Color is a sensation that ultimately happens in our brains. It's amazing we can produce full color, apparently continuous tone images in-computer, when computers understand color only as strings of ones and zeros.

Recipes for reproducing colors

How can we quantify *red* beyond saying it's a word used to describe a certain portion of the color spectrum? Assigning specific numeric values to each color gives us a universal, unambiguous way to discuss them.

Photoshop and other image editing applications work with multiple *color models*. A color model is a general method of specifying colors with a set of numeric values. Most color models have three primary components; e.g., RGB = red, green yellow; CMY = cyan, magenta, yellow. Some application-specific color models have more components, such as the "key," or black in CMYK.

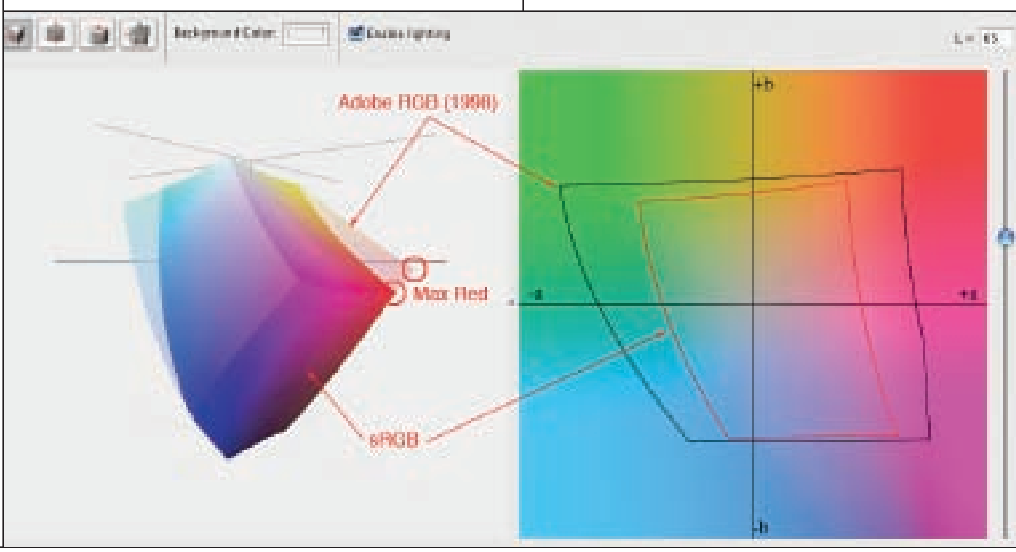
Some color models, such as x,y,Y and L*a*b*, encompass every color visible to humans; these models have a defined scale such that a particular color always has the same set of values. It's quite useful to be able to assign numeric values to specific colors based on how human vision distinguishes them from one another.

Such color models as RGB and CMYK are abstractions—they have no standard, defined scale or reference for each color. A color with an RGB value of R10/G30/B50, for example, doesn't tell us how to reproduce that color; the numbers are simply an ingredient of the primary components, without a necessary scale of the RGB primaries. In this example, we know that the primaries are red, green and blue, but we also need to know the scale of these primaries, *and* the units being specified. This is where a color space comes into play. A color space provides the additional information we need to reproduce specific colors.

Let's look at the term *space* as used in this context. I have three sets of numbers to define red, green and blue (R10/G30/B50), but how red or green or blue are these colors? What is the scale? We can plot any three primary values in three dimensions to define the scale. The coordinates we use represent all possible colors, including the extreme, most saturated reds, greens and blues. In other words, three coordinates of color in this three-dimensional space we've plotted can specify a color and its boundaries. This is a color space. When the scale of reds, greens and blues differs from the one in the illustration *(bottom, left)*—that is, the coordinates are different—we're looking at a color space other than RGB.

Think of a color model as a chocolate chip cookie recipe. Suppose I give you my recipe, which has only three ingredients, flour, butter and chocolate chips, but doesn't specify how much of each ingredient to use. You don't have enough information to make the cookies. When I tell you to use 1 cup of flour, 1 stick of butter, and 4 teaspoons of chocolate chips (or the same quantities in metric measures), you can now produce a batch of cookies. If I provide additional information such as the brand of chocolate chips to use, you can reproduce a batch of cookies that's exactly like mine. A color space is a color model that has a known reference and scale, in this case primaries (the ingredients) and scale (specific quantities of these ingredients).

Here, we'll use an RGB color model as an example, but keep in mind that these qualities are also true for CMYK and other color models. Suppose I



I used the X-Rite GamutWorks utility to create a 2D and a 3D gamut map of both Adobe RGB (1998) and sRGB. Note that the gamut of Adobe RGB (1998) is larger; the maximum red saturation is higher in Adobe RGB (1998), and it's a larger color space. The scale of the color space is defined by plotting the ICC profiles in a software utility like GamutWorks.

specify a color as R10/G30/B50, and provide a color reference by saying the color space (which defines the scale of the RGB primaries) is Adobe RGB (1998). With the units and reference defined, anyone with the proper tools can reproduce this color.

Different RGB color spaces use different scales of red green and blue. Adobe RGB (1998) and sRGB are separate color spaces, but both are based on the RGB color model. While each color space uses red, green and blue, the specific colorimetric scales are different. The scale of the RGB color primaries is more saturated in the Adobe RGB (1998) color space than the sRGB color space. While R225/G0/B0 is the reddest red ingredient in both Adobe RGB (1998) and sRGB, knowing that the scale is different in these two color spaces explains why this red value is more saturated in Adobe RGB (1998). This also illustrates how R225/G0/B0 alone can't tell us how red red really is without the scale, the color space.

There are hundreds if not thousands of different RGB color spaces just as there are hundreds if not thousands of different devices that create or reproduce RGB; same color model, different units. The same is true for all other color models, including CMYK, HSV, Grayscale, and others.

The beauty of ICC profiles is that they define the color space and thus the numbers. The illustration shows the gamut plot of two RGB working spaces. Because these profiles define the scale and the meaning of the numbers, we can fully communicate how these color spaces behave. ■

This is a condensed excerpt from Andrew Rodney's book "Color Management for Photographers," newly released in paperback by Focal Press.