

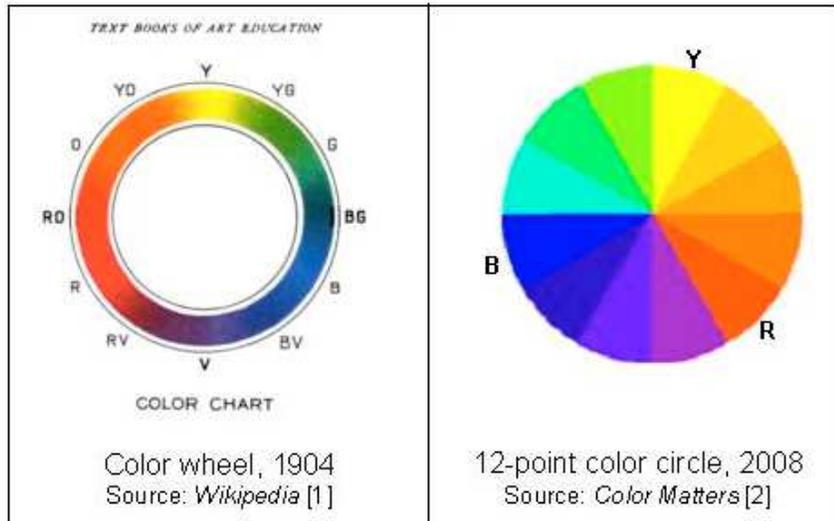
# CULTURAL HISTORY

## Primary Colors - Part 1 of 2

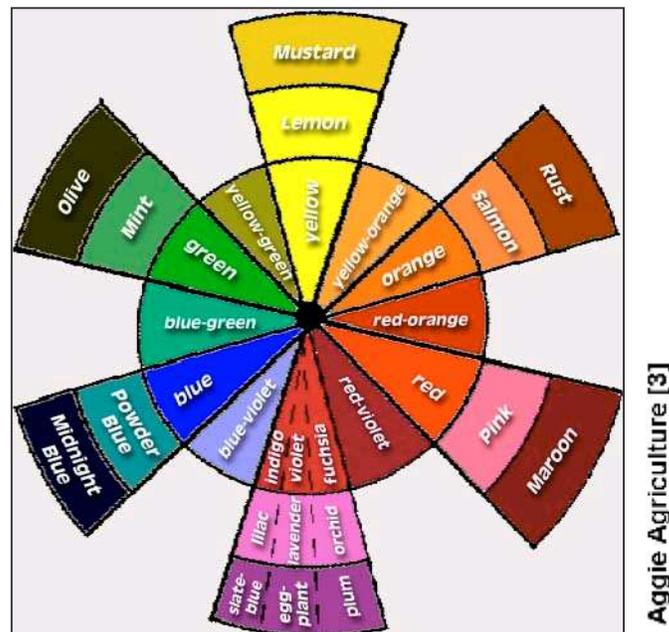
by Neal McLain

Ok, so what are the Primary Colors?

Since grade school art classes, we've been taught that the primary colors are red, yellow, and blue (RYB). Numerous "color charts" or "color wheels" have been published to support this view. Here are two examples:



Even our friends at Texas A&M use RYB primaries in an article about Container Gardening, noting that "Our Flower Color Wheel is similar to an artist's color wheel but we have used names that florists commonly use to describe color. We divided ... violet into three additional segments to include indigo (bluish violet) and fuchsia (reddish violet) because there are so many variations of violet in flower colors."

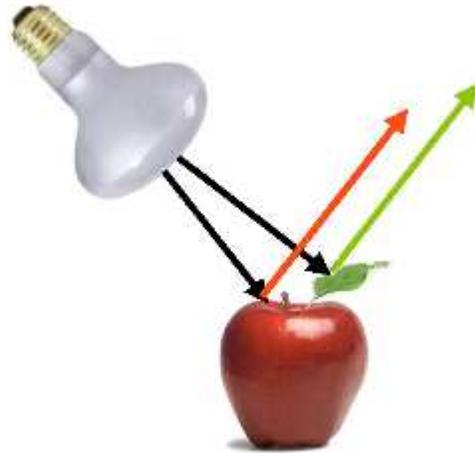


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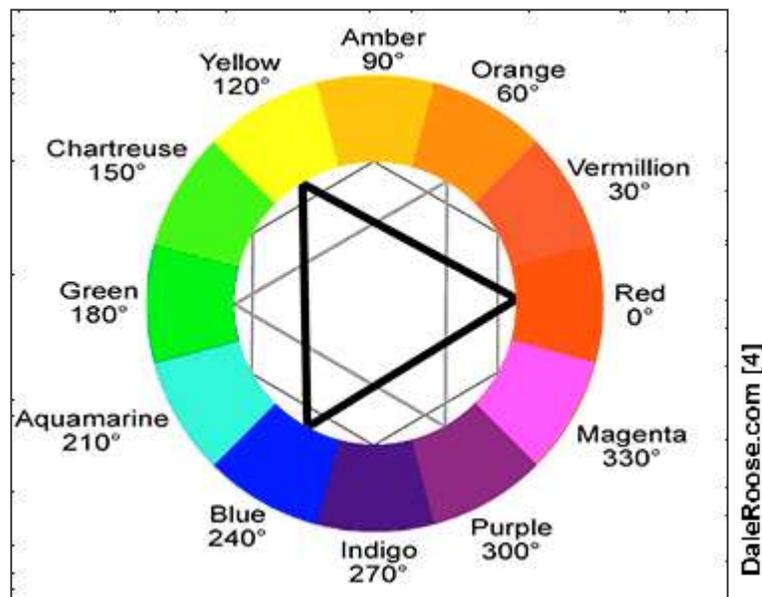
The RYB color scheme is a *subtractive* color system. When white light falls on a colored object, the object *reflects* one color and *absorbs* (subtracts) other colors.

Example: in the following sketch:

- The apple *reflects* red light and *absorbs* other colors.
- The leaf *reflects* green light and *absorbs* other colors.

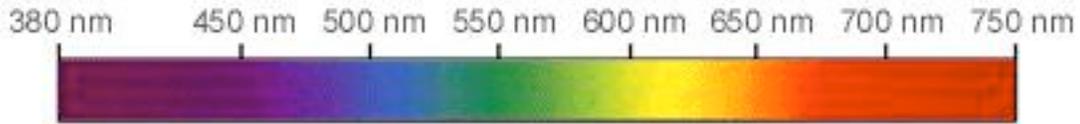


In (idealized) RYB color theory, every primary color has a "complementary" color, shown in the opposite position on the color wheel.



### Cultural History - Primary Colors

The RYB color wheel is an arbitrary construct. It has no basis in science; there are no standardized mathematical definitions of the colors (and there's certainly nothing that justifies assigning red at zero degrees). Indeed, the spectrum of visible light isn't even a circle; it's just a tiny band of frequencies within electromagnetic spectrum:



Nevertheless, the RYB color scheme has long been used in the preparation of pigments (paints and dyes). This theory posits that mixing two primary colors produces the complement of the third primary. Thus, for example, mixing red and yellow pigments produces orange, the complement of blue. When exposed to white light, orange pigment reflects red and yellow light (so it looks orange), and absorbs blue.

In actual practice, this pigment-mixing theory has limitations.

It works well enough for grade-school art classes. Mixing red and yellow pigments will indeed produce something that could be called orange. But for serious artists, it's not possible to obtain every desired color by mixing red, yellow, and blue pigments in any combination. The enormous variety of artists' paints available from art-supply houses today speaks to this fact.

Yet in spite of its limitations, the RYB color scheme remains a valuable tool for *subjective* color analysis. Artists (and their critics) in numerous fields—architecture, fashion design, floral design, graphic arts, interior design, landscape design, merchandising, retail sales, photography, printing, web design, videography—rely on it in their work.

The RYB color scheme is so engrained in our popular culture that it will always be regarded as "the primary colors."

## **The Additive Color Space**

You've probably heard that color video devices use a different set of primaries: red, green, and blue (RGB). This is true for your computer monitor, your television set, your cell phone screen, whatever.

So, why do video devices use RGB instead of RYB?

Because those are the colors that most closely correspond to the color sensitivity of the human eye.

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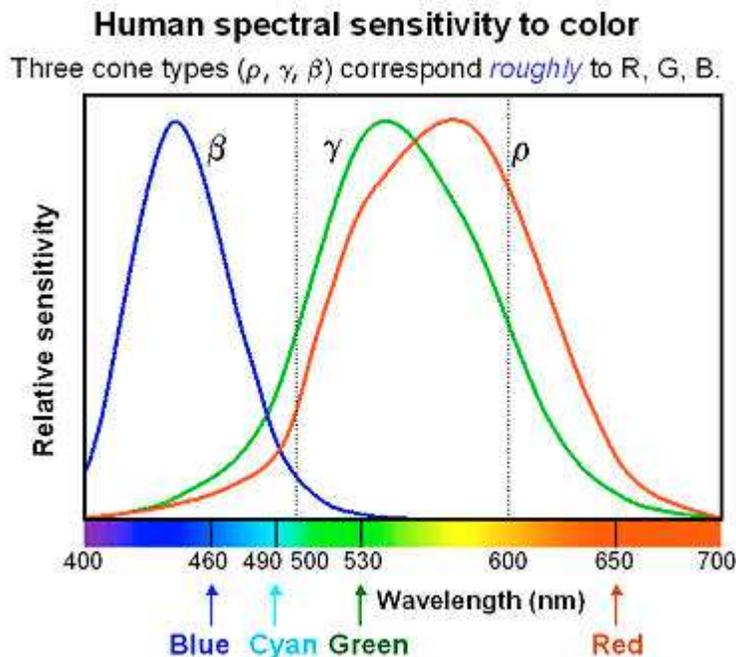
The retina of the eye is composed of (among other things) light-sensitive structures ("photoreceptors") of two types:

- **Rods:** These structures are sensitive to light without regard to color. They are very sensitive to light, but they do not distinguish color. They allow us to see at low light levels.
- **Cones:** These structures are sensitive to color. There are three types of cones, each most sensitive to a specific band of colors. These bands roughly correspond to blue, green, and red.

Cones are identified by lower-case Greek letters, and the corresponding colors are identified by wavelength:

IDENTIFIER	COLOR	WAVELENGTH
$\beta$ (beta)	blue	445 nanometer
$\gamma$ (gamma)	green	535 nanometer
$\rho$ (rho)	red	575 nanometer

The relative color sensitivity of the cones can be shown graphically as follows:



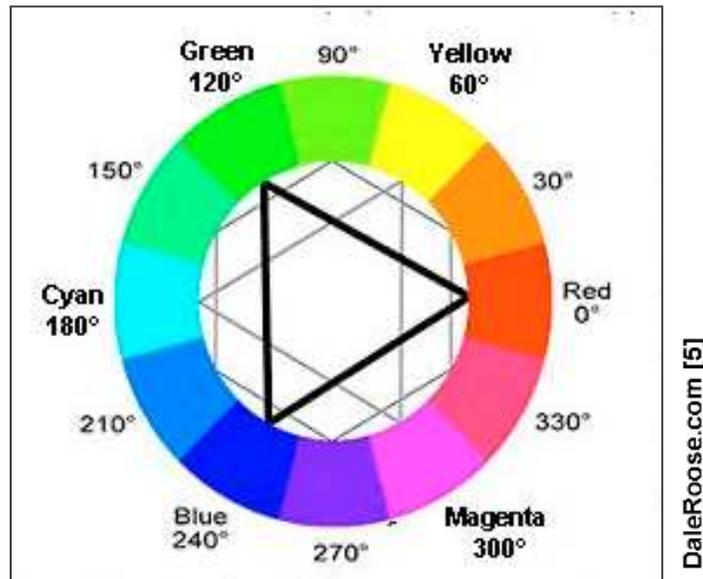
By studying this chart, we note:

- The **blue** (beta) cones are most responsive to **blue** light.
- The **green** (gamma) cones are most responsive to **green** light.
- The **red** (rho) cones are most responsive to **yellow** light. But they are the *only* cones that have significant response to **red** light.

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Combinations of red, green, and blue light yield other colors. Mixing ("adding") these primaries can produce the range of colors needed to render a color image on a computer or television screen.

We can arrange these colors in a color wheel. Compare this color wheel with the RYB color wheel on page 2. Both start with the same point (red, at 0°), and proceed counterclockwise. In this case, the three complementary colors are yellow, cyan, and magenta.



Taking this comparison one step further, we can posit that mixing two primary colors produces the complement of the third primary. Thus, for example, mixing red and green light produces yellow light, the complement of blue. Mixing all three produces white light.

It turns out that this is indeed true, with one important caveat: in order to match the color sensitivity of the human eye, the light sources cannot be at equal intensity ("brightness"). If we mixed red, green, and blue light in equal intensities, we would see some shade of purple.

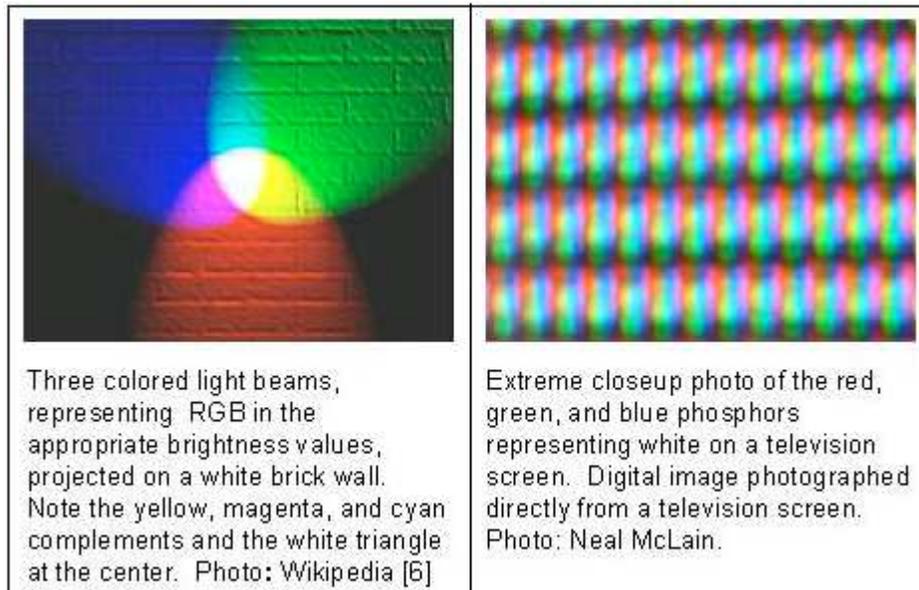
Extensive research efforts by Kodak (color photography), RCA (color television), and others have quantified these intensities. In the United States, the standard "white" for color television is defined as:

$$\text{White} = 59\% \text{ green} + 30\% \text{ red} + 11\% \text{ blue}$$

Take another look at the color wheel above and compare it with this equation. Intuitively, green "looks" brighter than red, and red "looks" brighter than blue. This equation states it mathematically.

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Following are a couple of actual examples of white light produced by additive primaries:



Similar mathematical definitions have been derived for the three complementary colors. Each complementary color is the additive mix of two primary colors *at the intensities that match the color sensitivity of the human eye*.

To illustrate this point, following is a digital representation of the standard "color bars" test pattern used in the television industry. Also shown is the underlying greyscale, representing the "brightness" of the corresponding color. Note that:

- Blue is so dark that it's almost black.
- Each complementary color is brighter than either of its component primaries.
- White (as defined by the equation on page 5) is white on the grayscale.



Next month, we'll continue this article with a discussion of the YCM (yellow-cyan-magenta) subtractive color scheme.

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**Endnotes**

[1] *RGB color model*. Wikipedia, The Free Encyclopedia. Retrieved 26 Jun 2008. Wikimedia Foundation, Inc. <[http://en.wikipedia.org/w/index.php?title=RGB\\_color\\_model&oldid=221910287](http://en.wikipedia.org/w/index.php?title=RGB_color_model&oldid=221910287)>.

[2] *Color Theory*. Colormatters.com. Retrieved 26 Jun 2008.  
<<http://www.colormatters.com/colortheory.html>>

[3] *Flower Color Wheel*. Aggie Horticulture.® Retrieved 26 Jun 2008.  
<<http://aggie-horticulture.tamu.edu/floriculture/container-garden/lesson/colorwheel.html>>

[4] *RYB Color Wheel*. DaleRoose.com. Retrieved 26 Jun 2008.  
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[5] *RGB Color Wheel*. DaleRoose.com. Retrieved 26 Jun 2008.  
<[http://www.daleroose.com/web\\_design/color\\_chart/](http://www.daleroose.com/web_design/color_chart/)>

[6] *RGB color model*. Wikipedia, The Free Encyclopedia. Retrieved 26 Jun 2008. Wikimedia Foundation, Inc.  
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