

**FERRUM  
COLLEGE**

**DEPARTMENT.**

**COLOR  
SYSTEMS  
HANDBOOK**

# The RYB, CMYK, RGB, HSV and Hexadecimal Color Models

## The RYB Color Model



- The red, yellow, and blue (RYB) primary colors became the foundation of color theories that described how artists mixed paint pigments to produce colors.
- These theories were summarized by Johann Wolfgang von Goethe (the famous German poet) in his document the *Theory of Colors*, published in 1810.
- In the late 19th century, German and English scientists established that a color model based on red, green, and blue (RGB) was better for describing human color perception because the cones in the human retina responded to these colors of light. The RGB color model is described below.
- The RYB Color Model is a subtractive system. A mixture of two primary colors is darker than the original colors. A mixture of all three primary colors should approximate black, although this is usually not precisely true.
- A popular theory in Europe during the late 18th century was that the harmony of a painting required colors with equal saturation. Bright red and blue colors existed (for example carmine and ultramarine), but no equally bright yellow. This motivated a large effort among chemists to develop a good yellow pigment.
- Although the secondary colors orange and green can be created by mixing primary colors (orange = red + yellow and green = yellow + blue), the resulting colors are darker than the original primary colors; it is better to use orange and green pigments directly.

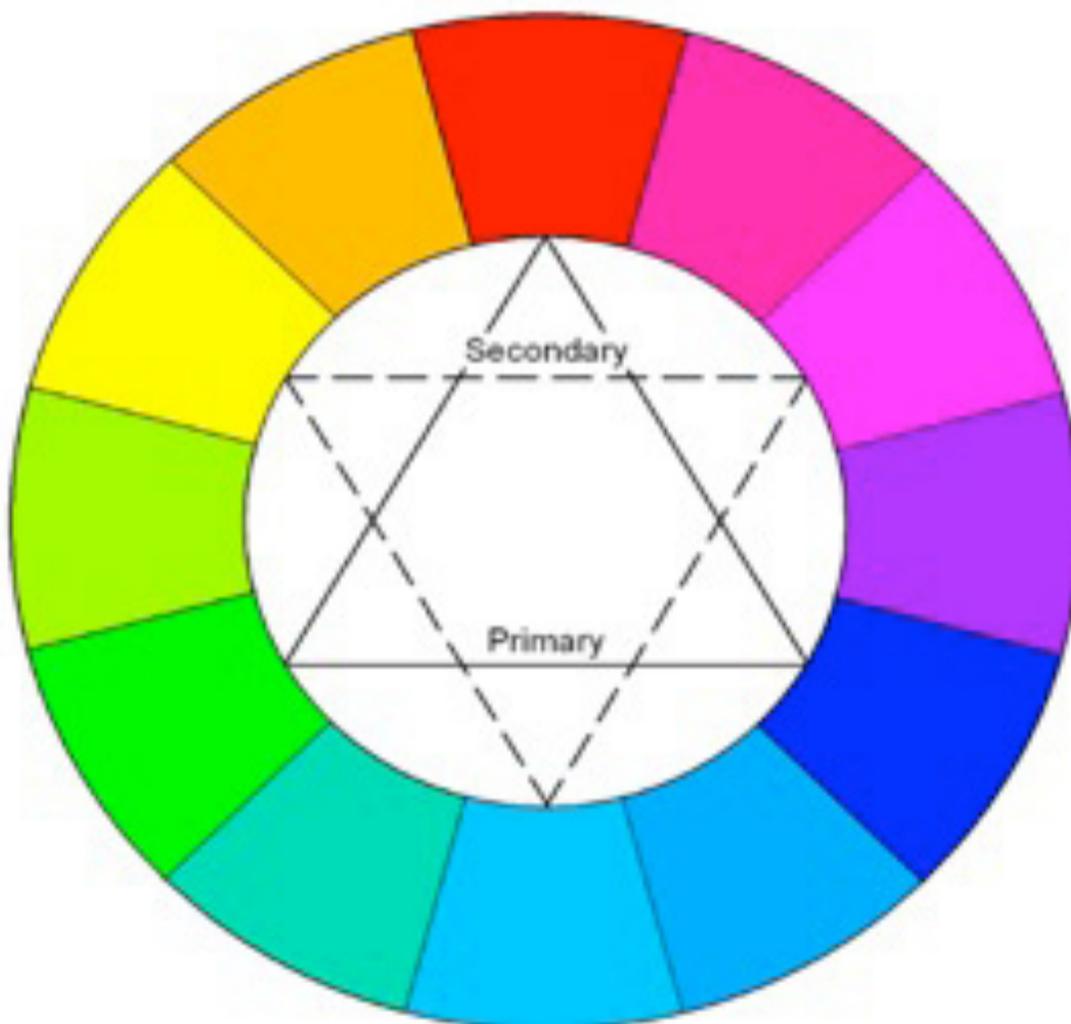
## The CMYK Color Model



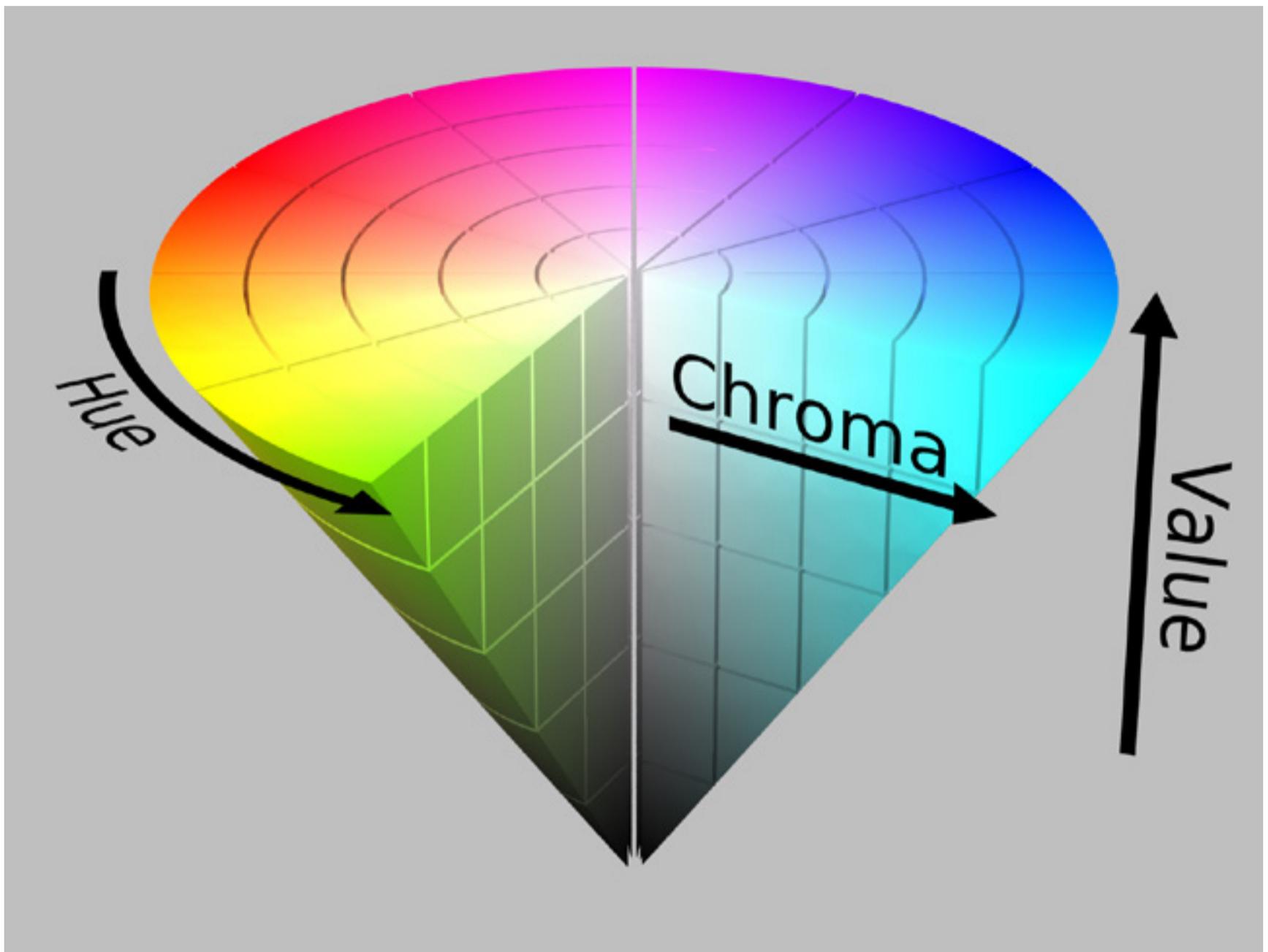
- Modern color printing prefers to use cyan, magenta, and yellow as primary colors instead of red, yellow and blue.
- Cyan, magenta, and yellow are the secondary colors on the RGB color wheel
- CYM is a subtractive system like RYG.
- Modern color printing systems use a four color system that includes black in addition to cyan, magenta, and yellow.
- This system is called CMYK, where K represents the "key" color black.
- Black is used in addition to CMY for these reasons:
  1. Black ink is cheaper than mixing C, M, and Y to obtain black.
  2. Text printed in black has fine detail that would be blurred if printed with three different colors.
  3. A mixture of C, M, and Y produces an imperfect shade of black.
  4. Soaking the page with three different inks produces a page that is slow to dry.
- To obtain white and light colors, halftoning is used.
- In addition to alternative to half-toning, the six-color system CMYKOG and the seven-color system CcMmYyK are used. (The colors c, m, and y are lighter versions of C, M, and Y.)
- Jacob Christoph le Blon (1667 - 1741) is credited with inventing the three-color (CMY) and four-color (CMYK) printing systems.

## The RGB Color Model

- The RGB color model was first described by Thomas Young and Herman Helmholtz in their Theory of Trichromatic Color vision (first half of the 19th century) and by James Maxwell's color triangle.
- In addition to providing a good description of human color perception, the RGB model is the basis for displaying colors in television and computer screens.
- The RGB model is also used for recording colors in digital cameras, including still image and video cameras.
- The RGB model is an additive system.
- In practice, the RGB model must be modified to account for the characteristics of each device. In many cases, the response of visual recording devices is nonlinear, which require some sort of gamma correction.
- To represent colors for a television or computer screen, each **pixel** of the screen is recorded as the triple (r,g,b) of numbers. One popular system uses numbers that range from 0 to 255 for each color.
- **Examples:**



## The HSV Color Model



- When artists began to use computers for graphic design, it was soon discovered that the RGB system is not a very intuitive way to represent colors.
- Alvy Ray Smith in 1978 was the first to describe colors using hue, saturation, and value (HSV model).

**Hue** is a saturated color

**Saturation** is the amount of white added to the color. 0% means that the color (at  $V=100\%$ ) is totally white; 100% means totally saturated with no white added (a fully saturated color is a pure hue on the outer rim of the HSV color wheel).

**Value** is the brightness of the color. 0% means totally dark or black; 100% means full brightness, with the color is fully determined by the hue and saturation.

- Graphic artists like the HSV color model because it is an intuitive way to modify the colors in a region of an image. For example:

Add more green to a region translates to "rotate the hue towards 120 degrees."

Make the color more of a pastel color translates to "decrease the saturation."

Make the colors in the image darker translates to "decrease the value."

# Hexadecimals!!!

## Code Demands Precision

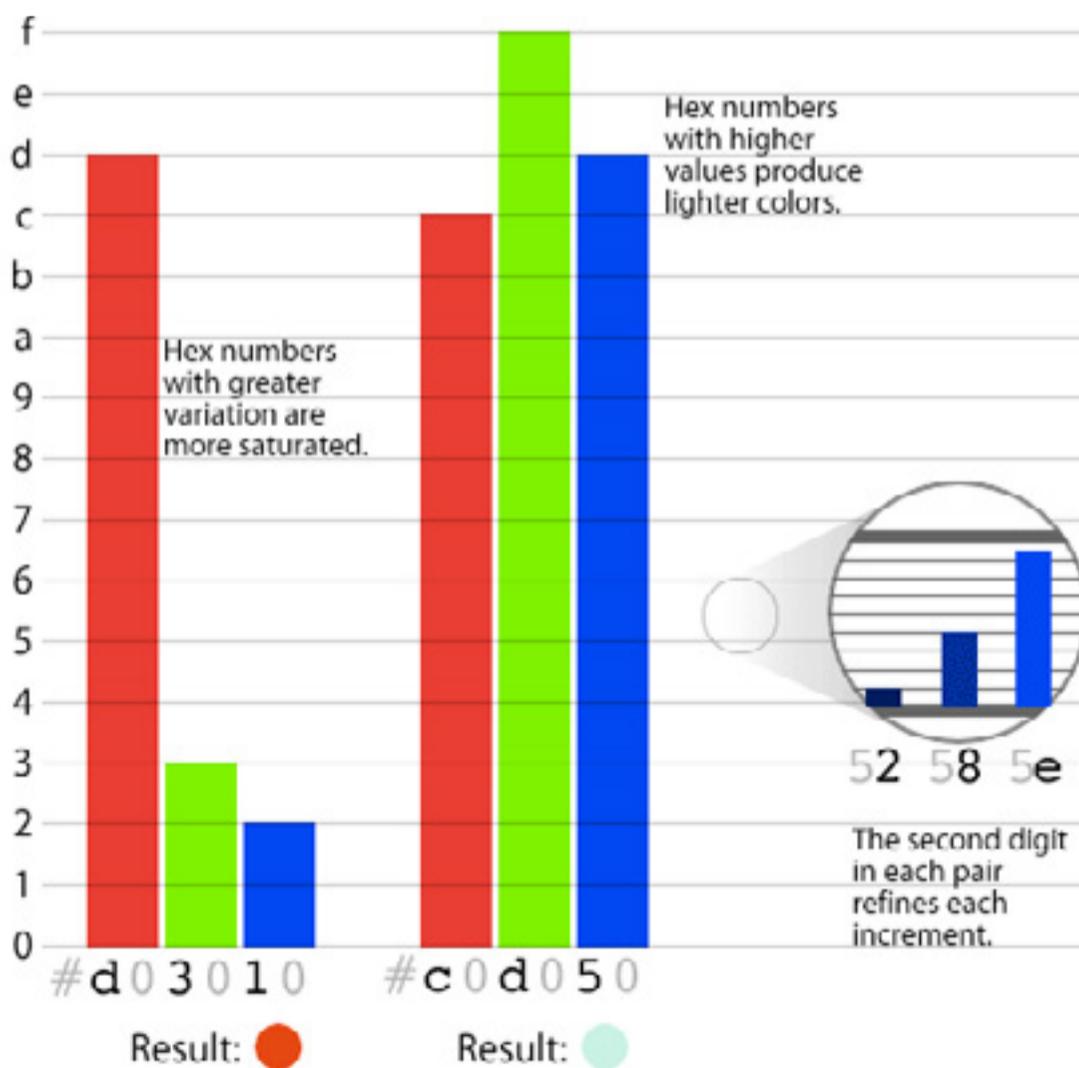
When computers name a color, they use a so-called *hexadecimal code* that most humans gloss over: 24-bit colors. That is, 16,777,216 unique combinations of exactly six characters made from ten numerals and six letters — preceded by a hash mark. Like any computer language, there's a logical system at play. Designers who understand how hex colors work can treat them as tools rather than mysteries.

Pixels on back-lit screens are dark until lit by combinations of red, green, and blue. Hex numbers represent these combinations with a concise code. That code is easily broken. To make sense of #970515, we need to look at its structure: The first character # declares that this "is a hex number." The other six are really three sets of pairs: 0–9 and a–f. Each pair controls one primary additive color.



*The higher the numbers are, the brighter each primary color is. In the example above, 97 overwhelms the red color, 05 the green color and 15 the blue color.*

Each pair can only hold two characters, but #999999 is only medium gray. To reach colors brighter than 99 with only two characters, each of the hex numbers use letters to represent 10–16. A, B, C, D, E, and F after 0–9 makes an even 16, not unlike jacks, queens, kings and aces in cards.

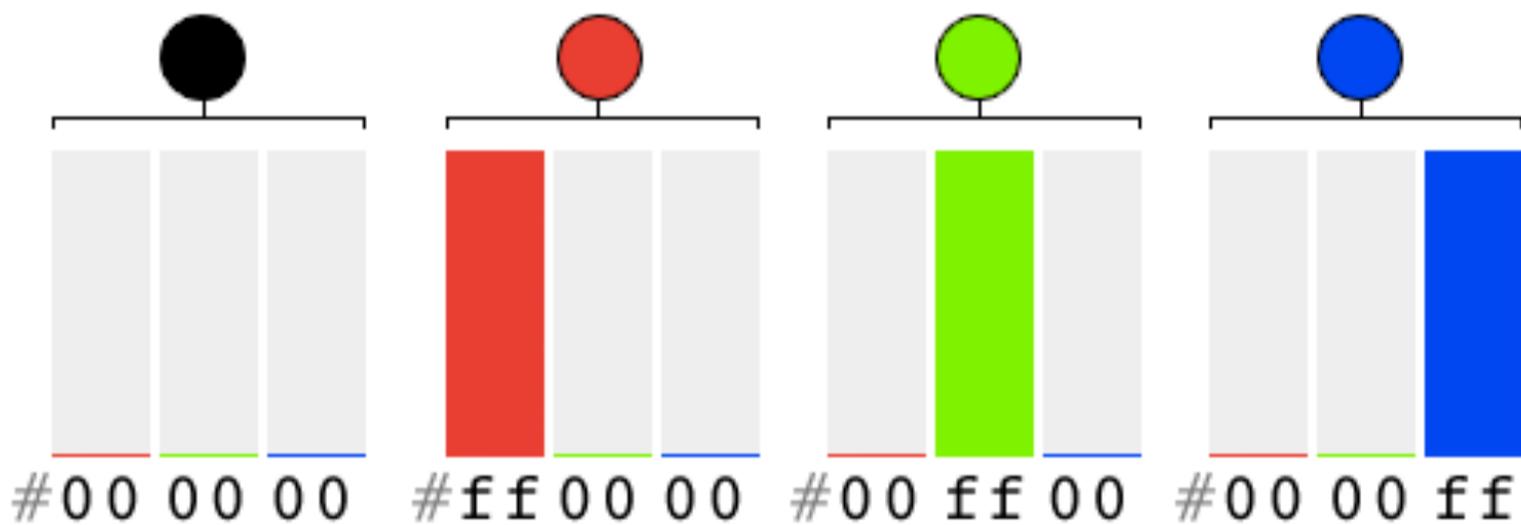


Being mathematical, computer-friendly codes, **hex numbers are strings full of patterns**. For example, because 00 is a lack of primary and ff is the primary at full strength, #000000 is black (no primaries) and #ffffff is white (all primaries). We can build on these to find additive and subtractive colors. Starting with black, change each pair to ff:

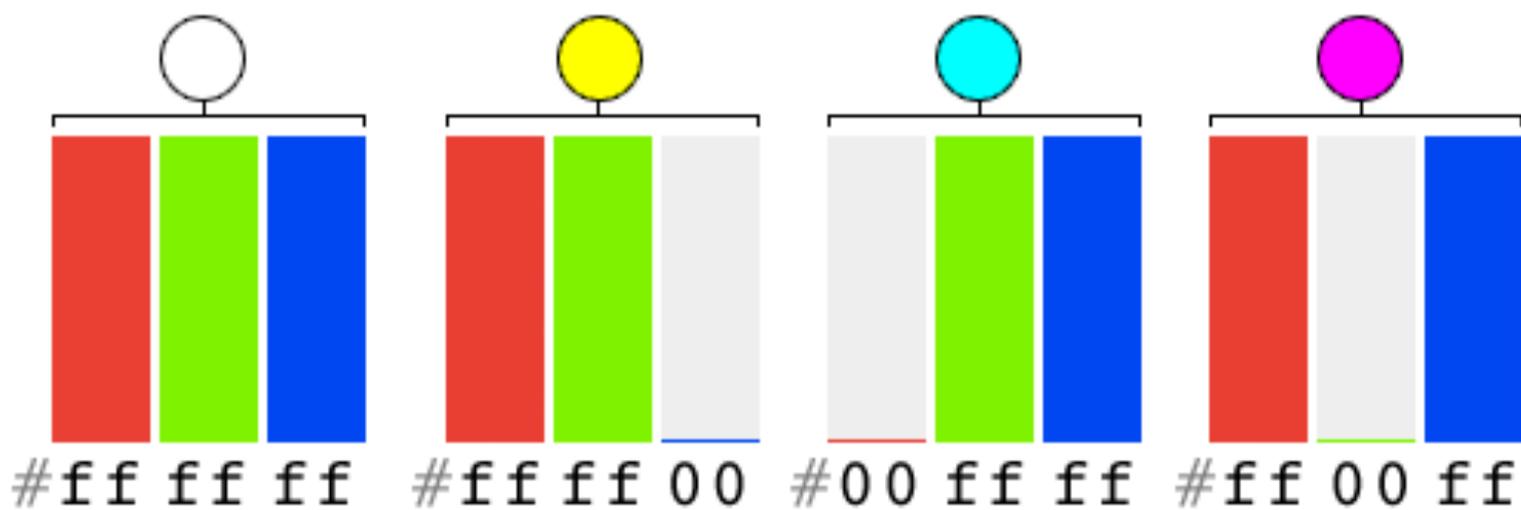
- #000000 is black, the starting point.
- #ff0000 stands for the brightest red.
- #00ff00 stands for the brightest green.
- #0000ff stands for the brightest blue.

Subtractive colors start with white, i.e. with the help of #ffffff. To find subtractive primaries, change each pair to 00:

- #ffffff is white, the starting point.
- #00ffffff stands for the brightest cyan.
- #ff00ff stands for the brightest magenta.
- #ffff00 stands for the brightest yellow.



No primaries  
means no color.



All primaries  
means all color.

## Shortcuts In Hex

Hex numbers that use only three characters, such as #fae, imply that each [ones place](#) should match the sixteens place. Thus #fae expands to #ffaaee and #09b really means #0099bb. These shorthand codes provides brevity in code.

In most cases, one can read a hex number by ignoring every other character, because the difference between the sixteens place tells us more than the ones place. That is, it's hard to see the difference between 41 and 42; easier to gauge is the difference between 41 and 51.

#970545

Example #1

Significant difference among  
the left-hand characters

#979085

Example #2

Not much difference on the  
left, so the right-hand  
characters are significant

The example above has enough difference among its sixteens place to make the color easy to guess — lots of red, some blue, no green. This would provide us with a warm violet color. Tens in the second example (9, 9 and 8) are very similar. To judge this color, we need to examine the ones (7, 0, and 5). The closer a hex color's sixteens places are, the more neutral (i.e. less saturated) it will be.

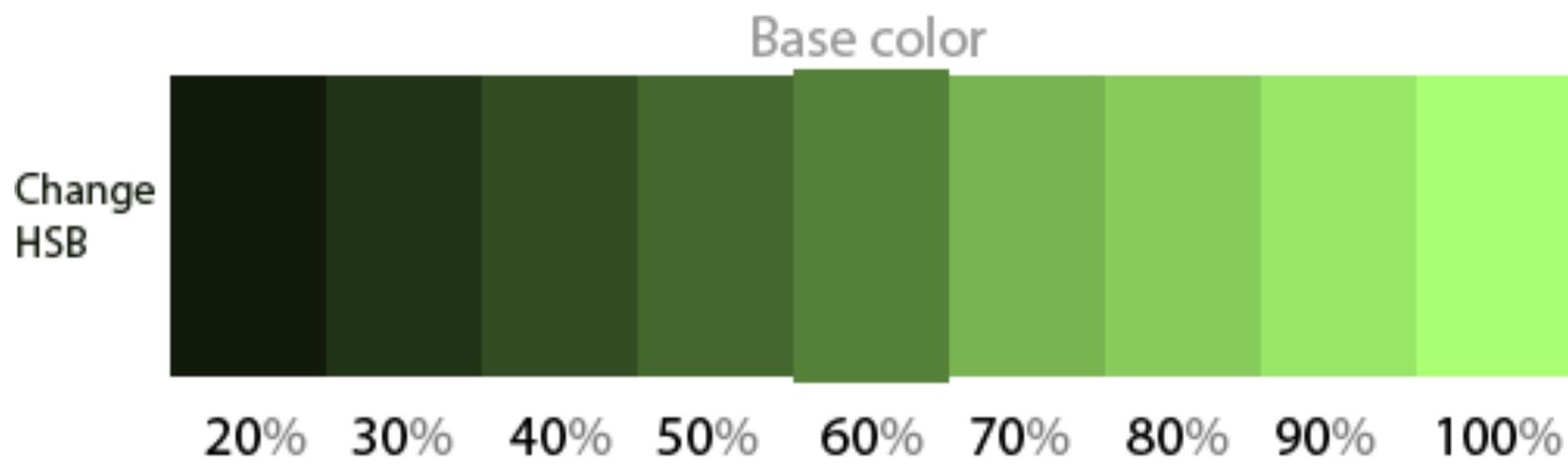
## Make Hexadecimals Work For You

Understanding hex colors lets designers do more than impress co-workers and clients by saying, "Ah, good shade of burgundy there." Hex colors let designers tweak colors on the fly to improve legibility, identify elements by color in stylesheets, and develop color schemes in ways most image editors can't.

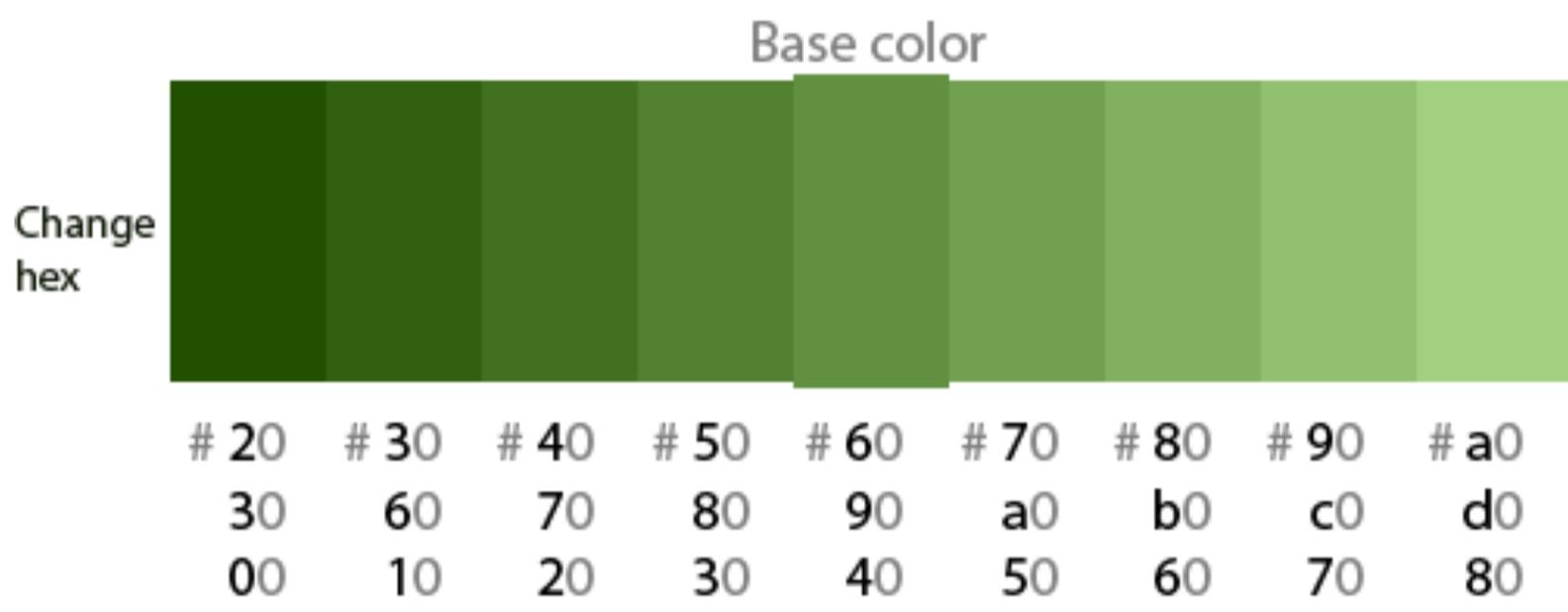
### Keep Shades In Character

To brighten or darken a color, one's inclination is often to adjust its brightness. **This makes a color run the gamut from murky to brilliant**, but loses its character on either end of the scale. For example, below a middle green becomes decidedly black when reduced to 20% brightness. Raised to 100%, the once-neutral green gains vibrancy.

A funny thing happens when we treat hex colors as if they were increments of ten. By adding one to each of the left-hand character of each pair, we *raise* a color's brightness while *lowering* its saturation. This prevents shades of a given color from wandering too closely to pitch black or brilliant neon. Altering hex pairs retains the essence of a color.



Brightness changes while saturation remains consistent.



Brightness increases as saturation drops.

In the example above, the top set of shades appears to gain yellow or fall to black, even though it's technically the same green hue. By changing its hex pairs, the second set appears to keep more natural shades.