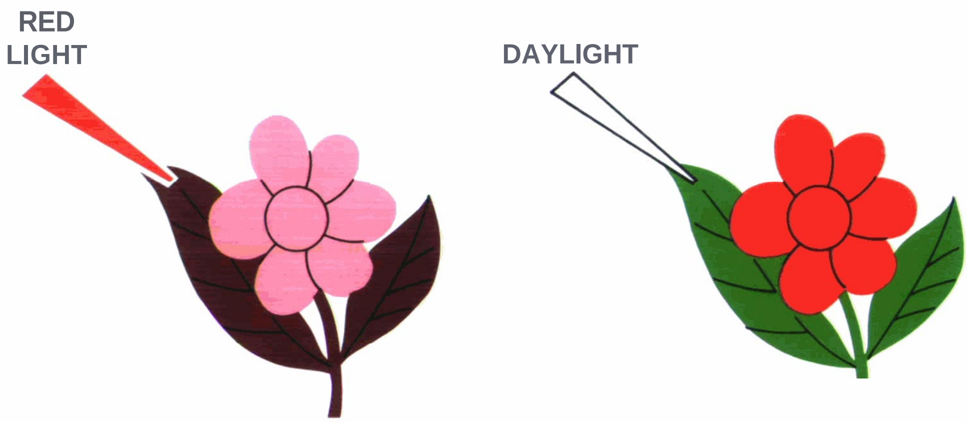
When the sun shines on a red flower, the red rays are reflected back to your eye. All the other rays (blue and green) are absorbed.



Sunlight falling on a leaf makes it look green. The coloring matter in the leaf absorbs all the light (the red and blue rays), **except** the green rays. These rays are reflected back to our eye to stimulate a green sensation.



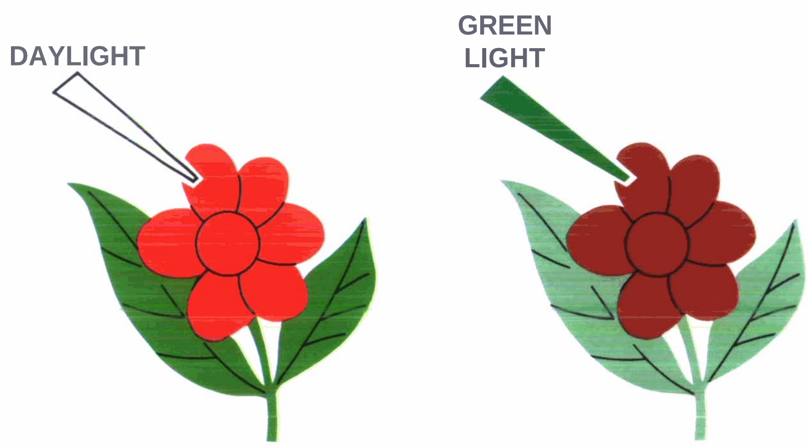
If you put this same red flower and green leaf under a red light, the red flower would look very light red. The same leaf that looked green under daylight would now look very dark and colorless. This is because the red light only produces red rays.



The leaf looked dark and colorless because it absorbed most of the red rays. The red light did not contain many rays the green leaf could reflect. It did contain many rays the red flower could reflect.

If you put that same red flower and green leaf under a green light, the green leaf would look very light green. The red flower would look very dark and colorless.

In this case, the green light did not contain many rays the red flower could reflect. But, this time, the green light did contain many rays the leaf could reflect.



REVIEW (Check your answers on page **26**):

1. If you place a **red** filter in front of a white light and shine it on a red flower with a green leaf, what color would the leaf appear to be? ______________

2. What color would the red flower be? ______________

3. What color would the leaf be if you used a **green** filter? ______________

4. What color would the flower be? ______________

5. The green leaf, under the red filter, looked dark and colorless because ____.

6. The red flower looked very light red because ____.

ANSWERS:

1. dark and colorless
2. very light red
3. very light green
4. dark and colorless
5. It absorbed most of the rays.
6. The red light contained many rays the red flower could reflect.

FILTERS

You will need an understanding of filters to help you in color printing, in evaluating color prints, and also in advanced methods of photography.

Let's look at what happens to light when you use filters.

If you placed a red filter, a blue filter, and a green filter over a single light source, the result would be __________

Are you surprised that the result was black, not white light? **Remember,** you used **filters** and light together, not direct light. Filters work on the principle of **subtractive** color.

It will help to think of filters as sponges that absorb (subtract out) **selective** colors of light, and allow the remaining colors to pass through.

When you see red, green, and blue filters together in front of a single light source, you have absorbed or blocked out **all** the light. No light passes through, so you have created black (the absence of color).

This time, picture a red filter in front of one white light source, a blue filter in front of a second white light source, and a green filter in front of a third white light source. If all three beams were focused at a single spot on a screen, what would be the result? ____

(Check your answers on page 27):

Let's look more closely at filters.

Remember, we have learned that:

- The sensors in the human eye and brain respond to red, green, and blue.
- White light is a combination of equal amounts of the primary colors of red, green, and blue light.

ANSWERS:
black
white light

Red, Green, and Blue Filters

Now, we need to know that:

Red, green, and blue FILTERS do not add light. Because they are filters, they SUBTRACT from existing light. Each filter **transmits its own color and subtracts out the other two primary colors from white light.** Our eyes only see the light the filter allows to pass through. We do NOT see what the filter absorbs or blocks out.

–A full-strength RED filter absorbs (subtracts out) green and blue light and transmits RED.

–A full-strength GREEN filter absorbs (subtracts out) blue and red light and transmits GREEN.

–A full-strength BLUE filter absorbs (subtracts out) red and green light and transmits BLUE.

Remember, we are discussing the effect of red, green, and blue light created by absorption through filters . . . not the addition of red, green, and blue light from a direct source.

What would happen if you placed a red filter in front of a white beam and then placed a green filter in front of the **filtered** red light? ____________

In this case, the red **filter** had already filtered out (absorbed like a sponge) all the green and blue parts of the white light. When the green filter was put over the filtered red light, it absorbed all the red light and transmitted no green because there was none there to transmit.

Remember what happened to the green leaf in red light? The leaf came out looking dark and colorless.

The same thing happens here, because the color is absorbed by the filters. In other words, green was created by the subtraction of light, using the filter, not the addition of light.

It will help you to look at this filter chart.

Filter Color	Light Absorbed	Light Transmitted
Red	Green and Blue	Red
Green	Red and Blue	Green
Blue	Red and Green	Blue

Remember, red, green, and blue **filters** subtract from existing light. Each filter subtracts out the two other colors from white light.

Besides **absorbing** (subtracting out) the other two primary colors, each red, green, and blue filter transmits its own (the remaining) color.

Look at this chart again.

Filter Color	Light Absorbed	Light Transmitted
Red	Green and Blue	Red
Green	Red and Blue	Green
Blue	Red and Green	Blue

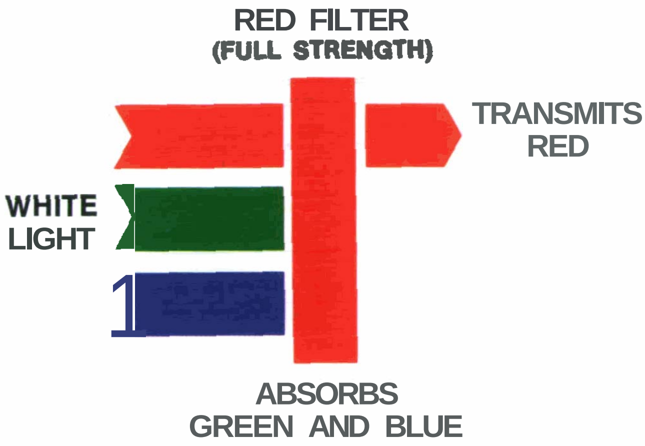
NOTE: In each case above, two colors were absorbed. These two colors of absorbed light together make up the complementary color of the light transmitted.

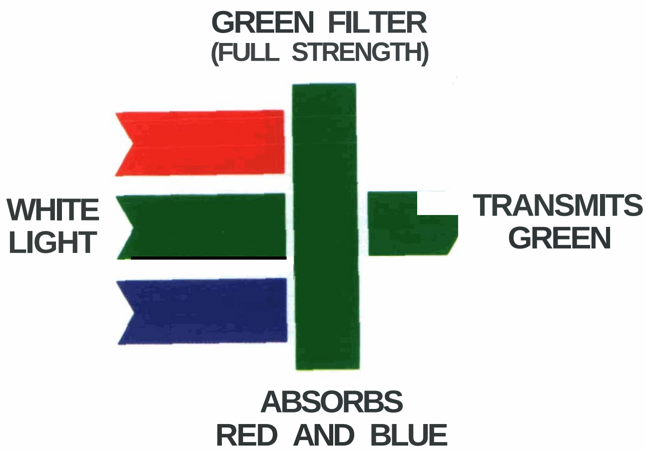
It may help you to think of the primary filters in this way:

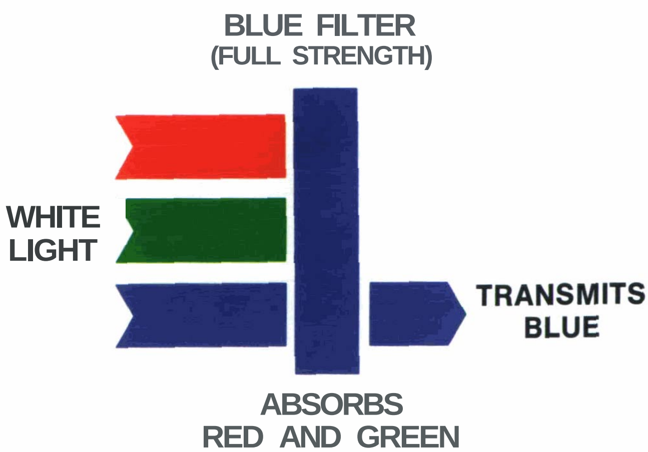
Each primary filter (red, green, and blue) transmits its own color and absorbs its complement.

Filter Color	Light Absorbed	Light Transmitted
Red	Cyan (green and blue)	Red
Green	Magenta (red and blue)	Green
Blue	Yellow (red and green)	Blue

Here is another way to look at this.







REVIEW (Check your answers on page 31):

1

Filter Color	Light Absorbed	Light Transmitted
Red		
Green		
Blue		

2. When a red filter is used, __________ and __________ are absorbed and __________ light is transmitted.

3. When a blue filter is used, __________ and __________ are absorbed and __________ light is transmitted.

4. When a green filter is used, __________ and __________ are absorbed and __________ light is transmitted.

Remember, the two systems of color. . . additive and subtractive **. . .** create all colors, but they create them by exactly **opposite methods.** The **subtractive system,** using filters, **absorbs light** by blocking it out selectively. The **additive system** works by **adding light.**

Now let's go on to a discussion of **cyan, magenta,** and **yellow filters.**

ANSWERS:

1.

Filter Color	Light Absorbed	Light Transmitted
Red	Green and blue (Cyan)	Red
Green	Red and blue (Magenta)	Green
Blue	Red and green (Yellow)	Blue

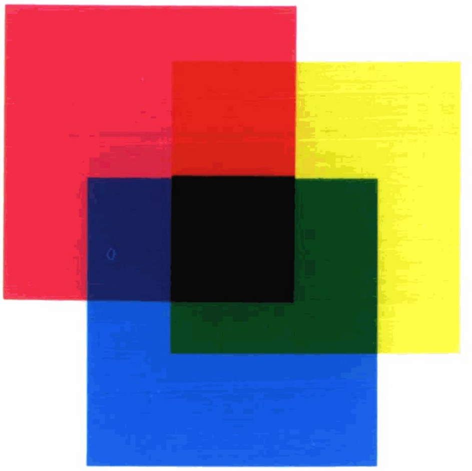
2. blue and green (cyan), red
3. red and green (yellow), blue
4. red and blue (magenta), green

Cyan, Magenta, and Yellow Filters

Now, we need to keep in mind that cyan, magenta, and yellow are opposite or complementary to red, green, and blue on the color triangle.

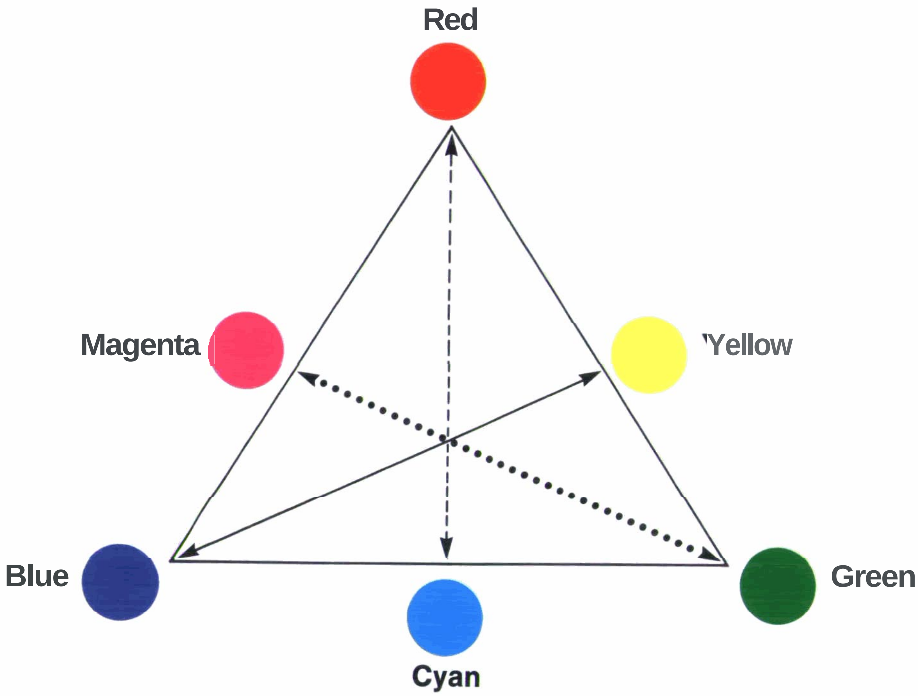
Using'the cyan, magenta, and yellow filters, hold all three filters up to a light source and look through them. What is the result? ______________________

Using the three complementary filters and a single light source, ALL of the light was absorbed, leaving black (the absence of light).



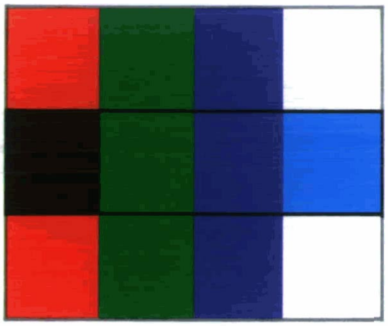
The combined filters give red, green, and blue. Where all three filters overlap, no light is transmitted.

By using a cyan, magenta, or yellow **filter** and **white light, each one transmits two primary colors and blocks out the other.** See the chart below. Each filter absorbs the color opposite it on the color triangle and transmits the two colors on either side.

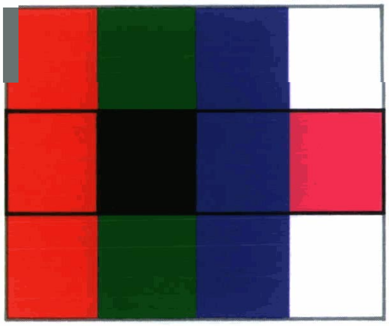


Filter Color	Light Absorbed	Light Transmitted
Cyan	Red	Green and Blue
Magenta	Green	Red and Blue
Yellow	Blue	Red and Green

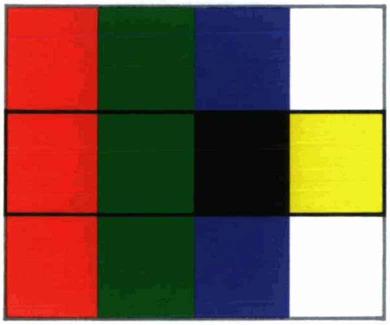
A cyan filter absorbs red light and transmits blue and green light.



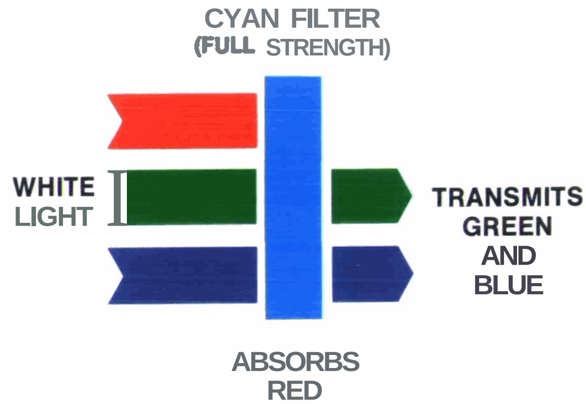
A magenta filter absorbs green light and transmits blue and red light.

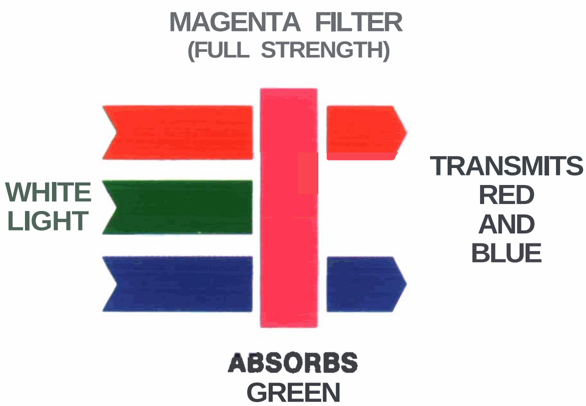


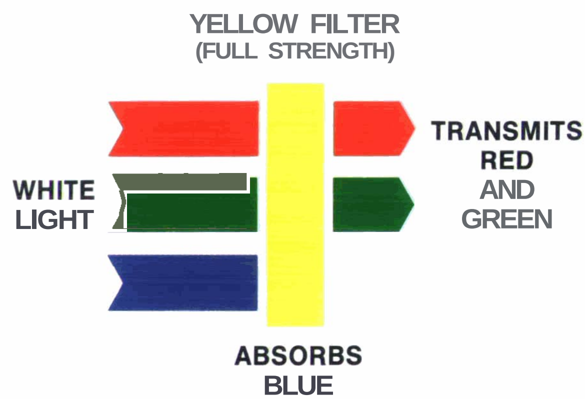
A yellow filter absorbs blue light and transmits green and red light.



Let's look at this another way:



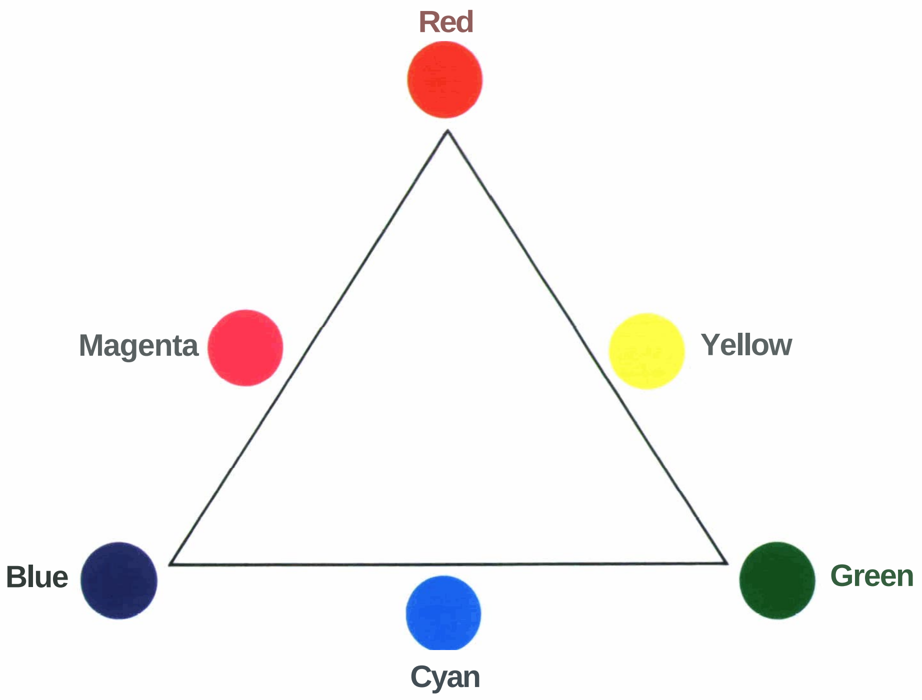




Each complementary filter (cyan, magenta, and yellow) absorbs its complement and transmits its own color.

Let's look at this chart again.

Filter Color	Light Absorbed	Light Transmitted
Cyan	Red	Cyan (Blue and Green)
Magenta	Green	Magenta (Blue and Red)
Yellow	Blue	Yellow (Red and Green)



You will use these charts often in your work, so you need to remember them. Study them carefully before you go to the next page.

Filter Color	Light Absorbed	Light Transmitted
Red	Green and Blue **(Cyan)**	Red
Green	Red and Blue (Magenta)	Green
Blue	Red and Green (Yellow)	Blue

Cyan	Red	**(Cyan)** Green and Blue
Magenta	Green	(Magenta) Red and Blue
Yellow	Blue	(Yellow) Red and Green

REVIEW (Check your answers on pages 40, 41 and 42):

1. When a cyan filter is used, ________ is absorbed and ________ and ________ are transmitted.

2. When a magenta filter is used, ________ is absorbed and ________ and ________ are transmitted.

3. When a yellow filter is used, ________ is absorbed and ________ and ________ are transmitted.

Fill in the missing blanks below:

4.

Filter Color	Light Absorbed	Light Transmitted
Red	______ and ______ (Cyan)	______
Green	______ and ______ (Magenta)	______
Blue	______ and ______ (Yellow)	______

5.

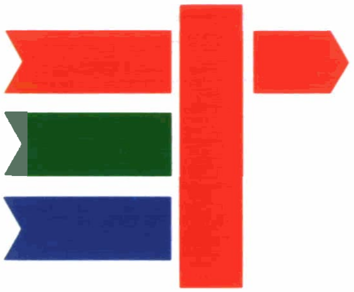
Cyan	______	______ and ______ (Cyan)
Magenta	______	______ and ______ (Magenta)
Yellow	______	______ and ______ (Yellow)

Fill in the missing information about the filters below:

6.

__________ Filter

White Light



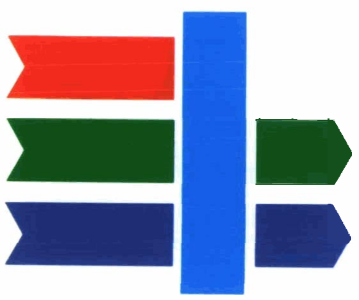
Transmits ____________

Absorbs __________ and __________
(Cyan)

7

____________ Filter

White Light



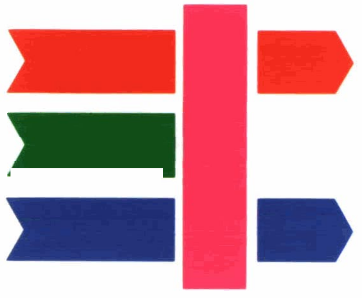
Transmits __________ and Blue
(__________)

Absorbs ____________

8.

__________ Filter

White Light



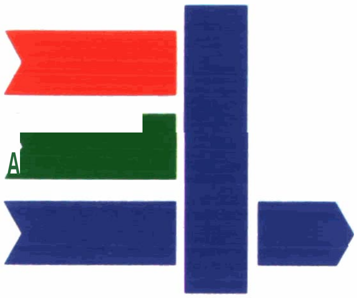
Transmits __________
and ________
(Magenta)

Absorbs ___________

9.

__________ Filter

White Light



Transmits __________

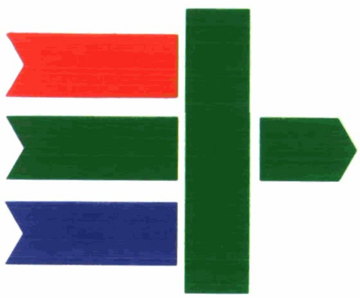
Absorbs red and __________

(________)

10.

__________ Filter

White Light



Transmits __________

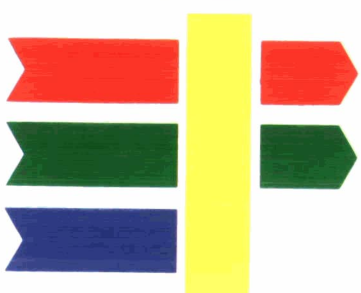
Absorbs __________ and __________

(________)

11.

__________ Filter

White Light



Transmits Red and __________

(________)

Absorbs __________

Match the following filters and results:

12.

Filter Color	Color of Light **Transmitted**
Red	
Yellow	
Cyan	
Blue	
Magenta	
Green	

13.

Filter Color	Color of Light **Absorbed**
Red	
Yellow	
Cyan	
Blue	
Magenta	
Green	

Now, let's leave our discussion of filters and talk about how all of this relates to color photography.

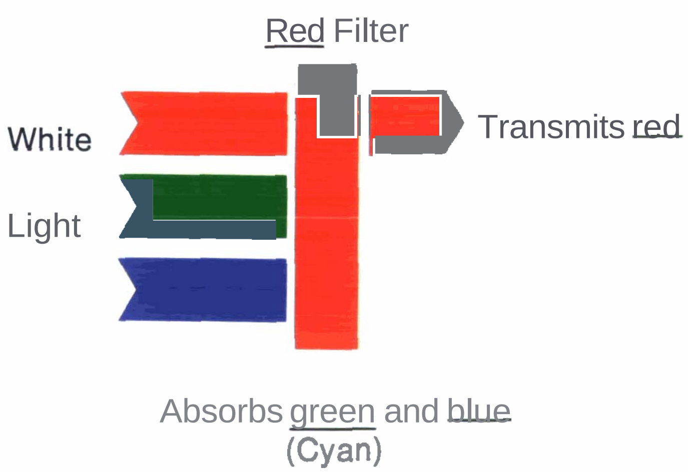
ANSWERS:

1. red, blue, green
2. green, red, blue
3. blue, red, green
4.

Filter Color	Light Absorbed	Light Transmitted
Red	Green and blue (Cyan)	Red
Green	Red and blue (Magenta)	Green
Blue	Red and green (Yellow)	Blue

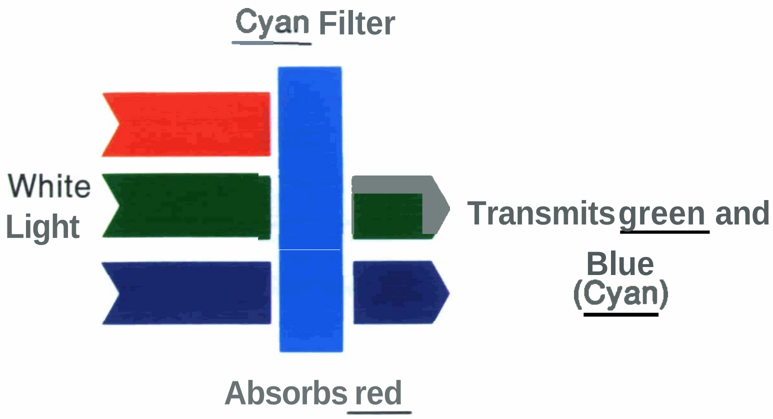
5.

Cyan	Red	Green and blue (Cyan)
Magenta	Green	Red and blue (Magenta)
Yellow	Blue	Red and green (Yellow)

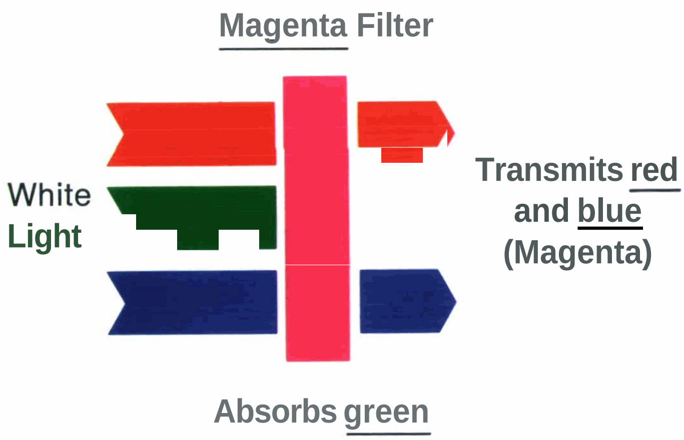


ANSWERS:

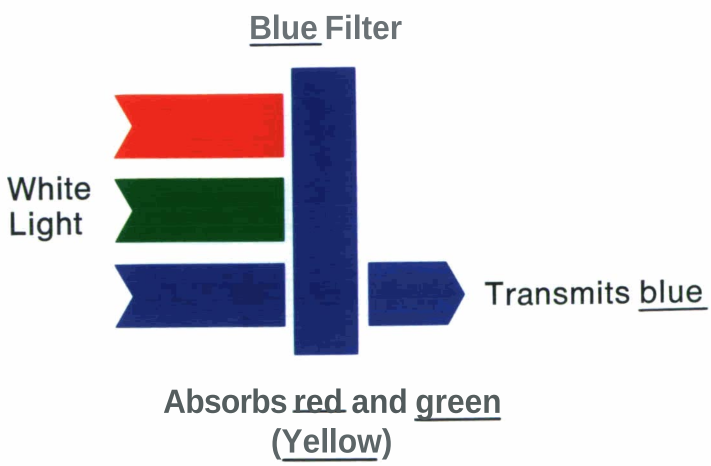
7.


Cyan Filter
White Light
Transmits green and Blue (Cyan)
Absorbs red

8.


Magenta Filter
White Light
Transmits red and blue (Magenta)
Absorbs green

9.

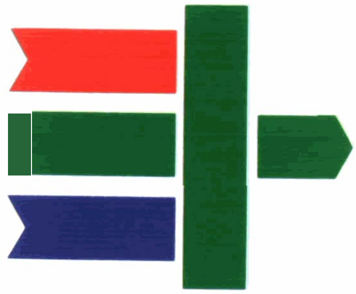

Blue Filter
White Light
Transmits blue
Absorbs red and green (Yellow)

ANSWERS:

10.

Green Filter

White Light



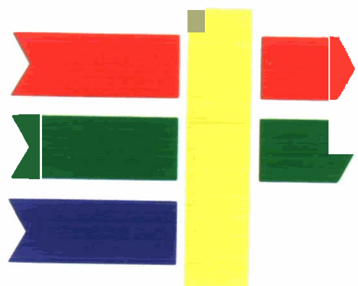
Transmits green

Absorbs red and blue (magenta)

11.

Yellow Filter

White Light



Transmits red and green **(yellow)**

Absorbs blue

12.

Filter Color	Color of Light Transmitted
Red	Red
Yellow	Red and Green **(Yellow)**
Cyan	Green and Blue (Cyan)
Blue	Blue
Magenta	Red and Blue **(Magenta)**
Green	Green

13.

Filter Color	Color of Light Absorbed
Red	Green and Blue (Cyan)
Yellow	Blue
Cyan	Red
Blue	Red and Green (Yellow)
Magenta	Green
Green	Red and Blue **(Magenta)**

SUBTRACTION–THAT'S THE KEY!

Now, what does all this theory have to do with photography?

When you look at a print or slide, you see many colors. All of them are combinations of the three primary colors to which the eye is sensitive: red, green, and blue.

This is fortunate because, if each of these countless hues and shades had to be produced individually, such as in a painting, color photography would not be practical.

Why Not Additive Color to Produce a Photographic Image?

You would think that the easiest way to produce a color image would be to ADD red, green, and blue primary dyes in proportion to the amount needed to duplicate a particular color in the photographed scene. This can be done; and in fact, the earliest color photographic images were produced this way. However, this method of color reproduction—the additive system—has a serious drawback.

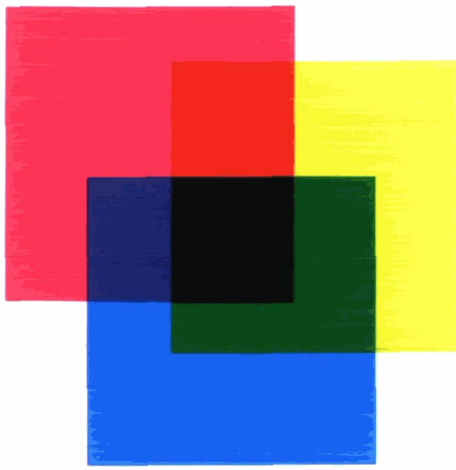
Remember what happened when you placed red, green, and blue filters in front of a single light source . . . the result was BLACK. Each of the additive primary dyes transmits or reflects only a narrow portion of the visible spectrum, blocking—or absorbing—all of the remaining light. For that reason, a very large amount of light is needed to show much of a range of colors. When two dyes are present in equal amounts, they block each other out, resulting in no color (black).

NOTE: If you need more time to think about this, look back at the section on Filters, page 26, for a review of transmission of light.

Why Use the Subtractive System for Color Images?

The subtractive system of color production overcomes the obstacle described on page 43. You may recall, from our previous discussion of absorption and transmission by filters, that each subtractive filter (or primary dye) blocks only a narrow portion of the spectrum, allowing most of the light to reach the eye.

The subtractive primary yellow filter (or dye), for example, absorbs blue light while transmitting or passing red and green light. As you can see, two colors of light are passed on, while only one is blocked off. Using a variety of combinations and densities of the three subtractive primary dyes, a wide range of colors can be produced for viewing at reasonably low light levels. Subtractive colors make color photography practical.



Color Film Construction

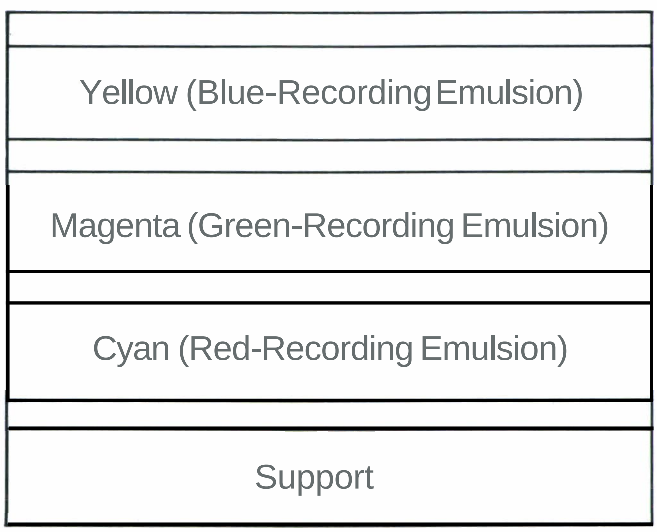
Photographic emulsions are sensitive to the light of the additive primaries. They produce subtractive primary dyes in proportions that accurately control the amount of red, green, and blue colors needed to record the original scene.

How Do They Do This?

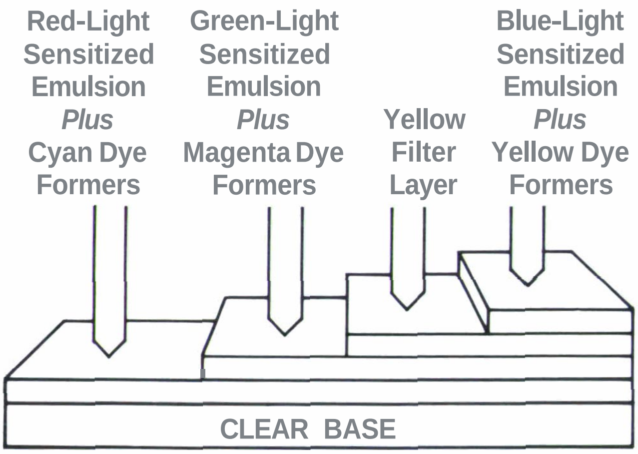
Color film is made up of layers of emulsion built on a support. Each of the emulsion layers contains a dye coupler with the potential to form dye and silver halide crystals sensitized to record a color of light. For example, one layer is sensitized to record red light and has a cyan **dye-**forming compound incorporated into the emulsion layer. Another layer is sensitized to record green light and has a dye-forming compound incorporated into it to form magenta dye. The third layer has a **dye-**forming compound for yellow dye, and this layer records blue light. Finally, all three emulsion layers are coated, one on top of the other, on a clear, flexible support.

This is a simplified diagram of the edge of a piece of color film magnified over 5,000 times. Here you can see, there are several emulsion layers coated on the base.

Color Negative Film



Color films generally have the red-recording layer at the bottom, the green-recording layer next, and the blue-recording layer on top. All silver halide crystals are sensitive to blue light. To keep blue light from being recorded in emulsion layers where it isn't wanted, a yellow filter layer is added to the film.



Basic Color Film Construction

There are several types of color films. These films are described in detail in more advanced publications. All you need to know, at this point, is that color-negative films require chemical processing. They also need a printing step, in order to get a picture that looks like the original scene. Slides, or reversal transparencies, do not require a printing step after processing to produce a picture that looks like the original scene.

Color Paper Construction

A second color photographic product, paper, is needed to make color prints. Like the film, paper also contains emulsion layers supported by a base. Each of three emulsion layers contains silver halide crystals sensitized to record one of the three additive primary colors. Each one also contains a dye coupler with the potential to form dye of the complementary subtractive primary color, when chemically processed. The order of the layers in color-print photographic paper may differ from that in film.

Color Corrections

If color prints are being produced, light and filters are used during printing to achieve the desired effect in the final product. During this step, it is possible to make some corrections to alter the color-balance relationships or the density of the final result. If you are interested in learning more about these relationships, and corrections, you should look for more detailed publications on printing and negative classification.

Now that you have had a look at basic color theory, you will want to put your understanding to use in photography. . . or just in the way you now look at color under ordinary circumstances. For more grasp of the basics, we suggest you experiment on your own with filters and the results of varying combinations under different lighting circumstances.

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