CHAPTER 1

DIGITAL IMAGING FOUNDATIONS

Photography is, and always has been, a blend of art and science. The technology has continually changed and evolved over the centuries but the goal of photographers everywhere remains the same: to make compelling images.

Mastering photography means mastering the art and *the craft. Proficiency with current tools facilitates much greater creative potential.*

This chapter provides the technical foundation to process your photographs for the highest quality.

1

The State of the Art

Until just a few years ago, professional photographers commonly would expose rolls or sheets of film, send them to a lab for processing and then review them on a light table. Though some photographers processed their own film and/or produced final prints, the amount of control offered in the analog process was inherently limited by the technology. As a result, not all photographers took a creative role in the final outcome of their photographs.

With the switch to digital imaging over the past decade or so, the technical demands on today's photographer are much greater than in the past, but the potential for individual creativity in photography is also greatly enhanced. With digital capture and processing, the photographer can remain in control all the way through the imaging process. The final manifestation of each image can be exactly what you want.

Making the most of this new technology requires learning new skills. Processing your digital photos requires strong computer abilities and the willingness to continually purchase and master new hardware and software. There's no getting around it: with the freedom of expression offered by modern photographic tools comes the responsibility to handle the process yourself. Take the time to improve your photography by continually learning to properly use the latest tools.

Before we get into the Lightroom workflow, let's be sure we're all on the same page with respect to a few key fundamentals of digital imaging.

Anatomy of a Digital Image

Understanding the characteristics common to every digital image will help you make better processing decisions. The primary attributes common to all digital images are *resolution, bit depth, color mode* and *file format.*

PIXELS AND RESOLUTION

By now most photographers understand that a digital image is made up of pixels. But what exactly is a pixel? It's simply a piece of binary information… a "picture element". A pixel is the building block of a *raster* or bitmap image. A pixel doesn't have an inherent size–is is just a piece of data in a fixed position on a grid. The pixel contains data for color and brightness, as well as alpha channel (transparency) information.

This is where resolution comes in, and many people get confused about it. Put most simply, resolution is the number of pixels in the image. Among other things, resolution determines the maximum size at which the file can be printed at

Figure 1–1: Close-ups of low and high resolution raster images

high quality. When printing, the image resolution can be specified as pixels-per-inch (ppi) to determine the output size.

Resolution also describes the ability to *resolve* detail (see Figure 1–1). More pixels equal higher resolution. Fewer pixels equal lower resolution. A digital photograph with high resolution has the potential to show more detail and be printed at a larger size. For example, if you photograph a tree in low resolution, one leaf might equal one pixel—not a lot of detail. Photographed in high resolution, one leaf could be made of dozens of pixels, showing stem, veins etc.—thus the power to resolve detail.

65,000 pixel limit

Lightroom can only import files up to 65,000 pixels on the longest side.

Native resolution and resampling

The original, unaltered resolution of a digital image file is its *native resolution*. Digital images can also be *resampled,* which either adds or discards pixels. *Upsampling* adds pixels and allows printing at larger sizes. *Downsampling* discards pixels and is usually used to reduce file sizes and to prepare files for viewing on screen, which requires less resolution than printing. Resampling requires the software to *interpolate* the existing image data in order to make new pixels. During interpolation, pixels are analyzed with their neighbors to generate new pixels. This results in a loss of data. For this reason, it is imperative that any resampling be done only when needed for a specific purpose. Resampling is discussed in more detail in Chapter 8.

When you work on photos in Lightroom, you're always working at the native resolution of the original file. You can't resize/resample images within Lightroom; you do this only when exporting derivative files from the originals or when printing. Resolution is discussed in more detail in Chapters 8 and 9.

Always process your master image files at native resolution

Keep your original masters in their native resolution. Later in the workflow you can resample as necessary and save derivative files for a particular purpose.

DIGITAL COLOR

After resolution, the second main characteristic of a digital image is color, or lack of it. In the computer, mathematical models numerically describe the way colors in the real world appear to the human eye. Image files can also be comprised of only black and white or grayscale values.

Bit depth and color values

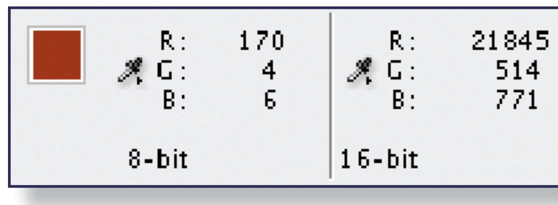

Figure 1–2: Bit depth and color values (from Photoshop)

The numeric values assigned to pixels in an image file are based on *bit depth*, which is the number of binary digits used to describe a color value (see Figure 1–2). All the pixels in a single image file have the same bit depth; it's the variation of the numeric values assigned to each pixel that provide color information and give the appearance of continuous tone in an image.

Bit depths most often range from 1-bit (black or white) to 8-bit (grayscale or color) and 16-bit (grayscale or color). Though few applications and devices currently support it, 32-bit can be used as an intermediate working space when making HDR (High Dynamic Range) images.

More bits mean that more data is being used to describe the color values of the pixels. An image containing 16-bit data provides more "headroom" for processing than does an 8-bit image. This is because the additional data can be manipulated further before the appearance of the image starts to degrade. 16-bit allows smoother transitions between colors and reduces the appearance of *posterization* where areas of color become solid and transitions become hard-edged.

Based on bit depth, each pixel in an image is assigned a numeric color or grayscale value. In the RGB (red, green, blue) color model, each pixel has a color specified by a combination of three numeric values, ranging from 0-255 in 8-bit or 0–32768 in 16-bit. For example, in 8-bit RGB color, pure red is 255, 0, 0; pure green is 0, 255, 0 and pure blue is 0, 0, 255. (You will rarely, if ever, see these pure values in your images, though; colors captured from the real world will contain arbitrary levels in each channel.)

Monitor bit depth

Your display hardware is dependent on color depth, too. Make sure your monitor color settings are as high-bit as available; at minimum, Thousands of Colors, and ideally, Millions, for the most accuracy evaluating your photos on screen.

Color modes and channels

The industrial revolution brought with it major advances in measuring and reproducing color. Throughout the 20th century various color models were developed and refined to mathematically describe colors from the real world. Because they are based on math, these models translate well to computer processing.

There are a variety of digital color models (often called *modes* in computer imaging) in use today. The most common color mode for photographic imaging is RGB (red, green, blue). This model is based on the cones in our eyes, which respond individually to red, green and blue wavelengths of light. In addition to RGB, common color modes you'll see are CMYK for printing (cyan, magenta, yellow, black (or *key*)) and Lab (Lightness plus a and b), which is most often used as an intermediate color mode during processing.

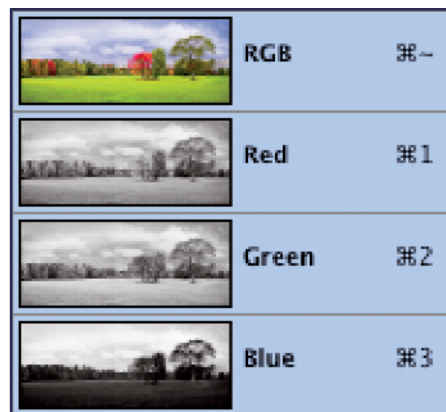

Figure 1–3: Color channels

In a color image, each *color channel* is made up of grayscale values (*levels*) that indicate the density of that color for each pixel (see Figure 1–3). An RGB image file contains three color channels: one each for red, green and blue. Lab also has three channels; CMYK has four channels and a grayscale image has only one channel.

It's useful to know the basis of the numeric color values. At times it's better to work with colors "by the numbers". Some images have compositions with color combinations that are deceiving to the eye, and knowing what the true color is, based on the numeric values, helps make accurate processing decisions.

Lightroom uses 16-bit color for internal processing and color measurements are displayed as percentages rather than actual numeric values (see Figure 1–4). For example, 0%, 0%, 0% is solid black and 100%, 100%, 100% is pure white.

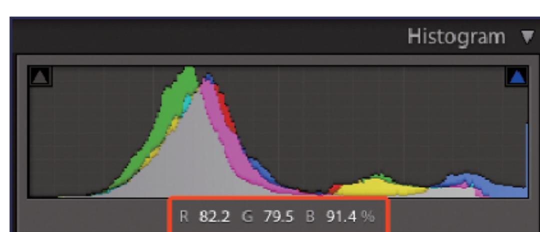

Figure 1–4: Lightroom color measurements

Components of digital color

Color in digital image files has three components (see Figure 1–5):

- **Hue:** the dominant wavelength and the named color, i.e. red, purple, orange are all hues.
- **Saturation:** purity of the hue; how far from neutral gray.
- **Luminance:** how light or dark the color is; how close to pure white or solid black. (In various software you may also see this referred to as Lightness, Brightness or Luminosity.)

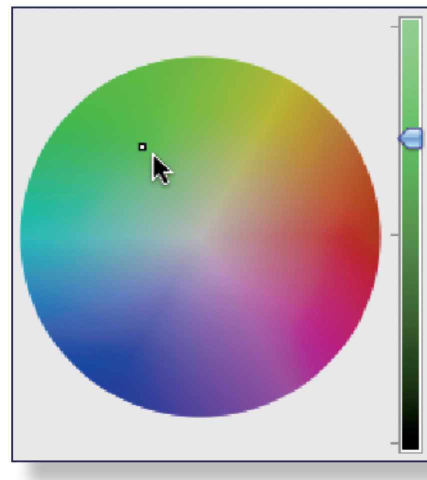

Figure 1–5: Hue and saturation are shown in the circle ; luminance is on the slider. The center of the circle is neutral gray; moving outward increases saturation.

Color temperature

With digital capture, you can control how the color of light in the scene affects the colors captured. *Color temperature* is measured in degrees Kelvin and refers to the measured color of light sources (see Figure 1–6). For example:

- Bright sunlight at midday is approximately 5000k;
- Open shade is around 6500k; and
- Tungsten light bulbs are about 2800k.

Color temperature dramatically affects the overall colors in a digital photograph so understanding how the color temperature of light affects the digital capture is essential. *White Balance* controls on your camera and in software let you manipulate the global rendition of colors in a photo based on color temperature. White Balance is covered in more detail in Chapters 4 and 7.

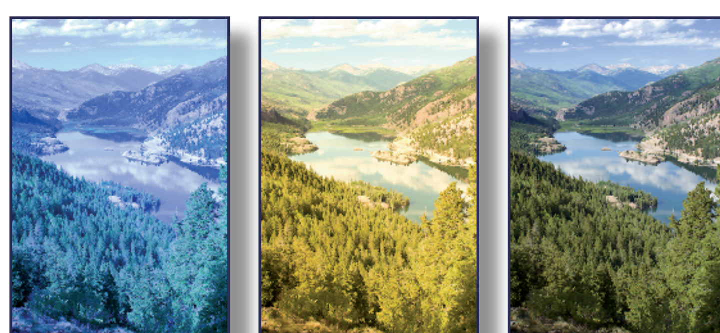

Figure 1–6: Color temperatures: tungsten, cloudy, daylight.

Challenges exist when translating colors from the real world into the digital realm. A given color, numerically described, will have different renditions on different devices. This is where *color management* comes in.

Color Management Essentials

Implementing color management is a critical aspect of getting your digital photos from capture through print; for your photos to look their best you should establish and follow a color-managed workflow. Color management refers to an integrated system of computer hardware and software working together to translate color from one device to another in a controlled way. The color management system (CMS) is built into your computer's operating system; on Mac it's ColorSync and on Windows it's ICM (WCS on Vista). The CMS handles color management at the system level. The CMS is responsible for translating digital color values to and from digital files and output devices. Software applications, such as Lightroom, Photoshop, etc., can be programmed to take advantage of the CMS (or not), and some programs, including most Web browsers, do not use color management at all. This is why a photo can look different depending on the application used to view it.

Lightroom Color Management

Lightroom is internally color-managed; there are no options to configure. If you're using a properly calibrated and profiled display, you can trust that the colors you see on-screen are very accurate. Lightroom will respect and preserve embedded profiles in image files, and uses a proprietary color space for internal processing.

COLOR SPACES

A *color space* is a 3-dimensional mathematical model describing the range of colors possible in an image file or on an imaging device, such as a monitor or printer (see Figure 1–7). Using the RGB color model, there are several color spaces in widespread use today. The most common RGB color spaces used in digital photography are:

- sRGB
- Adobe RGB (1998)
- ProPhoto

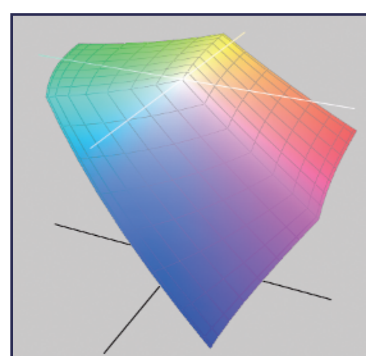

Figure 1–7: Three-dimensional plot of the Adobe RGB (1998) color space

Color spaces and their uses are discussed in more detail in Chapter 8.

ICC PROFILES

The color space of an image can be embedded as an ICC (International Color Consortium) profile. JPG files captured from your camera will contain the profile for the color space set on your camera (usually sRGB or Adobe RGB).

Camera raw and DNG files can not contain embedded ICC profiles, however, DNGs can contain a DNG profile. Previously processed image files on your hard drive, such as PSD and TIF, may or may not have embedded color profiles depending on processing previously done. For more information on file types and their uses see Chapter 8.

Source and Destination

An ICC profile describes the color space of an image file or imaging device. A color–managed workflow uses profiles for each file and device in the imaging pipeline.

Profiles are stored in specific places within your operating system so they are made available to any program using the CMS. The CMS uses the profile to handle the translation of numeric color values between devices. In a digital image file, an embedded ICC profile tells the color management system the rules for translating the colors in the image through the pipeline. For a device, the profile tells the CMS how to convert the color data in an image to the output device—a printer, monitor, etc.

The CMS processes the color values in the *source* profile to create the optimum values for the *destination*. For example, when printing, an image file in the Adobe RGB color space would be the source and an Epson printer profile would be the destination.

ICC profiles are also discussed in more detail in Chapter 8.

Gamut: The Range of Colors Available

Different devices (monitors, printers etc.) interpret color numbers in different ways, because of differences in the type of device and their primaries (their main colors: red/green/blue, or cyan/magenta/yellow/black, etc.) No device can reproduce all colors and all devices reproduce color differently. The range of colors that a device can reproduce (or that a digital file contains) is called the color *gamut* (see Figure 1–8). A large gamut contains many possible colors and a small gamut has relatively few colors available. The gamut is described within the ICC profile.

Of the three main color spaces, sRGB has a relatively small gamut, Adobe RGB is considered to have a relatively large gamut, and ProPhoto has the largest gamut and is capable of containing the most possible colors. (Note that there are a few lesser-used color spaces. Such as EktaSpace, that have even larger gamuts than ProPhoto.)

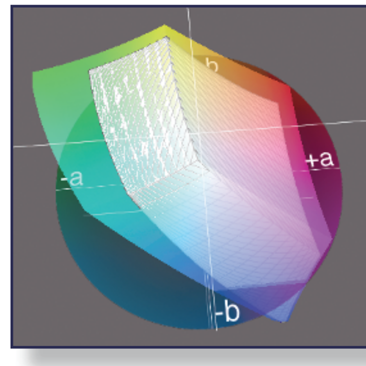

Figure 1–8: These plots of Adobe RGB (1998) on the outside and sRGB on the inside clearly show the difference in the sizes of their gamuts.

- Smaller color space=fewer colors
- Larger color space=more colors.

Rendering Intents

Out-of-gamut colors are those present in the source file but not in the destination profile. For example, the limited gamuts of many color printers pose difficulty reproducing bright shades of blue found in many RGB image files. When the source color can't be reproduced in the destination, the *Rendering Intent* determines how the color value(s) are translated to the destination space.

The two most common rendering intents are *Perceptual* and *Relative Colorimetric.* Perceptual compresses the gamut of the source to fit into the destination, remapping all the colors to preserve their visual appearance as perceived by the human eye. Relative Colorimetric keeps all the in-gamut colors unchanged and clips the out-of-gamut colors to the closest possible match within the destination gamut. Perceptual may provide for the most pleasing overall rendering for some images, but Relative Colorimetric is numerically more accurate and is most often ideal. Rendering Intents are discussed further in Chapter 9.

CALIBRATING AND PROFILING YOUR DISPLAY

The most important factor in achieving accurate color for your digital photographs is working on a calibrated and profiled display. Calibrating your display corrects its output settings, and profiling makes an ICC profile for use by the CMS.

Calibrating and profiling your display must be done with a combination of dedicated hardware and software. Software alone, such as Adobe Gamma, is not sufficient; you must use a measurement device to perform accurate calibration. I recommend the X-Rite i1 (Eye One) systems for this; see Resources in Appendix.

1

FILE FORMATS

There are many image file formats in use today, but most are highly specialized. In the digital photography workflow there are only a few kinds of files you need to deal with. Following are the file formats that Lightroom can read and, in most cases, write to:

- **Camera raw:** These files come directly from your camera with formats specified by the camera manufacturer and are encoded in a way that they cannot be directly modified. Common examples are Canon's .CR2 and Nikon's .NEF formats. Note that two raw files with the same file extension but from different cameras are likely to be programmatically different; your camera model's native format must be supported by Adobe for you to work with those files in Lightroom. Adobe imaging software supports nearly all digital cameras available on the market and support for new models is continually updated. However, when a new camera is released there may be a period of lag time during which your files cannot be read by Lightroom or Adobe Camera Raw. In our workflow, camera raw files serve as the original capture from the camera but are only used temporarily.

- **DNG (Digital Negative):** Adobe's open raw format. Camera raw files converted to DNG contain all the original raw data from a camera raw capture plus optional previews and metadata (embedded textual information about the file). DNG allows saving metadata inside the file and does not require sidecars (see below). dng is my recommended raw format.

- **TIF or TIFF (Tagged Image File Format):** Industry standard, open-source file format. May contain layers, vector objects and transparency. TIF files can be compressed using lossless algorithms.

- **PSD (Photoshop document):** Photoshop files must be saved with the Maximize Compatibility option enabled in order for Lightroom to read them.

- **JPG or JPEG (Joint Photographic Experts Group):** this is the standard format for presenting and exchanging continuous tone (photographic) images, especially on the Web. A JPG file is compressed using *lossy* algorithms, which means that data is discarded during saving (even at the highest quality level). In Lightroom, JPG files from your camera can be used as originals. However, for the best quality, always capture raw (see Chapter 4).

Lightroom doesn't support:

- Files in the CMYK color mode
- Adobe Illustrator® files
- Files larger than 65,000 pixels on any side
- Files larger than 512 megapixels
- Video files

Camera raw files and sidecars

Because a raw file straight from the camera typically cannot be modified using software, any metadata applied to the file must be stored elsewhere. The most common method is the use of *sidecar* files in .XMP (Extensible Metadata Platform) format. A sidecar file is associated with a specific, individual file and contains metadata changes made to the raw file in software such as Lightroom and Adobe Camera Raw. The sidecar must always accompany the original file in order for the metadata changes to be available to the software. This is one reason I recommend using DNG originals instead of native camera raw files.

Chapter Summary

All digital image files share several common characteristics. How these affect the quality of the data in the image file should be considered when making processing decisions. Implementing color management policies and calibrating your display are essential for accurate color reproduction.