A ShortCourses Book

The Textbook of Digital Photography

SECOND EDITION

Dennis P. Curtin

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CONTACT/FEEDBACK INFORMATION

ShortCourses.com
16 Preston Beach Road
Marblehead, Massachusetts 01945
E-mail: denny@shortcourses.com

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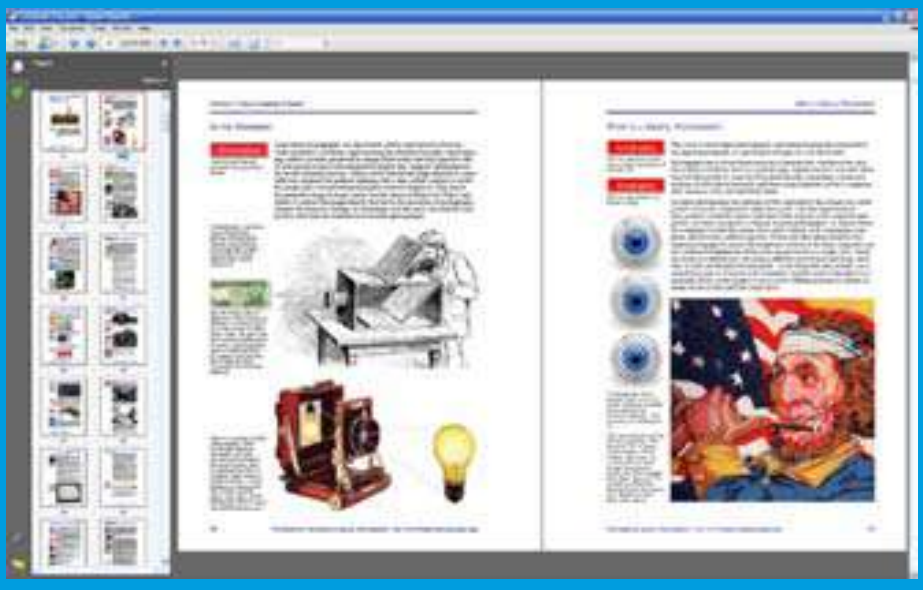

ISBN: 1-928873-75-8

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This text introduces the entire panorama of digital photography and includes the following topics:

• Digital cameras and digital images (Chapter 1)
• Digital workflow (Chapter 2)
• Camera controls and creative photography (Chapters 3–6)
• Flash and studio lighting (Chapter 7-8)
• Sharing and displaying digital images (Chapter 9–10)
• Exploring beyond the standard still image (Chapter 11)

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PREFACE

TRY THIS WITH FILM!

- In the summer of 2003, the Associated Press reported that a 15-year-old boy had foiled an abduction by using his camera phone to take photos of the man and his car's license number. The man was arrested the next day.
- A man stranded on an ice floe during a solo trek to the North Pole took a digital photo of the 1,000 foot runway he'd dug by hand and e-mailed it to air rescue showing them that a landing was possible.

Not long ago the course title "*Digital Photography*" implied a course on Photoshop. As digital cameras have become increasingly popular, the introductory course has also gone digital so you are now introduced to photography using a digital camera. As this new era of digital photography matures, it won't be long before the "*digital*" in "*digital photography*" becomes redundant. It will be assumed, because that is the way almost all photography will be done. One of the primary reasons for this rapid movement from film to digital imaging is that photography is embedded in a world that has gone digital. To take full advantage of the digital world in which we live, photographs also need to be digital. For awhile, capturing images on film and then scanning them into a digital format was a solution. However, this process is expensive and time consuming. Digital cameras remove those impediments and capture images that are already in a universally recognizable digital format that makes them easy to display and share. You can insert digital photographs into word processing documents or PowerPoint presentations, print them on almost any material, send them by e-mail, integrate them into slide shows to be played on the TV, post them on a Web site where anyone in the world can see them—even have them laser-etched into glass or granite. A digital camera, a computer, and a high-speed Internet connection make each of us a member of an ever-expanding network or community of photographers and viewers.

Just as digital images make it easy to integrate photos into many of the other things we do, digital technology makes it easy to add cameras to other devices. One of the current trends is to embed cameras into cell phones and other mobile devices. With just a push of a few buttons, you can snap a picture and immediately e-mail it or post it on a Web site. It won't be long before there are digital cameras everywhere, all the time. What impact this will have on our photography remains to be seen, but if history is any indicator, people will soon be discovering practical, creative, and even artistic ways to use these new tools.

Signs offering film developing are rapidly changing to signs offering to make prints from your digital files. "From today, painting is dead!" exclaimed painter Paul Delaroche when he saw the first daguerreotype in 1839. He was wrong, but can we revise the sentence to "From today, film is dead!"

Changes in technology always open new opportunities and present approaches that change the way images look and are used. For example, the introduction of the 35mm Leica in the 1930s was a revolutionary change that made it easier to capture fast-moving action. Images became more spontaneous and fluid, a far cry from the more formally posed images required by much larger and more awkward cameras. Smaller cameras allowed photographers to discretely capture life on the street and people in motion, without modifying the flow of action by his or her simple presence. Reality could be captured unchanged and unposed. With cameras built into almost all cell phones in the near future, an even larger impact is possible.

Although it's both the immediacy and flexibility of digital photography that has made it so popular, there is one aspect that is rarely mentioned. This is the new freedom it gives you to explore creative photography. In the 1870s when William Henry Jackson carried 20 x 24 glass plate negatives around the West on a mule, you can bet he hesitated before he took a photograph. He had to set up a darkroom, coat a glass plate, expose the image, develop the negative and then take down and repack all of the gear. We may not be carrying window-sized glass plates, but you and I also hesitate before taking a picture. We're always doing a mental calculation "is it worth it?" Subconsciously we're running down a checklist of costs, times, effort, and so on. During that "decisive moment," the image is often lost or we fail to try

The original Leica changed the way photographs were captured and now, with the M8, it too has gone digital.

new things. We lose the opportunity for creative growth and choose to stay with the familiar that has delivered for us in the past. Surprisingly, Jackson had one big advantage we've lost over the last century. If an image didn't turn out, or if he was out of glass plates, he could just scrape the emulsion off a previously exposed negative, recoat the plate, and try again. Digital photography not only eliminates that nagging "is it worth it?" question, it also returns us to that era of endlessly reusable film (and we don't need a mule to carry it). Hand the camera to the kids, take weird and unusual angles, shoot without looking through the viewfinder, and ignore all previously held conceptions about how to take photographs. You may be surprised at the photos you get if you exploit this new era of uninhibited shooting.

Digital cameras are only a few years old, and we are only at the dawn of this new era. Where it will lead no one really knows, but it's exciting to play a part in this dramatically changing world. As you begin to explore the field, you will be awash in technical jargon. Most of it can be safely ignored. To show how some things never change, here is what Jacob Deschin, the photographic editor of the New York Times, wrote in 1952 about the earlier era when the Leica revolutionized photography:

"When 35mm was in full flower in this country–in the miniature's golden Thirties–photographers in the new medium became "experts" overnight, full of tall talk about small grain and big enlargements. They had to, in self defence, for in those early days of the miniature it seemed important to be technically hep, at least in conversation. Never mind the pictures! In spite of much hokum, much good came to the surface, survived the babel and exerted an influence that has since benefitted all photography."

The virtue of the camera is not the power it has to transform the photographer into an artist, but the impulse it gives him to keep on looking—and looking.

Brooks Atkinson
Once Around the Sun

A mule carries William Henry Jackson's photographic outfit. Courtesy of the Library of Congress.

Extension

Click to view a PDF glossary of terms you may encounter in digital photography.

Contents

List of Animations & Extensions

Chapter 1
Digital Cameras & Images

A snow fence in the middle distance almost perfectly aligns with the horizon at the Washington Monument, Washington, D.C.

Digital images are formed from tiny dots of color. The dots, usually many millions per image, are so small and close together they blend into the smooth continuous tones we're so familiar with from film. These images are captured directly with digital cameras, or by scanning a transparency, negative, or print. The end result is an image in a universally recognized format that can be easily manipulated, distributed, and used. This digital format for images, and the development of the Internet in particular, have opened exciting new vistas for photography which we'll explore in this text. To begin, we first look at digital cameras and digital images. This chapter lays the foundation for your understanding of digital photography.

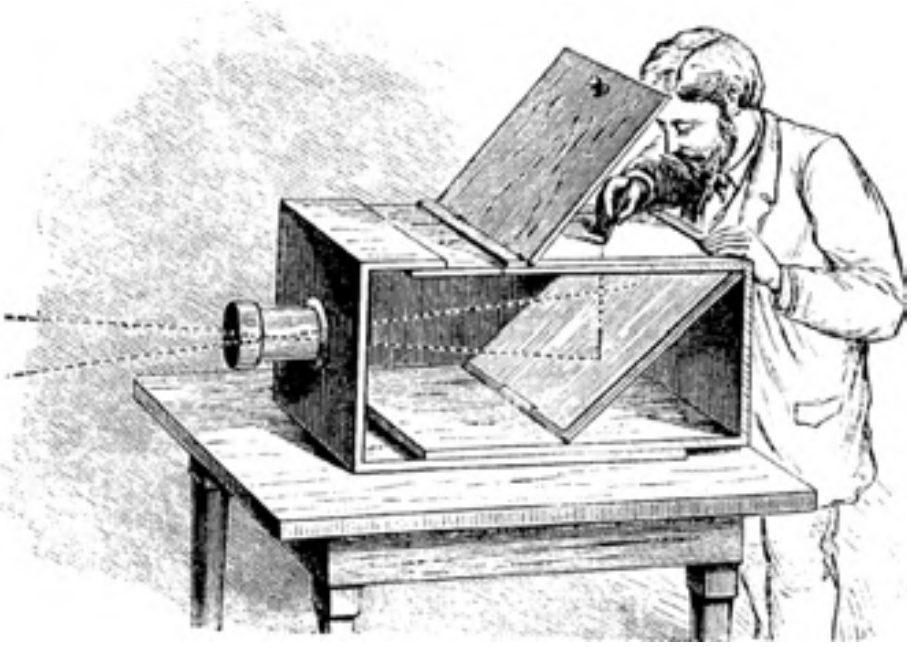
IN THE BEGINNING

Animation

Click to see how all cameras are just dark boxes.

Long before photography was discovered, artists used *camera obscuras*—"dark chambers" in Italian. Light entering the chamber through a small opening, called a *pinhole*, projected an image of the scene onto the opposite wall. At first special rooms were designed to display this "magical" phenomenon but in the sixteenth century, Italian artists shrunk the large chamber to a portable box, replaced the pinhole opening with a lens, added a mirror to invert the image and a translucent ground glass screen to display it. They traced the projected image by hand, and it was the desire of Henry Fox Talbot and others to capture the image directly that led to the invention of photography. Despite the dramatic changes in technology over the years, the dark box and the lens still form the foundation of modern photography.

Interestingly, cameras were discovered before photography. People were seeing the projected image hundreds of years before they could capture it.



Abu Ali Hasan Ibn al-Haitham, also known as Alhazen, is shown here on a new Iraqi 10,000 Dinar note. He gave the first correct explanation of vision, showing that light is reflected from an object into the eye. He is said to have 'invented' the camera obscura.

Here is a modern Wista view camera. With its flexible bellows removed, you can see the ground glass focusing screen that is replaced by film or a digital back when a photo is taken. A lens projects a scene onto this screen upside down. Courtesy of HP Marketing Corp at www.hpmarketingcorp.com.

What is a Digital Photograph?

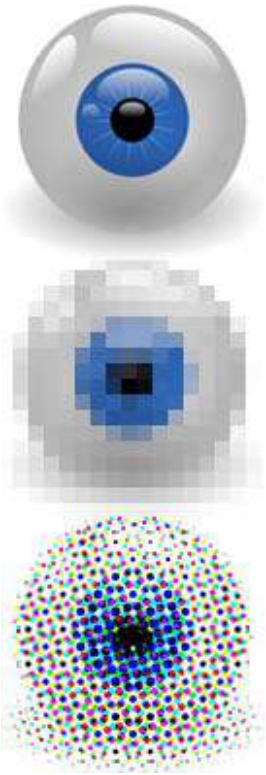
Animation

Click to see how pixels are printed using dots of colored ink.

This book is about digital photography and understanding the end product, the digital photograph, is a good place to begin. It is all about dots.

Photographs have always been made up of minute dots whether silver crystals in film or halftone dots on a printed page. Digital cameras have just taken this dot-like quality to a new level by electronically converting a scene into millions of dots almost instantly and then using computer power to organize, edit, enhance, store, and distribute them.

In digital photographs the millions of dots captured by the camera are called *picture elements*—commonly called just *pixels*. Like the impressionists who painted wonderful scenes with small dabs of paint, your computer and printer use these tiny pixels to display or print photographs. To display them, the computer divides the screen into a grid of pixels, each containing a red, green and blue dot—called *subpixels*. It then uses the values stored in the digital photograph to specify the brightness of each of the three subpixels and the combined brightnesses of the pixel are perceived as a single color. Prints are made in a related way, but using a different set of colors and many more dots of color are blended for each pixel. To see these dots for yourself, use a magnifying glass to examine your computer's monitor and a color photo in a magazine, book, or newspaper or use a photo-editing program to enlarge an image on the screen until the pixels show.



A photograph of an eyeball (top) with its pixels showing (middle) and screened for printing (bottom). Art courtesy of webweaver.nu.

This reproduction of the famous painting "The Spirit of '76" is done in jelly beans. Think of each jelly bean as a pixel and it's easy to see how dots or pixels can form images. Jelly Bean Spirit of '76 courtesy of Herman Goelitz Candy Company, Inc. Makers of Jelly Belly jelly beans.

DIGITAL PHOTOGRAPHY—THE PAST AND THE FUTURE

This illustration shows the relative sizes of photos captured by the first digital cameras (small) and by more recent models (large).

It was not that long ago, around 1995, when many of us first became aware of digital photography. That was the year when Apple's QuickTake 100 and Kodak's DC40 both broke the sub-$1000 barrier for digital cameras. These filmless cameras captured very small images, but they were immediate hits. Small businesses, realtors, insurance agents, and other early adopters snapped them up. They were so popular that the early models were soon followed by a steady stream of digital cameras from Casio, Sony, Olympus and others. The race was on and the stream of new cameras not only continues, it accelerates. Things have advanced so far that the same money that would have bought one of those early cameras will now buy one that captures images 20 times larger and has many more features such as video, sound, and professional style controls.

The Canon EOS DCS 3 digital camera was introduced in July 1995 and captured images containing 1.3 million pixels. It cost about $17,000.

These early consumer cameras weren't developed in isolation. Professional cameras, based on film cameras but with image sensors added to capture digital images, were growing in popularity among professionals. However, their high prices, often $20,000 or more, made these cameras available only to an elite few. Kodak had also already introduced the Photo CD so photographers could have their slides and negatives inexpensively scanned into a digital format. The process caught on with professionals, but not with amateurs as Kodak had hoped. Meanwhile, publishing, advertising, medicine, and many other fields were going digital. Digital images slipped easily into this trend because they could be instantly displayed, e-mailed, and inserted into documents. It was professionals who led the change from film to digital, but it wasn't long before many more of us were headed in the same direction. Film is no longer just a mature industry, it's dying. Given the scale of this change, how did it all come to pass?

If there were ever two inventors who haven't received the public credit they deserve, it's George Smith and Willard Boyle, co-inventors of the charge-coupled device (CCD) at Bell Labs. At the time they were attempting to create a new kind of semiconductor memory for computers. A secondary consideration was the need to develop solid-state cameras for use in video telephone service. In the space of an hour on October 17, 1969, they sketched out the

The Canon PowerShot 600 digital camera was introduced in July 1996 and captured images containing 500 thousand pixels. It was priced just over $1000.

Willard Boyle (left) and George Smith (right). Courtesy of Lucent Technologies.

With cameras now added to cell phones like Apple's iPhone, you can capture photos and send them to a friend or post them on a Web site. Image courtesy of Apple.

CCD's basic structure, defined its principles of operation, and outlined applications including imaging as well as memory.

By 1970, the Bell Labs researchers had incorporated the CCD into the world's first solid-state video camera. In 1975, they demonstrated the first CCD camera with image quality good enough for broadcast television. CCDs then quickly went on to revolutionize the fax, scanner, copier, bar code, and medical photography fields.

One of the more exciting, and demanding applications has been in astronomy. Since 1983, when telescopes were first equipped with solid-state cameras, CCDs have enabled astronomers to study objects thousands of times fainter than what the most sensitive photographic plates can capture, and to capture in seconds images that would have taken hours using film. Today all optical observatories, including the Hubble Space Telescope, rely on digital information systems built around mosaics of ultra sensitive CCD chips. Researchers in other fields have put CCDs to work in applications as diverse as observing chemical reactions in the lab and studying the feeble light emitted by hot water gushing out of vents in the ocean floor. CCD cameras also are used in satellite observation of the earth for environmental monitoring, surveying, and surveillance.

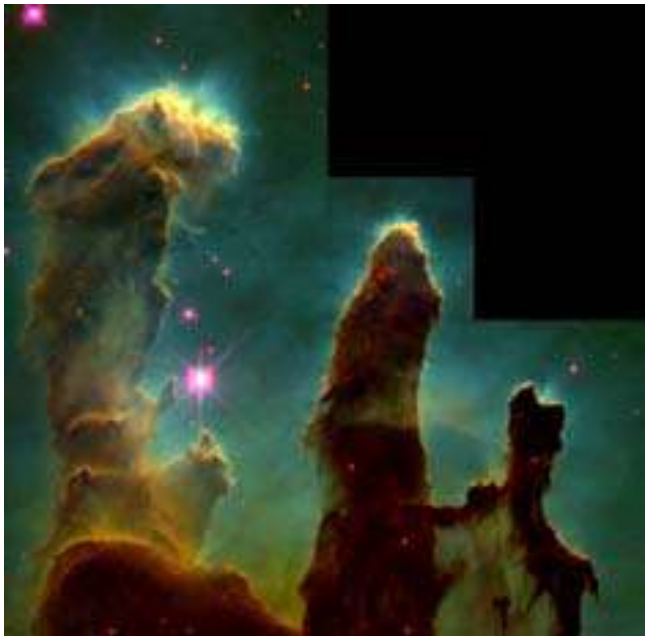
Extension

Click to see the manual for the Kodak DC40, one of the first consumer digital cameras.

Image quality has improved dramatically over the years so most people are now satisfied with the quality and sharpness of their photos. For this reason, the marketing battle, especially in the point-and-shoot or pocket camera categories is now all about features. Since digital cameras are basically computers, companies can program them to do all sorts of things that older, mechanical cameras could never do. They can identify faces in a scene to focus on, detect and eliminate red-eye, and let you adjust colors and tones in your images. There is a tipping point somewhere in the endless checklist of possible features where complexity begins to increase rather than decrease and the usefulness of features begins to decline. We are probably already at that tipping point and perhaps beyond it. When you read about features ask yourself how often you would really use them and how much control you want to turn over to your camera. When considering features, keep in mind that most of the great images in the history of photography were taken using cameras that only let you control focus, the aperture, and the shutter speed.

CREDIT

The material in this section about Willard Boyle and George Smith is adapted from material written by Patrick Regan of Bell Labs Media Relations.



Digital photography started in astronomy and still serves that field well. Here is an amazing photo of gas pillars in the Eagle Nebula. The tallest pillar (left) is about 4 light-years long from base to tip. Forming inside are embryonic stars. Credit: Jeff Hester and Paul Scowen (Arizona State University), and NASA (http://hubblesite.org).

WHY GO DIGITAL?

Kiosks in many stores let you print photos on the spot.

Most of this book assumes you are already a digital photographer or have decided to become one. If you aren't fully converted and are wondering why digital photography has almost entirely replaced film in less than a decade, here are some of the reasons. It would be reasonable to assume that it's because of image quality since digital images are now equal to, and often better than film images. However, the real reason for the switch lies elsewhere, in the fact that once captured, digital photographs are already in a format that makes them incredibly easy to share and use. For example, you can insert digital photographs into documents, print them at a kiosk, send them by e-mail to friends, or post them on a Web site where anyone in the world can see them. With most cameras you can immediately see your images on a small LCD monitor on the back of the camera, or you can connect the camera to a TV and show them as a slide show. Some cameras can even be connected to a telescope or microscope to display dramatically enlarged images on a large-screen TV. It's this ability to instantly share photos with anyone, anywhere that makes digital photography so attractive.

Here are a few more reasons why the change has been so dramatic:

• Going digital saves you money in the long run since you don't have to buy rolls of film and pay for their development and printing.

• It saves you time because you don't have to make two trips to the store to drop off and then pick up your pictures (although you can do this with a digital camera's memory card).

You can place images on interactive maps just by dragging and dropping them.

• Digital cameras instantly show you how your pictures look so you'll no longer have those disappointments a day or two later when your film is developed.

• You can view images before they are printed and if you don't like what you see, you can edit them to perfection or save money by not printing, or even deleting them.

• Digital photography (at least your part in it) doesn't use the toxic chemicals that often end up flowing down the drain and into our streams, rivers, and lakes.

• No more waiting to finish a roll of film before having it processed. (Or wasting unexposed film when you can't wait.)

• Many digital cameras are able to capture not only still photographs, but also sound and even video—they are as much multimedia recorders as they are cameras.

• You can use a photo-editing program to improve or alter digital images, sometimes right in the camera. For example, you can crop them, remove red-eye, change colors or contrast, and even add and delete elements. It's like having a darkroom with the lights on and without the chemicals.

You can have images printed and bound into photo books. Courtesy of PhotoWorks.com.

• You can post your images on a Web site so others can view and even print them.

• You can have your images printed on the pages of a bound book, like those you see in bookstores.

• You can create slide shows that can be burned to a DVD for playback on a TV complete with background music or narration.

TYPES OF DIGITAL CAMERAS

This old Kodak ad slogan now applies to the entire field of digital photography. With print kiosks everywhere, it's easy to shoot and print images without using a computer.

When it comes time to choose a new digital camera, there is quite a range of designs, sizes and features to choose from. Pocket sized cameras usually don't have all of the features of larger cameras, but they are more convenient to carry. The best news is that despite their great differences, most cameras will capture very good image quality, especially when used to create snapshot-sized prints.

Extension

Click here for a PDF extension on buying a digital camera.

Point and shoot cameras usually have fewer controls than other digital cameras but many are also small, bordering on tiny. With a camera that fits into your pocket, you're more likely to have it when you need it.

Camera phone quality is improving with 10 megapixel models already available in some parts of the world. These cameras may eventually present real competition to point and shoot cameras. This N95 from Nokia has a 5 megapixel camera and GPS built-in.

The fastest selling point and shoot digital cameras are those built into camera phones. The problem with these cameras is that their image quality is improving very slowly and doesn't yet match that of dedicated cameras.

One-time-use cameras take surprisingly good pictures and some even have a monitor on which you can review your results.

Digital photography has already matured to the point where there are one-time-use point and shoot versions.

Fixed lens cameras often have great zoom lenses and capture large images.

Canon's TX1 has a unique vertical design and captures 7 megapixel images and HDTV movies.

High-end fixed lens cameras usually have a zoom lens and many of the exposure and focus controls found on SLR cameras.

SLR cameras from major companies have more lenses than you'll ever need.

Single-lens reflex cameras (SLRs) are the most flexible and often the most expensive cameras.

Pentax makes cameras you can use underwater.

One of the most popular camera types among professionals and serious amateurs is the single-lens reflex, better known as a digital SLR. These cameras are expensive but have certain advantages over other camera types:

- You can change lenses.
- They usually focus more quickly and capture images with less noise.
- You see the scene through the lens so what you see is what you get.
- You can select from a large variety of accessories, including powerful external flash units.

Extension

Click here for a PDF extension on Canon Lenses.

Minox makes a Leica M3 miniature camera with a 3.2 Megapixel image sensor. Courtesy of Minox at www.minox.com.

Rangefinder cameras such as the Leica dominated photojournalism and fine arts photography for decades. They were quiet, small, and their large, bright viewfinders made it easy to focus and compose images. There aren't many digital rangefinder cameras, but Leica's first one in the tradition of their film cameras is the Leica M8.

You'll rarely be without a camera if it's on your key ring.

What's interesting about the model name is that it numerically follows the film-based M7 and isn't called *digital*. It's obvious that Leica sees digital as the only way forward and that we've reached the point where, when it comes to cameras, digital can be assumed without its being mentioned.

Extension

Click here for a PDF extension on camera straps and bags.

Video cameras often have the ability to capture still images. The images are smaller than those captured by many digital still cameras, but it's nice to have this option when you are videoing an event. Most digital cameras also have a movie mode that lets you capture short video clips. The secret to interesting movies for most of us is to keep them short. A video camera may be able to capture hours of footage, but who wants to watch it? Short, one minute or so videos can capture highlights and be shared by e-mail or by posting them on popular sites such as YouTube.com.

CAMERA SIZE

When it comes to digital cameras, size doesn't matter as much as you think. Small pocket cameras can take images that are as good as those taken by larger cameras. The only difference is they usually have fewer features and lower resolution.

Extension

Click to see a PDF extension on caring for your camera.

Professionals, just like the rest of us, use SLRs and even point-and shoot cameras. However, when they move into the studio or explore some speciality field, they often use other cameras. One of the main reasons is that they want a larger image sensor with more pixels.

Some professional cameras, including this medium format Hasselblad, are one-shot models that work just like your digital camera. When you press the shutter button the picture is taken immediately.

Other professional cameras, such as the Linhof view camera shown here, are converted to digital by the simple addition of a digital back that replaces the traditional film holder. Some backs work like scanners. When you press the shutter button, the digital back scans the scene a line at a time building up the image line by line. Some capture the image in a single pass, others make three passes—one each for the red, blue, and green light reflecting from the subject. These cameras are slow so they can't be used with moving subjects or with strobe lights.

JUMP START—TAKING PHOTOS WITH FULL AUTO MODE

Many digital cameras have a mode dial you turn to select various exposure modes including automatic.

All digital cameras have an automatic mode that sets focus and exposure for you. With the camera set to this mode, all you have to do is frame the image and press the shutter button. You'll find that this mode is ideal in the vast majority of situations because it lets you focus on the subject and not on the camera. Here are some things to expect and things to do when using auto mode on almost any digital camera.

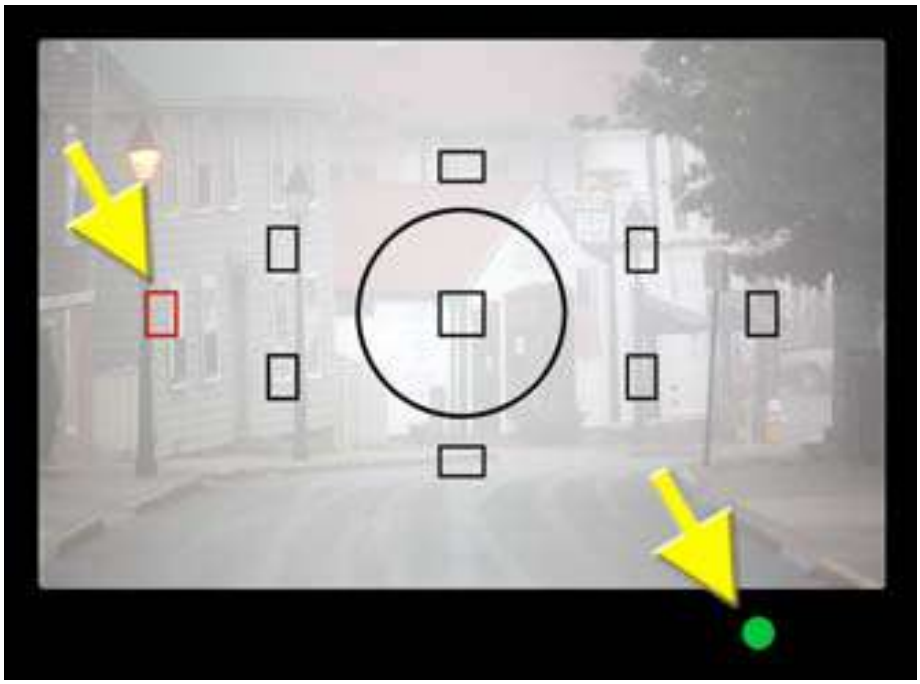
• **Getting the camera ready**. Turn the camera on and set it to auto mode. If possible, to conserve your batteries, turn off the monitor and compose your image using the viewfinder. If the camera has a lens cap, be sure to remove it. The first time you use the camera, or if the batteries have been removed or dead for an extended period, you should enter the date and time. When accurately recorded in your images, the date and time help you organize, locate, and identify them later.

• **Checking settings**. Always check camera settings at the beginning of a session. Notice how many pictures you can take at the current settings and the status of the battery charge. Also, learn what any icons mean because it's not at all unusual to change a setting, then forget you have done so. Some of these settings remain changed even when you turn the camera off and back on again and affect all subsequent pictures.

• **Holding the camera**. When taking pictures, hold the camera in your right hand while supporting the lens with your left. Be sure not to block the flash, sensors, or lens.

• **Framing the image**. Use the monitor, or viewfinder if your camera has one, to compose the scene you are going to capture. If your camera has a zoom lens, you can zoom it in and out by pressing a button or lever or by turning a ring on the lens. Zooming out widens your angle of view and zooming in narrows it. If the image in the viewfinder is fuzzy, see if the camera has a *diopter adjustment* dial you can use to adjust it.

Some digital cameras have more than one focus area and the one that's being used lights up or blinks when you press the shutter button halfway down (top arrow). When focus locks, an indicator light is often displayed (bottom arrow) and the camera may beep.



• **Autofocus**. Compose the image in the viewfinder so the subject that you want sharpest is covered by one of the focus areas in viewfinder or on the monitor. Some cameras have more than one focus area and will focus on the closest part of the scene covered by one of them. Other cameras have one focus area but let you move it to cover any part of the scene. These options make it easy to focus on a subject that isn't centered in the viewfinder.

• **Autoexposure**. An exposure system measures light reflecting from various parts of the scene and uses these readings to calculate and set the best possible exposure. This happens at the same time focus is locked—when you press the shutter button halfway down.

• **Autoflash**. If the light is too dim, the autoexposure system will usually fire the camera's built-in flash to illuminate the scene. If the flash is going to fire, it pops up or a flash lamp glows when you press the shutter button halfway down. If the flash lamp blinks instead, the flash is charging. Release the shutter button for a few seconds and try again.

• **Automatic white balance**. Because the color cast in a photograph is affected by the color of the light illuminating the scene, the camera automatically adjusts white balance to make white objects in the scene look white in the photo.

• **Taking the picture**. The shutter button has two stages. When you press it halfway down, the camera locks focus and exposure and the camera beeps or an indicator lights up. (If the indicator blinks, it means the camera is having trouble focusing.) At this point, press the shutter button all the way down to take the picture. Captured photos are first stored in the camera's buffer. When the buffer is full you'll have to wait until one or more of the images has been transferred to the memory card before taking any more pictures.

• **Image review**. Many cameras briefly display the image immediately after it's captured. This lets you decide if it's good enough or needs to be reshot.

When taking a picture don't jab the shutter button! Press it gently halfway down and pause there until the camera locks focus and exposure. Only then do you press it gently the rest of the way down to take the picture.

• **Increase your odds of getting a better photo** by taking as many shots of a given scene as you can think of; changing positions, distances, and angles. You may be surprised later at what works and what doesn't.

• **Quit**. When finished taking pictures, turn the camera off to conserve battery power. If an image is being stored when you turn the camera off, the image will be completely stored before the camera powers down.

CAMERA CONTROLS

The Kodak EasyShare has a touch-sensitive screen where you can make menu selections using a stylus.

Animation

Click to see a PDF poster of typical digital camera icons.

Many cameras have an LCD panel that displays settings and an LCD monitor that displays images and menus.

Some cameras display settings and setting choices on the monitor when you use buttons or dials.

There are two ways to change settings on a camera—using menu commands or a combination of buttons and dials. Menu commands are usually slower and can be difficult in bright light when you can't read the monitor on which they are displayed. Buttons and dials are faster because you can get familiar enough with them to use them without looking, but at first their functions are harder to remember.

Most cameras use both approaches, putting the most frequently used functions on buttons and dials and less frequently used ones on menus. One recent addition to the button/dial family is a button or dial with four points. Pressing any of the points, or in some cases rotating the dial, moves a menu highlight up, down or sideways or lets you scroll through images in playback mode. A button or joystick-like lever in the middle of this "button" acts like the Enter key on a computer by completing commands.

On many cameras icons indicating the current settings are often displayed on a separate LCD panel. Some new cameras dispose of this second screen and display them on the monitor.

As you change settings, it is sometimes easy to forget what you've done or it's time consuming to reset them to their original values one at a time. For this reason some cameras have a button or menu command that lets you quickly reset the camera to its original factory default settings.

Buttons and dials vary from camera to camera but here are some that are fairly common on all but the simplest point and shoot models. In some cases the same button performs different functions in shooting and playback modes.

• **Zoom lever** or buttons zoom the lens. (On SLR cameras you zoom by turning a ring on the lens.)

• **Shutter button** locks exposure and focus when pressed halfway down, and takes the picture when pressed all the way.

• **Continuous/self-timer button** sets the camera to shoot sequences of photos one after another or turns on the self-timer.

• **Mode dial** selects various shooting modes such as auto or programmed. The same or a different lever or button switches between shooting and playback modes.

• **ON/OFF button** or lever turns the camera on and off.

• **Flash button** selects flash modes.

• **Macro button** turns macro mode on and off.

• **MENU button** displays or hides the menu.

• **Print/Share button** lets you print or download images when connected to a printer or computer.

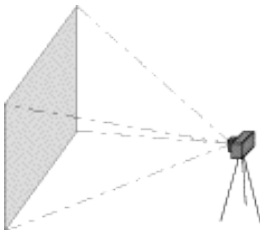
• **Erase or delete button** deletes the selected image in review or playback mode.

COMPOSING IMAGES

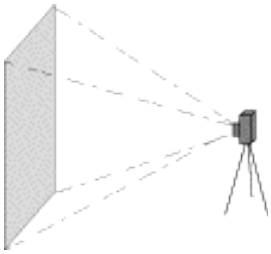
Monitors show you what the view looks like through the lens.

The best monitors are those that swivel and tilt to any angle, called a vari-angle monitor.

With a swiveling monitor, you can put the camera on the ground and shoot up as was done with this newt.



Landscape mode shows the image horizontally.



Portrait mode shows the image vertically.

When choosing a digital camera, one of the first things to decide is whether you want one with both a monitor and viewfinder. Many of the latest small cameras have dropped viewfinders, partly to make more room for a larger monitor. This is a mixed blessing because the primary roles of these two features are quite different, although there is some overlap. If your camera has no viewfinder, you are forced to compose all of your images using the monitor. This means you have to deal with glare on sunny days and find a way to avoid blur in your images caused by camera movement while holding the camera out at arm's length.

MONITORS

Monitors are small LCD color screens built into most cameras. Their size, usually between 1.5 and 4 inches, is specified using the diagonal measurement. Most have brightness adjustments that you can change manually, or which the camera adjusts automatically in different lighting situations. These screens are used to display menus and play back images you have captured. However, on many, but not all cameras, you can also compose an image on the monitor. Most digital SLR cameras don't let you do this because they use a mirror to bounce the image formed by the lens into the viewfinder. The image sensor only creates the image when the mirror swings up out of the way and the shutter opens. A few SLR cameras use a second sensor in the viewfinder to continuously feed an image to an LCD monitor—a process called *live view*. This not only lets you use the monitor to compose images, it can also be used to capture movies, something other SLRs can't do. Only time will tell if this feature catches on and spreads.

• **Image review** displays an image on the screen for a few seconds immediately after you've taken it. Some cameras let you keep the image on the screen longer so you can delete it or perform other image management functions. A few cameras seamlessly integrate image review and playback mode so after reviewing the current photo you can scroll through other photos and use all of the playback commands.

• **Histograms** are graphs showing the distribution of brightnesses in your image so you can check that the exposure is correct. Most cameras that offer this feature only let you view a histogram after capturing a photo, but a few let you see the histogram as you compose the image.

If your camera lets you compose an image on the monitor (not all do), the displayed image is taken directly from the image sensor, so it is a true TTL (through-the-lens) view. However, there are times when you may not want to use the monitor to compose images for the following reasons.

• **Battery drain**. Large monitors drain batteries quickly, so it's best to keep them turned off as much as possible and use the optical viewfinder for taking pictures.

• **Glare** makes the image on the monitor hard to see in bright sunlight.

• **Steadiness** is diminished when you hold the camera at arm's length. This tends to introduce blur into your images through camera shake.

Despite the drawbacks, there are a few situations in which using the monitor to compose an image is very useful.

SLR viewfinders display focus areas and camera settings.

• **Close-ups**. When taking close-ups, the monitor is a great way to compose and focus the image since it shows the scene exactly the way it will be in the image you'll capture. An optical viewfinder doesn't show the same view because it is offset from the lens.

• **Odd angles**. When photographing over a crowd, at ground level, or around a corner, a camera with a tilting and swiveling monitor lets you compose the image without holding the camera up to your eye.

When considering a monitor, here are some things to keep in mind:

• The monitor gets its image directly from the image sensor so it shows the view seen through the lens (TTL). Most show the entire image.

• The monitor often gives you a preview of how light or dark the captured will be. This lets you use the flash or adjust the exposure to make it the way you want it.

Animation

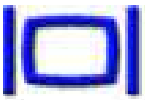
Click to see the light path through an SLR.

• Tilt and swivel (vari-angle) monitors let you shoot from different angles.

• Screen size and resolution are important not only to evaluate images but to share them with others.

• A wide viewing angle lets a small group see the photos together.

• A transparent cover keeps the monitor from being scratched. They are cheap and easy to replace.



A common monitor icon.

• You can connect some cameras to a TV when taking photos so everything is displayed on a much larger screen.

• A glare-proof surface and brightness adjustment help you read menus and see images in bright sunlight where many monitors just become mirrors.

VIEWFINDERS

Viewfinders are ideal for following fast action as it unfolds—waiting for the decisive moment. One of the advantages of some, but not all, of them is that they don't draw battery power so your batteries last longer. Also, most viewfinders are coupled to the zoom lens and show the same area that will be captured in the photo. There are three kinds of viewfinders and most photographers would consider the rangefinder viewfinder the best, followed by the type used in SLRs.

Because an optical viewfinder is offset from the lens, what you see through the viewfinder (top) is different from the image you actually capture (bottom).

• **Viewfinders on digital SLR cameras** show the scene through the lens (TTL). A mirror bounces light coming through the lens into a prism that directs it out of the viewfinder. When you take a picture, the mirror swings up and the shutter opens to let light hit the image sensor and create the image. These are true "what you see is what you get" viewfinders because you see exactly what the lens sees. Some cameras have interchangeable focus screens so you can adapt the camera for your preferences. For example, if you do architectural or product photography you may want grid lines in the viewfinder so it's easier to keep things aligned. Some cameras let you add the grid lines digitally by changing a camera setting.

Animation

Click to explore how parallax affects your view of a subject.

• **Optical viewfinders on point-and-shoot and rangefinder cameras** show the scene through a separate window that is slightly offset from the view seen by the lens. The offset view isn't a problem except in close-up photography where parallax causes you to see a view that is slightly offset from the one the lens sees, so a subject centered in the viewfinder won't be centered in the image. Rangefinder viewfinders such as those on the Leica, have a bright window with lines framing the area of the scene that will be captured

The Leica M8 viewfinder has lines that indicate the coverage of a 24mm and 35mm lens.

Slipping an eyepiece cover over a viewfinder blocks light from entering and affecting the exposure when using a self-timer or remote control.

Electronic viewfinders are small flat-panel displays inside the viewfinder. Courtesy of Zight.

Some point and shoot cameras have eliminated the viewfinder so you have to compose images using the monitor.

In this cutaway view of a Canon SLR you can see the mirror that bounces light up into a prism for the viewfinder. The mirror swings up out of the way when you take a picture. Courtesy of Canon.

by various focal length lenses. You can almost always see more than the lens will capture so you can make fine adjustments in composition and better anticipate movement into the frame.

• **Electronic viewfinders** use a small LCD monitor built into the viewfinder to display the same through-the-lens image seen by the image sensor. Many of these cameras let you switch between the monitor and viewfinder and both show exactly the same scene and same information. Because these viewfinders are electronic you can display menus and change settings without lowering the camera from your eye. This is especially useful on bright days when a monitor is hard to read because of glare. These viewfinders are also great if you normally need reading glasses because you can use the diopter adjustment control to bring menus and images into focus without first putting on your glasses. The biggest shortcomings of these viewfinders are their refresh rate and resolution. A slow refresh rate means that as you move the camera, the image on the screen lags behind the scene you are pointing at. When panning, the screen seems to jump between frames. On some cameras the refresh stops when you press the shutter button halfway down to lock focus so the image you capture may be different from the one you see. The low resolution of these viewfinders makes it hard to tell exactly what you are photographing. You don't see fine details, colors, or tones the way they actually are.

When considering a viewfinder, here are a few other things to think about:

• With the exception of rangefinders where the viewfinder shows more than the area that will be captured, most viewfinders only show about 95%.

• Eyepiece covers are needed on SLRs to keep light from leaking through the viewfinder when using a self-timer or remote control and you are not blocking the light by looking through the viewfinder.

• Optical viewfinders on point and shoot cameras don't display important shooting information such as focus and exposure settings.

• Fixed lens cameras with electronic viewfinders differ from SLRs in that they don't use a movable mirror to bounce light into the viewfinder.

• You can connect some cameras to a TV while you are taking pictures and let others see them as they are taken. This sets up lively interaction if there is a group of people watching as you take pictures.

CAPTURING IMAGES

Responsiveness is most important when photographing moving subjects.

Henri Cartier-Bresson is famous for his photographs that capture that "decisive moment" when unrelated actions intersect in a single instant that makes an arresting photograph. His eye-hand coordination was unrivaled, and he was able to get the results he did because he was always ready. There was never any fumbling with controls or lost opportunities. Most digital cameras have automatic exposure and focus systems that free you from the worry about controls. However, these cameras have other problems that make decisive moments hard to capture. Many of these problems have been eliminated on expensive cameras, but remain on less expensive ones.

One of the things that has driven many photographers to distraction is the delay between pressing the shutter button and the camera actually taking the picture. This and other delays built into digital cameras affect your ability to capture fleeting expressions or respond to fast action when taking pictures.

• **The startup time** is how long it takes for you to take a photo after turning on the camera. Cameras used to take a long time to do this, but now many start up almost instantly.

• **The shutter-lag time** is the delay you experience between pressing the shutter button and actually capturing an image. This delay occurs because it takes the camera time to clear the image sensor, set white balance to correct for color, set the exposure, and focus the image before it fires the flash (if it's needed) and take the picture. The best cameras now have almost no lag.

• **The processing delay** occurs as an image is processed and stored, especially when using noise reduction. This delay has been dramatically reduced by the addition of internal memory, called a "*buffer*." Images are temporarily stored in the buffer while awaiting processing because they can be stored there faster then they can be stored on a memory card. You can continue shooting until the buffer fills, and then resume when some images have been transferred from it to the memory card.

• **A flash recycle delay** occurs after taking a series of flash photos one after another. While the flash is recharging you often can't take a picture, or if you can, it comes out dark. In either case you need to wait for the flash to recharge and try again.

When anticipating action, compose the scene and focus the camera. When the action happens you can then capture it instantly.

• **Viewfinder blackout**. When you take a picture with an SLR, its mirror swings up so light can strike the image sensor. While it's up, you can't see through the viewfinder. This viewfinder blackout should be as short as possible.

All of these delays affect how quickly you can get off the first shot or capture a series of photos one after another (often referred to as *shot-to-shot time*). If the delays are too long, you may miss a picture.

To reduce delays when capturing action shots, compose the image and press the shutter button halfway down to lock focus and exposure. Continue to hold it down until the action you anticipated happens and then press it rest of the way down to take the picture. (This does drain batteries faster.) The camera shoots immediately because focus and exposure have already been calculated. On some cameras you can also press the shutter button all the way down in one action, but there will be a delay before the photo is taken and it may be out of focus.

CONTINUOUS PHOTOGRAPHY

The speed at which you can capture images in continuous mode is specified in frames per second (fps). This is often between 3–5 fps.

In most situations, you normally take one photo at a time, but you're not limited to that way of shooting. You can also capture sequences of photos. In this *continuous mode*, you just hold down the shutter button and images are captured one after another until you release it. The number of images you can capture in a single burst is usually limited by the size of the camera's *buffer*—a form of memory capable of rapidly storing images as they are captured one after another. On less expensive cameras with smaller or nonexistent buffers, the camera may use a smaller image size to capture sequences because this reduces the processing and storage time.

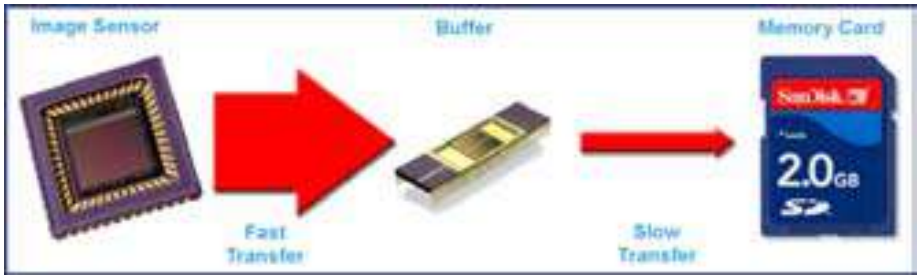
After capturing a sequence you can choose the best image from the sequence, use all of them to create an animation so the images are quickly displayed one after the other like frames in a movie, or join a series of sequences together into a short movie.

Continuous mode can capture a series of images much like movie frames. You can select the best one for printing, use them all to created an animation, or use the series to analyze an action such as the swing of a golf club or baseball bat.

Animation

Click to see how continuous mode can be used creatively.

Continuous (top) and single (bottom) shooting mode icons.



A camera can store images in its buffer faster than it can transfer them to a memory card. A large buffer lets you shoot more images continuously.

PLAYBACK MODE

The Kodak EasyShare lets you drag and drop photos into albums using a stylus.

Almost every digital camera has an LCD monitor and a playback mode so you can display and scroll through the images you have taken. Although very useful, it's difficult to make "keep or delete decisions" about images because the size and resolution of these monitors is nowhere near those on high-quality computers. Despite this limitation here are some of the useful features to expect in playback mode.

• **In-camera editing** let's you remove red-eye, adjust tones and colors, reduce a photo's size, add borders and use special effects. All changes are made to a copy so the original image remains unchanged. This relatively new feature will only grow in importance as more cameras are enabled to send photos directly to photo sharing sites, printers and e-mail addresses.

• **Slide shows** display your images one after another on the camera's monitor but many digital cameras have an analog video output terminal (NTSC or PAL) so they can be connected to a TV using standard input or video-in terminals. Some cameras use special effects such as dissolve to transition from one image to the next and some even let you accompany a show with music. However, unless you copy older images back into the camera, this is only a transient benefit. Once you have erased images to make room for new ones, you can no longer display them from the camera. However, you can use software on your computer to create slide shows and save them on DVDs that will play in a DVD player. Many cameras also let you playback video and audio clips you've captured.

• **Photo albums**. If your camera lets you store a selection of photos in photo albums, you can display the photos in this mode.

• **Image management** let's you scroll through the images you've taken and delete, rotate, rename, print, protect, copy or otherwise manage them. Many cameras also display thumbnails of a group of images in *index view* so you can quickly locate and select the images you're looking for. Most also let you enlarge an image to zoom in on details—a great way to check sharpness, colors and tones. A few cameras now have touch-sensitive monitors so you can manage your images with a stylus instead of dials and buttons.

• **Direct printing** lets you use the monitor to select images for printing when you bypass the computer to print directly from the camera.

• **An orientation sensor** in many cameras detects when you turn the camera vertically to take a picture and even knows which end is up. When you then replay the image, it is rotated on the screen so you don't have to rotate the camera to view it or turn your head sideways if looking at it on a TV set. (Auto rotation doesn't work well when shooting straight up or down, so you may want to turn it off.) The images may or may not be rotated when transferred to your computer because this depends on the software you are using. You can also use a separate *Rotate* command on many playback menus to rotate just specific images that you've already taken.

• **Information** about an image can be displayed on many cameras. This information, called *Exif metadata*, is stored in the image file at the time you take a picture. It may include the date and time the picture was taken, shutter speed and aperture used, and a small thumbnail image. Many cameras will also display a histogram and highlight (overexposure) warning. Some cameras let you select how much information is displayed so you can display it all when reviewing images and turn it all off when giving a slide show.

METADATA?

Metadata is data about data. In digital photography it's information inserted into the header of an image file that describes what the contents of the file are, where it came from, and what to do with it. You are already familiar with two examples, an image file's name and the date it was created. Other metadata includes the Exif data created by most digital cameras that tells what camera was used, what the exposure was, and whether a flash was used.

When you take a photo in portrait mode (top) it is rotated when you view it in landscape mode (bottom).

WHEN THINGS GO WRONG

Icons on the camera's control panel or monitor indicate the status of the batteries. The icons, many of which look like these, show when the battery is fully charged (left) and getting low (right).

TIPS

Before each session check that:

- The lens is clean.
- The battery is charged.
- The memory card is in the camera and has enough room.
- All settings are the way you want them.

When deleting files or formatting memory cards, think before you do so. It's easy to loose files. If you ever delete photos or format a card by mistake, the chances are you can recover the images with software. Some camera companies supply this software with the camera, but in most cases you have to Google "digital image recovery" to locate it on-line.

According to Murphy's Law, if anything can go wrong, it will. Here are some of the things you might encounter with a digital camera.

• If the camera seems to be turned off, it may just have entered *sleep mode*. When you don't use any controls for a specified time, the camera enters this mode to reduce battery drain. To wake it up, you usually just press the shutter button halfway down. After a longer period of inactivity, some cameras shut off completely and you have to turn them back on. You can often change the time it takes before either of these events occurs.

• If you can't turn on the camera, the batteries are dead or have been removed, or a memory card hasn't been inserted.

• If your batteries drain quickly, stop using the monitor to take and play back pictures. If it's cold, keep the batteries or camera under your coat.

• When you turn the camera on, a battery shaped icon on the control panel indicates when the batteries are fully charged, getting low, or almost empty and should be replaced immediately. It's always wise to carry a spare set of fully charged batteries.

• When you turn on the camera, an error message is usually displayed if there is a problem with the memory card or camera.

• If you can't take a picture, it may be because the memory card is full. To free up room for new pictures, move the images to a computer and erase the memory card, delete some you don't need, or switch to a smaller image size. Also, many cameras won't take a picture unless it's in focus.

• To control which part of the scene the camera focuses on, read the user guide that came with your camera so you understand how focus works in various exposure modes.

• If the focus lamp blinks when you press the shutter button halfway down, the camera may be having trouble focusing.

• If the flash lamp blinks when you press the shutter button halfway down, the flash is charging. Release the shutter button for a few seconds and try again.

• If flash photos are too dark, you are probably too far from the subject. Most built-in flash units are only good up to about ten feet. They don't have the power to illuminate subjects much father than that.

• If photos are too light when using flash, you may want to reduce the flash power.

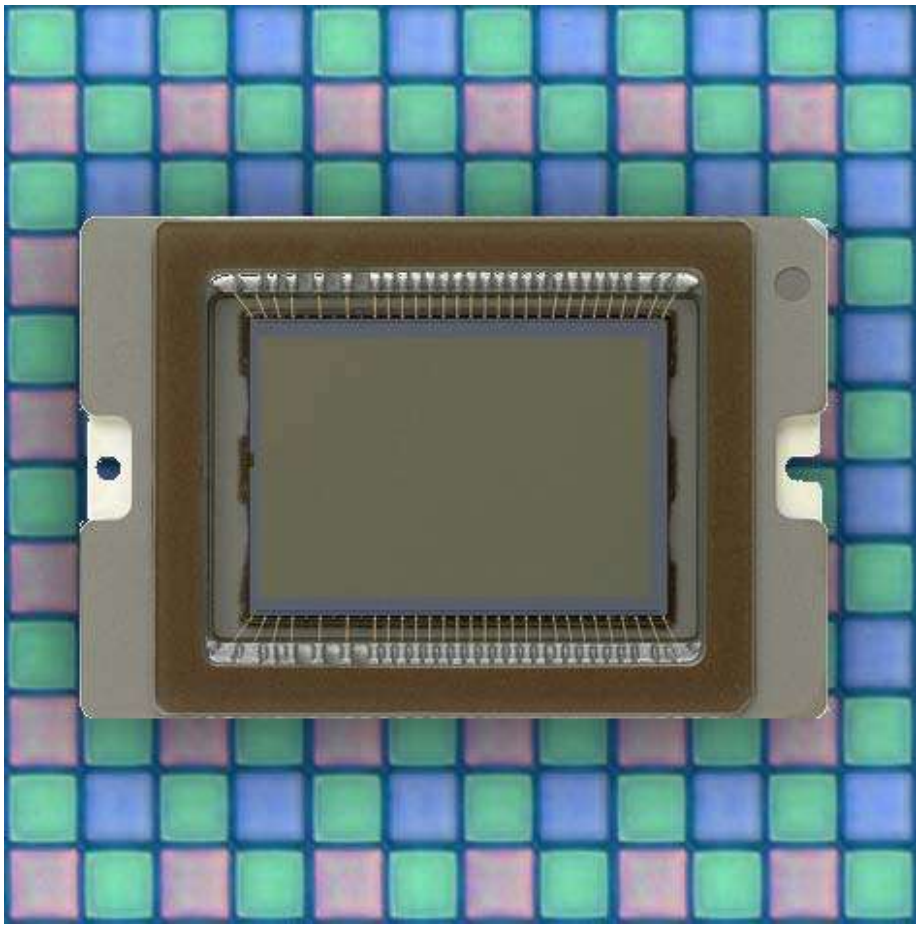
• If your pictures are blurred, you may not be holding the camera steady as you smoothly press the shutter. Most blurry photos are caused by jabbing the shutter button. You may also be too close to the subject, or the subject may be moving too fast.

• Never take pictures of the sun or other bright light sources. Doing so can injure your eye or damage the camera's image sensor.

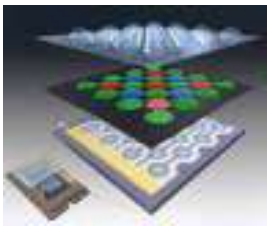
• If your pictures are not at all the way you expect, it may be because the camera remembered a change you made in its settings and continues to use that changed setting. Some cameras remember changes even when you turn it off and back on. See if your camera has a procedure that resets all settings to their factory defaults.

IMAGE SENSORS—INTRODUCTION

Digital cameras have roots going back almost 200 years. Beginning with the very first camera all have been basically black boxes with a lens to focus the image, an aperture that determines how bright the light is, and a shutter that determines how long the light enters. The big difference between traditional film cameras and digital cameras is how they capture the image. Instead of film, digital cameras use a solid-state device called an *image sensor*. In some digital cameras the image sensor is a *charge-coupled device* (CCD), while in others it's a *CMOS sensor*. Both types can give very good results. On the surface of these fingernail-sized silicon chips are millions of photosensitive diodes, each of which captures a single pixel in the photograph to be.



An image sensor sits against a background enlargement of its square pixels, each capable of capturing one pixel in the final image. Courtesy of IBM.



A CCD is like a three-decker sandwich. The bottom layer contains the photosites. Above them is a layer of colored filters that determines which color each site records. Finally, the top layer contains microlenses that gather light. Courtesy of Fujifilm.

Animation

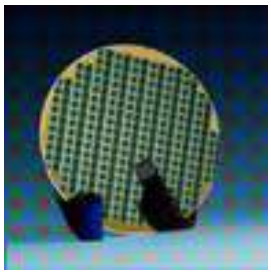
Click to explore how exposure determines how light or dark an image is.

When you take a picture, the camera's shutter opens briefly and each pixel on the image sensor records the brightness of the light that falls on it by accumulating photons. The more light that hits a pixel, the more photons it records. Pixels capturing light from highlights in the scene will have many photons. Those capturing light from shadows will have few.

After the shutter closes to end the exposure, the photons from each pixel are counted and converted into a digital number. This series of numbers is then used to reconstruct the image by setting the color and brightness of matching pixels on the screen or printed page.

IMAGE SENSORS—TYPES

This photo shows the pixels on an image sensor greatly enlarged. Courtesy of IBM.



A silicon wafer used to make image sensors. Courtesy of IBM.

Animation

Click to see where the name "charge-coupled device" comes from.

When using a film camera you can insert any kind of film you want. It's the film you choose that gives photographs distinctive colors, tones, and grain. If you think one film gives images that are too blue or red, you can change to another film. With digital cameras, the "film" is permanently part of the camera so buying a digital camera is in part like selecting a film to use. Like film, different image sensors render colors differently, have different amounts of "grain," different sensitivities to light, and so on. The only ways to evaluate these aspects are to examine some sample photographs from the camera or read reviews written by people you trust.

Initially, charge-coupled devices (CCDs) were the only image sensors used in digital cameras. They had already been well developed through their use in astronomical telescopes, scanners, and video camcorders. However, there is now a well-established alternative, the CMOS image sensor. Both CCD and CMOS image sensors capture light using a grid of small photosites on their surfaces. It's how they process the image and how they are manufactured where they differ from one another.

• **CCD image sensors**. A charge-coupled device (CCD) gets its name from the way the charges on its pixels are read after an exposure. The charges on the first row are transferred to a place on the sensor called the *read out register*. From there, they are fed to an amplifier and then on to an analog-to-digital converter. Once a row has been read, its charges in the readout register row are deleted, the next row enters, and all of the rows above march down one row. With each row "coupled" to the row above in this way, each row of pixels is read—one row at a time.

• **CMOS image sensors**. Image sensors are manufactured in factories called wafer foundries or fabs where the tiny circuits and devices are etched onto silicon chips. The biggest problem with CCDs is that they are created in foundries using specialized and expensive processes that can only be used to make other CCDs. Meanwhile, larger foundries use a different process called Complementary Metal Oxide Semiconductor (CMOS) to make millions of chips for computer processors and memory. CMOS is by far the most common and highest yielding chip-making process in the world. Using this same process and the same equipment to manufacturer CMOS image sensors cuts costs dramatically because the fixed costs of the plant are spread over a much larger number of devices. As a result of these economies of scale, the cost of fabricating a CMOS wafer is significantly less than the cost of fabricating a similar wafer using the specialized CCD process. Costs are lowered even farther because CMOS image sensors can have processing circuits created on the same chip. With CCDs, these processing circuits must be on separate chips.

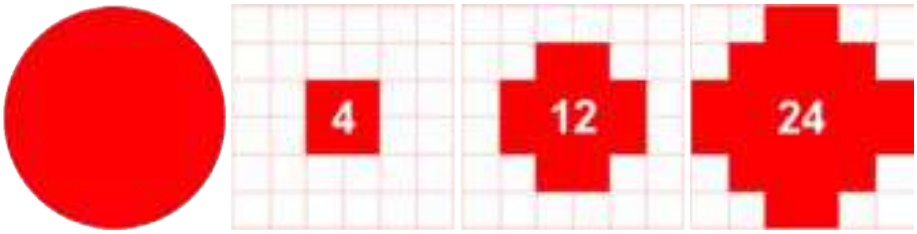
Despite their differences, both types of sensors are capable of giving very good results and both types are used by major camera companies. Canon and Nikon both use CMOS sensors in their high-end digital SLRs as do many other camera companies.

IMAGE SENSORS—IMAGE SIZE

Extension

Click for a PDF extension on pixels and read Part 1 on pixels and image sizes.

When capturing an image, the number of pixels used to capture it (sometimes referred to as *resolution* or *pixel count*) has a big effect on how large it can be displayed on the screen or printed. At any given size, more pixels add detail and sharpen edges. Because numbers matter so much, the best approach is to shoot using the largest available size. You can always make an image smaller in a photo-editing program, but you can never make it larger while retaining the original quality.



Square pixels are arranged in patterns to form curved lines and edges in a photo. The more pixels used, the smoother these curves will be. Here the same red ball is represented by 4, 12, and then 24 square pixels. As more pixels are added, edges become more refined and the shape becomes more like the original.

The pixel size of a digital image is specified in one of two ways—by its dimensions in pixels or by the total number of pixels it contains. For example, the same image can be said to have 4368 × 2912 pixels (where "×" is pronounced "by" as in "4368 by 2912), or to contain 12.7 million pixels (4368 multiplied by 2912). Since the term "megapixel" is used to indicate 1 million pixels, an image with 12 million pixels can also be referred to as a 12 megapixel image.

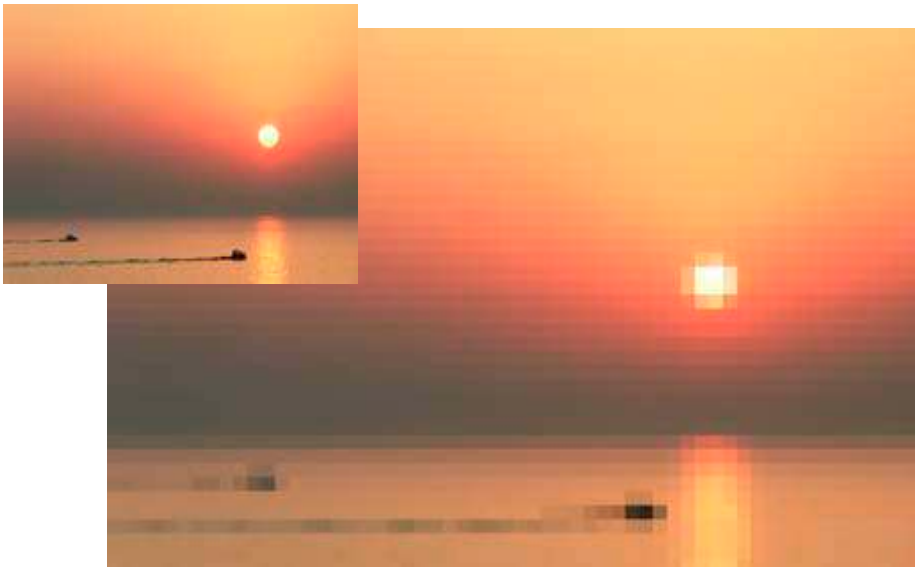
Image sizes are expressed as dimensions in pixels (4368 × 2912) or by the total number of pixels (12,719,616).

No matter how many pixels an image has, when you enlarge it enough, it begins to loose sharpness and eventually the pixels begin to show—an effect called *pixelization*. This is not unlike traditional silver-based prints where grain begins to show when prints are enlarged past a certain point. The more pixels an image has, the larger it can be displayed or printed before pixelization occurs. However, with even inexpensive cameras capturing 6 and 8 megapixel images, most images will never bump up against this limit even when enlarged to 8 x 10 inches.

Animation

Click to explore how more pixels give sharper images.

Another advantage of larger images is seen when editing. Not only can you crop them more, changes to such aspects as color balance, hue, saturation,



When a digital image is displayed or printed at the correct size for the number of pixels it contains (left), it looks like a normal photograph. When enlarged too much (right), its square pixels begin to show.

Animation

Click to see the effects of pixelization as an image is enlarged.

Animation

Click here for a PDF extension on pixels and read Part 2 on displaying images and Part 3 on printing images.

contrast, and brightness are more effective on larger images because there is more image data to work with. After making these adjustments, you can reduce the file to the needed size.

As you might expect, all else being equal, costs rise as the size of the image sensor increases. Although larger sensors can give you sharper images and better enlargements, more pixels also means larger image files. Not only do larger files take up more storage space, they take longer to transfer, process, and edit and are often far too large to e-mail or post on a Web site. Smaller image sizes such as 800 x 600 are perfect for Web publishing, e-mail attachments, small prints, or as illustrations in your own documents and presentations. For these uses, higher resolutions just increase file sizes without significantly improving the images.

One advantage of a large image size is that it gives you the freedom to crop the image and still have it be a usable size.

CHOOSING IMAGE SIZES

The camera you use determines how large your images can be, but most also allow you to select smaller sizes. Here are some rules of thumb about what image sizes you need for certain outputs.

• **On the Internet**, images are displayed on screens that have resolutions of 1280 x 1024, 1152 x 864, 1024 x 768, 800 x 600, or 640 x 480. A few years ago, a 1024 x 768 monitor was unusual so most people in the industry settled on assuming that the lowest common denominator for screen sizes was 640 x 480 or, at best 800 x 600. For this reason, images to be e-mailed or posted on the Internet should be of similar or smaller sizes—no more than 800 pixels wide. This ensures that the images will display correctly on the vast majority of computers. If an image is too large, users will not be able to see it all at once and will be forced to scroll around it. If too small, details will be lost. Size also affects the speed with which images travel over the Web. Smaller (and more compressed) images travel faster so people see them more quickly.

• **For laser and inkjet printers** you need between 200–300 image pixels per inch. If your camera can capture images that are 2400 pixels wide, you can expect good results when prints are up to 12 inches wide.

• **When images are printed on a printing press**, as they might be for a catalog, the pixels in the image are printed as dots on the page. Photographs

that are to be printed on a press are first digitally "screened" to break the image up into dots. If you are ever involved in this process your print shop will give you specifications for your images

The number of pixels in an image, sometimes referred to as its resolution, determines the size of the image when it's displayed on the screen or how large a print can be made that is still sharp.

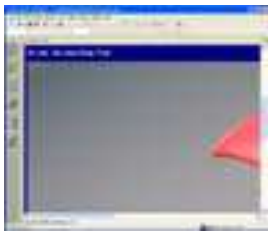
SCREEN RESOLUTIONS

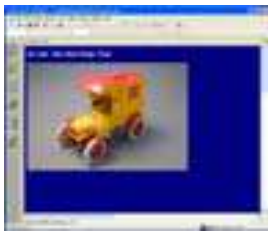
CGA	320 x 200
EGA	640 x 350
VGA	640 x 480
SVGA	800 x 600
XGA	1024 x 768
SXGA	1280 x 1024
WXGA	1366 x 768
SXGA+	1400 x 1050
UXGA	1600 x 1200
WSXGA+	1680 x 1050
WUXGA	1920 x 1200
QXGA	2048 x 1536
QSXGA	2560 x 2048
QUXGA	3200 x 2400
WQUXGA	3840 x 2400

Animation

Click to see how it's the output device, not the camera, that determines image sizes.

Here are the relative sizes of two images sized to be printed or displayed at 4 x 5 inches. The larger image (1500 x 1200 pixels) will print at 300 dots per inch. The smaller one (360 x 288) will be displayed on the screen at 72 dpi. Although greatly different in the number of pixels they contain, the different output devices will render them the same size.





If an image is too large for a screen (top), the viewer has to scroll around it. When sized correctly (bottom) they can see the entire image. Most digital photography programs automatically resize images to fit the available space unless you specify a different size.

INTERPOLATED RESOLUTION

Beware of claims about resolution for cameras because there are two kinds of resolution; optical and interpolated. The *optical resolution* of a camera is an absolute number because an image sensor's pixels or photosites are physical devices that can be counted. However, optical resolution can be increased using a process called *interpolated resolution* that adds pixels to the image to increase the image's size. To do so, software evaluates those pixels surrounding each new pixel to determine what its color should be. For example, if all of the pixels around a newly inserted pixel are red, the new pixel will be red. What's important to keep in mind is that interpolated resolution doesn't add any new information to the image—it just adds pixels and makes the file larger. This same thing can be done in a photo-editing program such as Photoshop by resizing the image. Beware of companies that promote or emphasize their device's interpolated (or enhanced) resolution. You're getting less than you think you are. Always check for the device's optical resolution. If this isn't provided, you're dealing with marketing people who don't have your best interests at heart.

ONE TERM—TWO MEANINGS

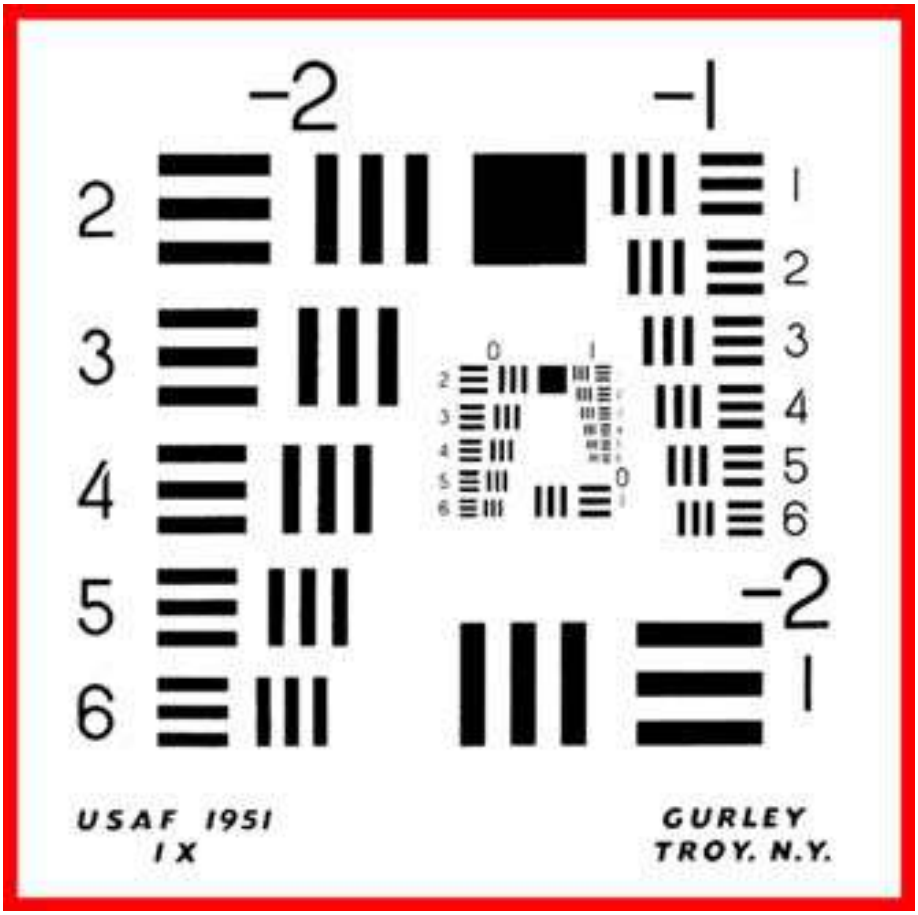
The term "resolution" has two meanings in photography. Originally it referred to the ability of a camera system to resolve pairs of fine lines such as those on a test chart. In this usage it's an indicator of sharpness, not image size. With the introduction of digital cameras the term began being used to indicate the number of pixels a camera could capture. Two meanings for the same term is not a good turn of events in any field.

Animation

Click to see how some cameras inflate their pixel counts.

Animation

Click to explore the original meaning of "resolution."



Test charts have pairs of lines at various spacings

IMAGE SENSORS—SIZES AND ASPECT RATIOS

Image sensor sizes range from the tiny up to ones as large as a frame of 35mm film—called a full frame sensor.

Animation

Click to explore the sizes of image sensors.

Animation

Click here for a PDF extension on pixels and read Part 1 on aspect ratios.

The aspect ratio of an image sensor determines the shape of your prints.

TIP

A 16:9 wide-screen mode captures images and film clips that are perfect for display on your wide-screen TV or computer monitor.

The image sensor in a camera has two important and related physical characteristics—its size and aspect ratio.

SENSOR SIZE

Image sensors come in a variety of sizes with the smallest ones used in point and shoot cameras and the largest in professional SLRs. Consumer SLRs often use sensors having the same size as a frame of APS film. Professional SLR cameras occasionally use sensors the same size as a frame of 35mm film—called *full-frame sensors*. (Large format cameras use even larger sensors.)

Larger image sensors generally have larger photosites that capture more light with less noise. The result is pictures that are clearer, brighter, and sharper. Because the size of photosites is so important, a large 6 Megapixel sensor will often take better pictures than a smaller 8 Megapixel sensor. Not only is noise a problem but smaller sensors also require better, more expensive lenses, especially for wide-angle coverage. Here are some typical sensor sizes:

Size	Width (mm)	Height (mm)	Used in
1/4	3.2	2.4	Point & Shoot Cameras
1/3	4.8	3.6	Point & Shoot Cameras
1/2	8	6.4	Point & Shoot Cameras
2/3	11	8.8	Point & Shoot Cameras
1	16	12.8	Point & Shoot Cameras
APS-C	22.2	14.8	Consumer SLRs
Full frame	36	24	Professional SLRs

ASPECT RATIOS

Image sensors come in a variety of *aspect ratios*—the ratio of the sensor's width to height. The ratio of a square is 1:1 (equal width and height) and that of 35mm film is 1.5:1 (1½ times wider than it is high). Most image sensors fall in between these extremes. The aspect ratio of a sensor is important because it determines the shape and proportions of the photographs you create. When an image has a different aspect ratio that the device it's displayed or printed on, it has to be cropped or resized to fit. Your choice is to crop part of the image or waste part of the paper or display area. To imagine this better, try printing a square image on a rectangular sheet of paper so either the entire image is printed or the entire paper is filled.

Image	Width x Height	Aspect Ratio
35mm film	36 x 24	1.50
Computer display	1024 x 768	1.33
Canon 5D	4368 x 2912	1.50
Canon S3 IS	2816 x 2112	1.33
Photo paper	4 x 6	1.50
Printing paper	8.5 x 11	1.29
HDTV	16 x 9	1.80

To calculate the aspect ratio of any camera, divide the largest number in its resolution by the smallest number. For example, if a sensor has a resolution of 4368 x 2912, divide the former by the later. In this case the aspect ratio is 1.5, the same as 35 mm film but different from an 8.5 x 11 sheet of paper.

These examples illustrate different aspect ratios. The top image was sized to fill the width of a sheet of 11 x 8.5 paper. This leaves empty bands at the top and bottom of the paper. The bottom image was sized to fill the height of the paper but parts of the image extending past the sides are left unprinted.

Here is Hasselblad's 39 Megapixel (36x48mm) sensor (top) compared with an 11 Megapixel full-frame (24x36mm) sensor from a 35mm DSLR. Notice how they differ in both size and aspect ratio. Courtesy of Hasselblad.

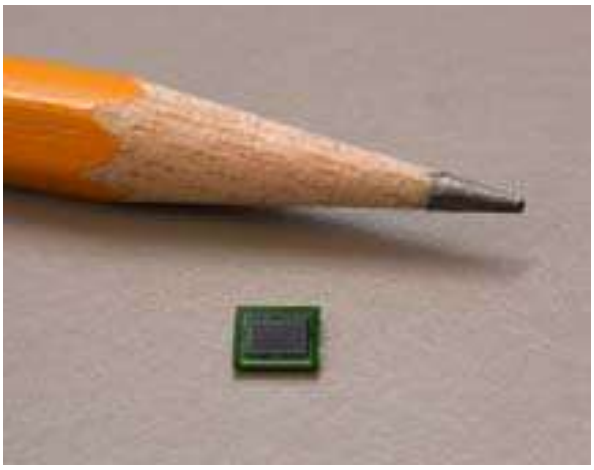


Image sensors in camera phones are very small. Courtesy of OmniVision.

IMAGE SENSORS—SENSITIVITY AND NOISE

TIP

To see one kind of noise, leave the lens cap on and take a picture. The long exposure will create noise that you can see when you open the picture in a photo editing program and enlarge it.

In some situations images are not as clear as they otherwise are. They appear grainy with randomly scattered colored pixels that break up smooth areas. This is what's known as *noise*. It has three basic causes:

- **Small photosites** on the sensor. There is nothing you can do about this cause, but it also makes the following causes even more severe.
- **A long shutter speed** that lets light into the camera for a long time, usually in a dim or dark setting, gives noise a chance to build up.
- **A high ISO setting** let's you use a faster shutter speed to avoid blur but also amplifies the noise along with the signal.

Many cameras have one or more *noise reduction modes* that reduce the effects of this noise.

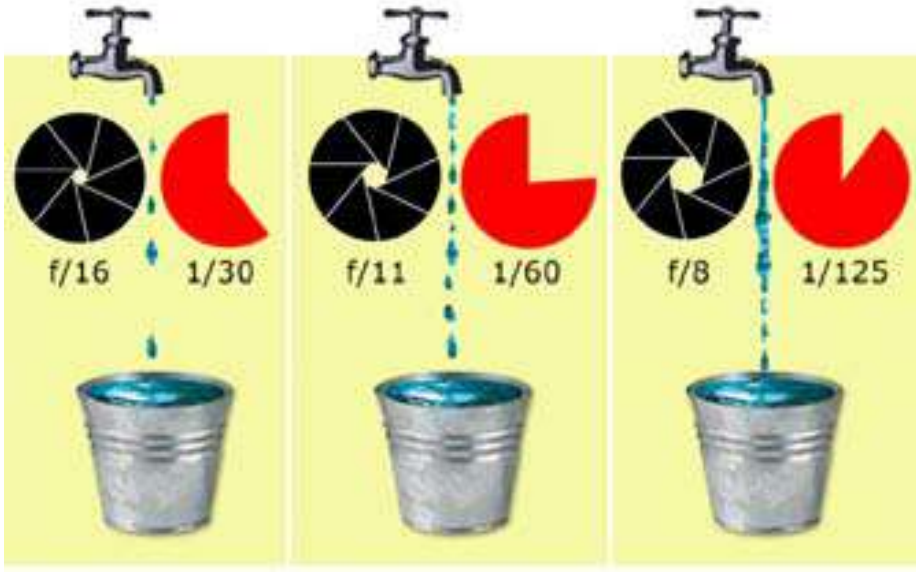
Noise appears in images as random color pixels especially when you use long shutter speeds or high ISO settings.

Animation

Click to see the effects of increasing ISO.

Animation

Click to see the effect of noise in an image.

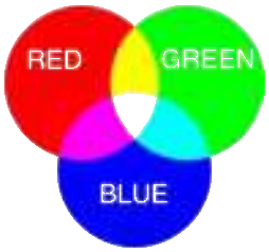


At slow shutter speeds (left) the exposure, like dripping water, is so slow noise has a chance to build up in the image. At faster speeds, (middle and right), the noise is overwhelmed by how fast the exposure is completed.

IMAGE SENSORS—IT'S ALL BLACK AND WHITE AFTER ALL

It may be surprising, but pixels on an image sensor only capture brightness, not color. They record the *gray scale*—a series of tones ranging from pure white to pure black. How the camera creates a color image from the brightness recorded by each pixel is an interesting story with its roots in the distant past.

The gray scale, seen best in black and white photos, contains a range of tones from pure black to pure white.



RGB uses additive colors. When all three are mixed in equal amounts they form white. When red and green overlap they form yellow, and so on.

When photography was first invented in the 1840s, it could only record black and white images. The search for a color process was long and arduous, and a lot of hand coloring went on in the interim (causing one photographer to comment "So you have to know how to paint after all!"). One major breakthrough was James Clerk Maxwell's 1860 discovery that color photographs could be created using black and white film and red, green and blue filters. He had the photographer Thomas Sutton photograph a tartan ribbon three times, each time with a different color filter over the lens. The three black and white images were then projected onto a screen with three different projectors, each equipped with the same color filter used to take the image being projected. When brought into alignment, the three projected images formed a full-color photograph. Over a century later, image sensors work much the same way.

Maxwell (top) and his actual photograph of the tartan ribbon taken in 1861 (bottom).

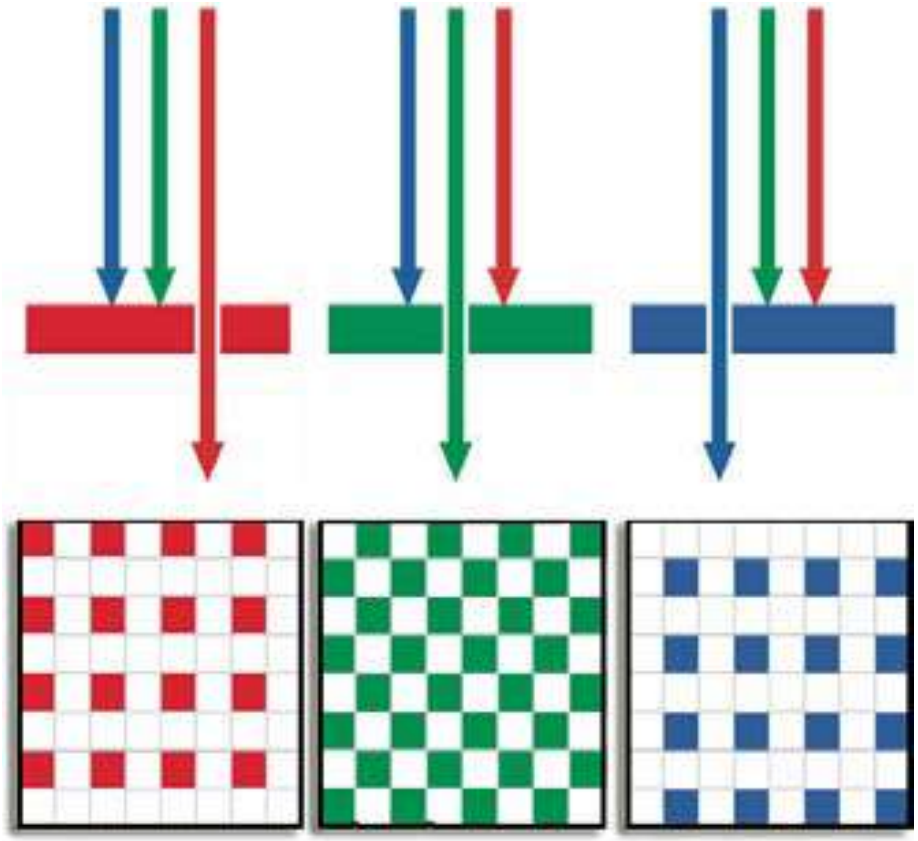
Colors in a photographic image are usually based on the three primary colors red, green, and blue (RGB). This is called the *additive color system* because colors are created by mixing the three colors. This RGB system is used whenever light is projected to form colors as it is on the display monitor (or in your eye). Another color system uses cyan, magenta, yellow and black (CMYK) to create colors. This system is used in almost all printers since it's the color system used with reflected light. It's called subtractive because it absorbs, or subtracts, colors so only red, green, and blue are reflected.

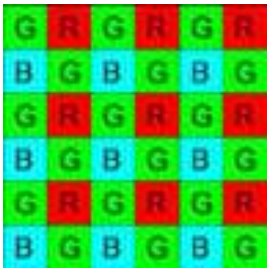
Animation

Click to explore how red, green and blue can create full color images.

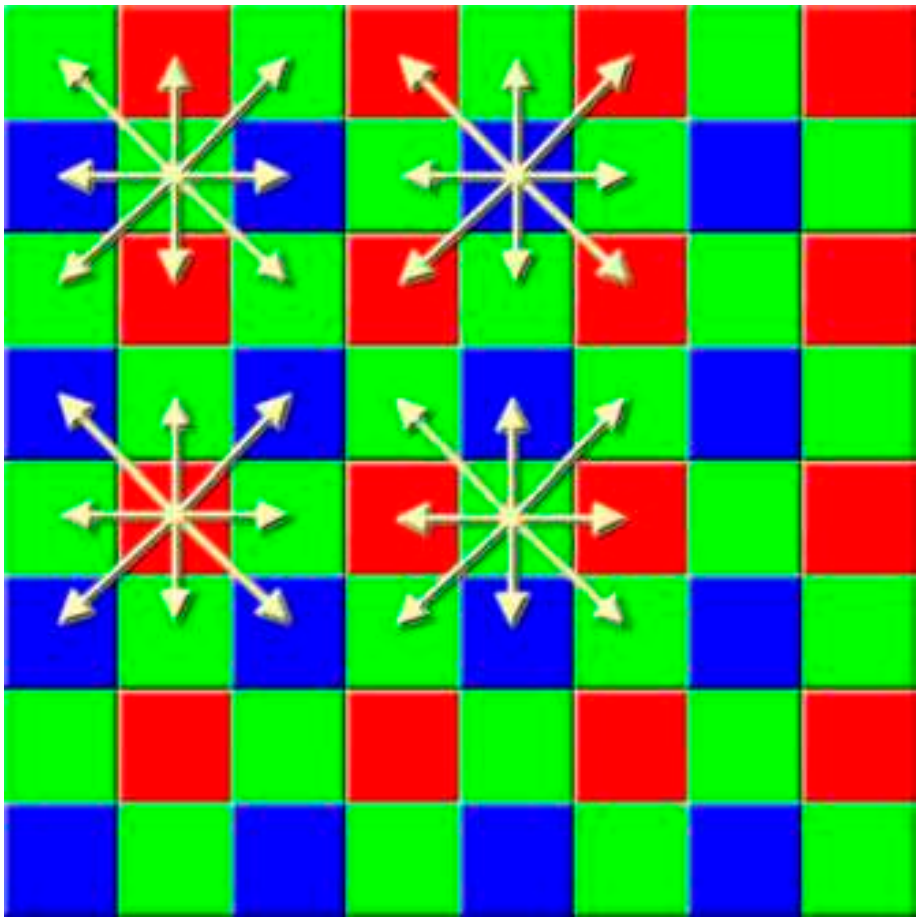
Since daylight is made up of red, green, and blue light; placing red, green, and blue filters over individual pixels on the image sensor can create color images just as they did for Maxwell in 1860. Using a process called *interpolation*, the camera computes the actual color of each pixel by combining the color it captured directly through its own filter with the other two colors captured by the pixels around it.

Because each pixel on the sensor has a color filter that only lets through one color, a captured image records the brightness of the red, green, and blue pixels separately. (There are usually twice as many photosites with green filters because the human eye is more sensitive to that color so green color accuracy is more important.) Illustration courtesy of Foveon at www.foveon.com.





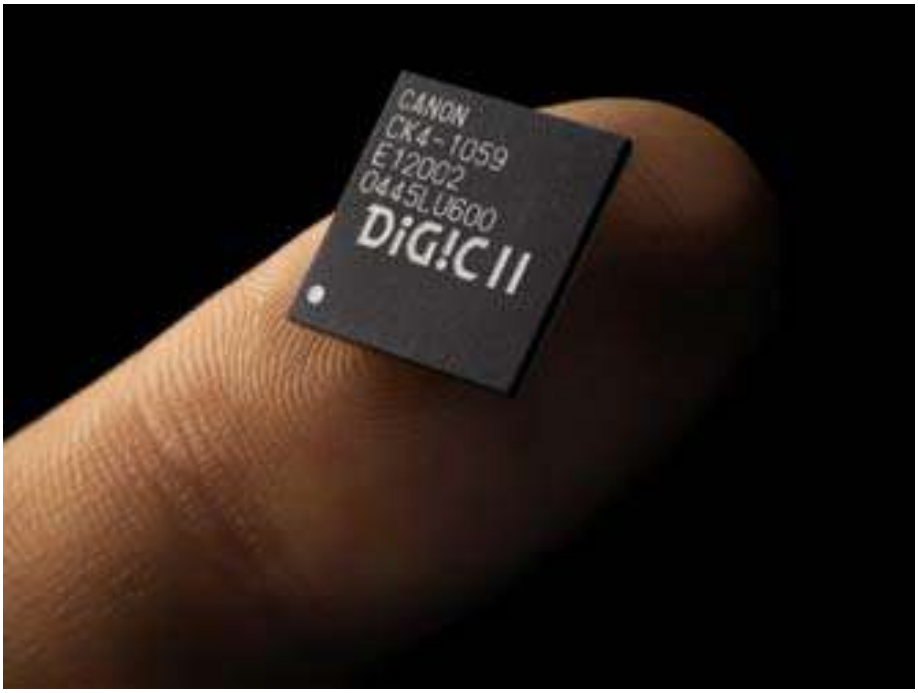
Each pixel on an image sensor has red, green, and blue filters intermingled across the photosites in patterns designed to yield sharper images and truer colors. The patterns vary but the most popular is the Bayer mosaic pattern shown here.



To create a full color image, the camera's image processor calculates, or interpolates, the actual color of each pixel by looking at the brightness of the colors recorded by it and others around it. Here the full-color of some green pixels are about to be interpolated from the colors of the eight pixels surrounding them.

There are at least 256 tones captured for each color—red, green, and blue. Only one tone at the shadow (black) end of the range and one at the highlight (white) end are pure and have no detail.

Each time you take a picture, millions of calculations are made in just a few seconds. It's these calculations that make it possible for the camera to interpolate, preview, capture, compress, filter, store, transfer, and display the image. All of these calculations are performed in the camera by an image processor that's similar to the one in your desktop computer, but dedicated to this single task. How well your processor performs its functions is critical to the quality of your images but it's hard to evaluate advertising claims about these devices. To most of us these processors are mysterious black boxes about which advertisers can say anything they want. The proof is in the pictures.



Cameras with the latest programmable image processors can be programmed by camera companies to perform a variety of functions. Currently these functions include in-camera photo editing and special effects such as red-eye removal, image enhancement, picture borders, stitching together panoramas, removing blur caused by camera shake, and much more.

When a camera company programs its processors its goal isn't to exactly reproduce a scene's colors. Instead, using a process called *color rendering*, its goal is to create what the programmers believe will be a pleasing reproduction. Frequently the contrast and color saturation are boosted, especially in the midtones and specular highlights are compressed for printing and viewing on typical displays. The processed images can be so distinctive that it's possible for some people to tell when an image was taken with a Canon or Nikon camera.

IMAGE SENSORS—CLEANING

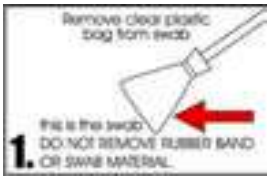
Animation

Click to see the effects of dust on your images.

When you change lenses a lot on a digital SLR, or even once in a windy or dusty environment, dust can enter the camera and stick to the low-pass filter covering the image sensor. This dust creates dark spots on any images you then capture. One way to check if this has happened is to take a few photos of a clear sky or white card. Open the images in your photo-editing program and enlarge them to see if there are any dark dust spots in what should be even, light areas.

The dust problem is so serious that camera companies are doing everything they can think of to reduce it including the following:

• **Reduce the dust** by minimizing the dust and particles created by the camera itself, by using materials in the body cap and shutter that don't create dust and other particles during normal wear and tear.

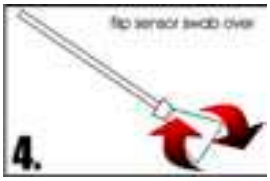


• **Make it difficult for the dust to stick** by coating the low-pass filter with a non-stick coating. (The low pass filter in front of the image sensor is designed to eliminate moiré patterns and give more accurate color.)

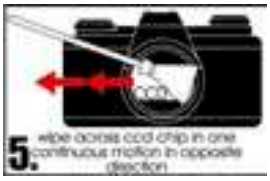
• **Repel the dust** by applying an anti-static charge to the low pass filter covering the sensor to prevent static-charged dust from adhering to it.

• **Remove the dust** by attaching an ultrasonic vibrating unit to the low-pass filter so it can shake off any dust particles that are adhering to it. The newly liberated dust is then captured by an adhesive material that prevents it from becoming airborne again. This shaking may occur automatically when you turn the camera on or off, or manually when you make a menu selection.

• **Put the dust out of focus**. The low-pass filter, normally a single unit, can be divided into two layers, a front and a rear. The front layer, where any dust would accumulate, is positioned far enough away from the sensor so any dust on it will be out of focus and less likely to show in the images.



• **Process the dust away**. You just photograph a white wall or sheet of paper (or, in a pinch, remove the lens from the camera) and the camera maps (records) the size and position of the dust particles on the low pass filter. This map is then attached to all images as metadata. When the images and appended dust data map are transferred to a computer, software supplied with the camera can use the information in the map to remove the effects of dust on the image.



Here are the five steps recommended by Photographic Solutions for cleaning your image sensor with their sensor swabs and Eclipse cleaning fluid. Courtesy of photosol.com.

• **Manually clean the sensor**. When all else fails your remaining choice is to return the camera to the camera company's service center (tiresome after awhile) or clean it yourself (a high risk procedure). If you decide to do it yourself, you use a menu command that locks the mirror up and out of your way and opens the shutter so you can get to the surface of the image sensor. You then clean the sensor (actually the low pass filter) with sensor swabs and cleaning fluid developed specifically for this purpose. NEVER use compressed air, or other cleaning products, on the sensor. Cleaning supplies are available from sources such as B&H and Calumet. For more information Google "cleaning image sensor" but proceed at your own risk.

Chapter 2
Digital Workflow

The photo was taken from the brink of Niagara Falls.

Capturing a digital photograph is just one step in a multi-step process called the *digital workflow*. Every photographer personalizes their workflow to some extent, but all include the post-capture steps of transferring pictures from the camera; reviewing, organizing, and ranking them; then adjusting, publishing and archiving them. Many of the steps in this workflow have traditionally been performed using a variety of applications including those that do image management, RAW image conversion, and photo-editing. However, the first generation of truly innovative applications in the form of Apple's Aperture and Adobe's Lightroom are reshaping the playing field. These programs are integrating into a single application almost all of the steps in the digital workflow so post capture digital photography is easier, faster, and more efficient. These programs also make working with RAW files as easy as working with JPEGs. In this chapter we'll explore the steps in the digital workflow from capturing images through to organizing and editing them on your computer. The emphasis is on Adobe's Lightroom, mainly because it runs on both Apple and Windows machines. Apple's Aperture is a highly regarded program and shares many of the same goals and features.

DIGITAL WORKFLOW

Extension

Click for a PDF extension on scanning images into a digital format.

If you have ever performed the same task over and over again, the chances are that you developed a routine, a series of steps that eliminated variations and problems from the process. In digital photography we call this routine the *workflow*. Creativity is confined to the capture and editing steps in the routine that is otherwise highly structured. Although each photographer personalizes their workflow to meet their own needs, all include some variation of the following steps—each of which can be broken down farther into a series of substeps. The exciting thing about Aperture and Lightroom is that they handle all of these steps, providing an end-to-end workflow solution.

STEP 1. CAPTURING PHOTOGRAPHS

When you pick up your camera at the start of a session, the first workflow-related steps include checking that the lens is clean, the battery is charged, the memory card is in the camera and has enough storage capacity for the number of photos you plan to shoot, and all settings are the way you want them.

TIP

Lightroom and Aperture comprise a new class of applications that is so new it does not yet have a generic class name. However, since it draws on two other classes, image management and photo-editing, these programs might be called image management and processing (IMAP) applications.

STEP 2. STORING & ORGANIZING PHOTOGRAPHS

After capturing images, you usually transfer them to a computer for more permanent storage. As you do so, you need to transfer them in an organized manner so you can quickly find images later. The latest image management programs provide a number of tools that make this easier such as the ability to rank images, add keywords, and sort images by a number of criteria.

STEP 3. EDITING PHOTOGRAPHS

When a photograph is in a digital format, you can edit or manipulate it with a photo-editing program. In some cases you improve an image by eliminating or reducing its flaws, adjusting its tones, colors and sharpness. In other cases, you adjust an image for a specific purpose, perhaps to make it smaller for e-mailing or posting on a Web site. The latest programs such as Apple's Aperture and Adobe's Lightroom make improving your images much easier and all changes are *non-destructive* so they can be undone at any time.

STEP 4. SHARING PHOTOGRAPHS

Once an image is the way you want it, you'll find that there are many ways to display and share it. These include printing it (on almost anything from art paper to coffee mugs), inserting it into a document, posting it on a photo sharing Web site or a blog, e-mailing it, including it in a printed book or a slide show that plays on a DVD player connected to the TV or a DVD drive in a computer, or displaying it in a digital photo frame.

Sony's ImageStation Web site lets you design your own AlbumPrint photo book and have it printed and bound in portrait or landscape mode.

STEP 5. ARCHIVING AND BACKING UP PHOTOGRAPHS

When you have photos for which you have no immediate use, but want to save, or important photos you don't want to loose, you can copy them to CD/DVDs or even another hard disc. If you then delete the images from the hard disk on your main system the remaining files are referred to as *archive files*. If you also keep them on the main system the duplicates are called *back up copies*.

IMAGE FORMATS

Animation

Click to explore the differences between JPEG and RAW formats.

One of the most important workflow related decisions you make when capturing images is which image file format to use. All cameras let you use the JPEG format but many also let you use a higher-quality RAW format. A few cameras also offer alternate formats including TIFF and DNG.

FORMATS

Since many digital cameras offer more than one image format, here are some things that might help you select the best one for your needs.

• **JPEG** is the default format used by almost every digital camera ever made. Named after its developer, the Joint Photographic Experts Group (and pronounced "jay-peg") this format often lets you specify both image size and compression. At the moment you capture an image in this format a processing chip in your camera manipulates it based on the camera settings you used, and then compresses it to reduce its size. The changes made to the image cannot be undone later because it's the final, altered image that is saved in the image file. Some of the original image data is lost for good.

TIP

There are so many RAW file formats in the marketplace that it's becoming a major problem. Here are just some of the RAW filename extensions that indicate different and incompatible formats.

- Nikon—NEF
- Olympus—ORF
- Fuji—RAF
- Sony—SRF
- Canon—CR2
- Pentax—PEF
- Generic—DNG

• **RAW** is a format that's available on many cameras, especially SLRs. One of Ansel Adam's better know expressions, drawn from his early experiences as a concert pianist, was "The negative is the score, the print is the performance." In digital photography, the image file is your score and your photo-editing program is where you perform. For the highest possible quality, you want to start with the best possible score—a RAW image file. These files contain all of the image data captured by the camera's image sensor without it being processed or adjusted in any way. This lets you move the images to the computer and interpret this data the way you want to instead of having the camera do it for you. When you want total control over exposure, white balance, and other settings, this is the format to use because only four camera settings permanently affect a RAW image—the aperture, shutter speed, ISO, and focus. Other camera settings are saved as metadata and affect the appearance of the thumbnail or preview images but not the RAW image itself.

With many cameras you can capture RAW images by themselves or with a companion JPEG image that gives you an identical high quality RAW file and a smaller, more easily distributable image file. Both the RAW and JPEG files have the same names but different extensions. The latest applications such as Lightroom have made working with RAW images so easy this is no longer really useful and the duplicate JPEG images just take up room.

One thing to keep in mind is that RAW images are not always noticeably better. Where they shine is when you have exposure or white balance problems. Because RAW images have dramatically more information to work with you can open up shadow areas, recover lost details in highlights, and make fine adjustments to colors.

STORAGE CAPACITY

The number of new images you can store at the current settings is usually displayed on the camera's monitor or control panel.

• **DNG** (Digital Negative). Cameras companies have introduced many different, and frequently changing, raw file formats. For example, one source states that there are over 140 RAW formats with more coming—some of them specific to a single camera model. On top of this, manufacturers are often pointlessly secretive about their specifications so there are almost always RAW files your software can't read—at least until someone reverse engineers the formats so they can support them. This lag time and inconvenience can be laid at the doorstep of the camera companies. These proprietary RAW files

The DNG logo.

are at risk over time since companies come and go and interest waxes and wanes. One solution to this growing problem is a new Adobe format called the *Digital Negative* (.DNG). This publicly defined and openly shared format for RAW files is an attempt to ensure that you will be able to access your image files in the future. If your camera doesn't capture RAW images in this format, you can convert them to DNG using a program such as Photoshop or Lightroom. When you do so, you can even choose to store the original RAW image inside its DNG file so you can extract it at some future date should you need it. The DNG format is supported by Photoshop and other Adobe products, some other software companies, and a number of camera companies. As with all things in computing, only time will tell if the format becomes widely accepted or gradually fades away.

• **TIFF** (tagged image file format) is a format that's often used to exchange files between applications and computer platforms. It's supported by virtually all paint, image-editing, and page-layout applications. TIFF files tend to be larger than both JPEG and RAW images and can be saved using either 8 bits or 16 bits per color.

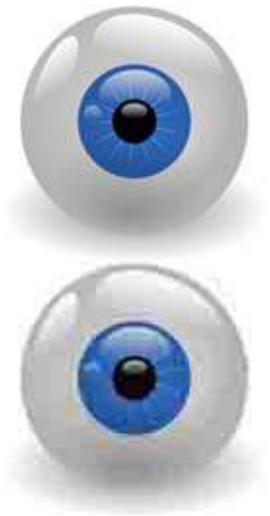
The almost universally recognized icon for image quality.

FILE COMPRESSION

Image files are huge compared to many other types of computer files. For example, files captured by a 12 Megapixel camera can range up to 18 Megabytes. As resolutions continue to increase, so will file sizes. To make image files smaller and more manageable, digital cameras use a process called *compression*. During compression, data that is duplicated or that has little value is eliminated or saved in a shorter form, to reduce a file's size. For example, if large areas of the sky are the same shade of blue, only the value for one pixel needs to be saved along with the locations of the other pixels with the same color. When the image is then opened and displayed by any application, the compression process is reversed more or less depending on which form of compression was used—*lossless* or *lossy*.

Click to see the effects of compression.

• **Lossless compression** compresses an image so when it is uncompressed, as it is when you open it, its image quality matches the original source—nothing is lost. Although lossless compression sounds ideal, it doesn't provide much compression so files remain quite large. For this reason, lossless compression is only used by the highest quality image formats—namely TIFF and RAW.



Here, two versions of the same image. The image on top is the original JPEG. The one on the bottom shows what happens after it's saved a few times at the lowest quality setting. Art courtesy of webweaver.nu.

• **Lossy compression** (rhymes with "*bossy*") can dramatically reduce file sizes. However, this process degrades images to some degree and the more they're compressed, the more degraded they become. In many situations, such as posting images on the Web or making small to medium sized prints, the image degradation isn't obvious. However, if you enlarge an image enough, it will show. The most common lossy file format is JPEG and many cameras let you specify how much they are compressed. For example, many cameras let you choose Fine (1:4), Normal (1:8), and Basic (1:16) compression. This is a useful feature because there is a trade-off between compression and image quality. Less compression gives you better images so you can make larger prints, but you can't store as many images.

COLOR DEPTH

When you view a natural scene you are able to distinguish millions of colors. A digital image can approximate this color realism, but how well it does so depends on your camera and the settings you choose. The number of colors

TIP

When discussing color depth, photographers refer just to the bits per color or the total number of bits, and both forms of reference mean the same thing. For example, if you say "8 bit images" or "24 bit images," people will know you are talking about JPEGs and not RAW images.

in an image is referred to its *color depth* and is determined by the number of bits used to store each of a pixel's three colors—red, green, and blue. JPEG images use 8 bits per color. To calculate how many different colors can be captured or displayed, you raise the number 2 to the power of the number of bits used to store them. For example:

• For each color 8-bits captures 256 levels of brightness because $2^8 = 256$.

• For all three colors combined there are 24 bits (8 per color times 3), and the total number of colors is over 16 million ($2^{24} = 16{,}777{,}216$).

RAW images have greater color depth and that gives you smoother gradations of tones and more colors to work with as you make adjustments. How many more is astronomical. RAW images are initially captured by the sensor in an analog form and an analog to digital converter converts them to 10, 12 or 14 bits per color which is increased to 16 bits per color for RAW images and reduced to 8 bits for JPEG files.

• For each color 16-bits captures 65,536 levels of a brightness ($2^{16} = 65{,}536$).

• For all three colors there are 48 bits (16 per color times 3), and the total number of colors is over 281 trillion ($2^{48} = 281{,}474{,}976{,}710{,}656$).

Extension

Click for a PDF extension on pixels and read Part 4 on color depth and file sizes.

These extra colors are not actually used by display screens, printers, or most other devices, but are there to give really fine gradations when editing and adjusting the images into their final form.

Here's a table that summarizes these color depth facts.

Name	Bits per color	Total bits	Formula of colors	Number of colors
JPEG	8	24	2^{24}	16,777,216
RAW	16	48	2^{48}	281,474,976,710,656

CHOOSING A FORMAT

When choosing between JPEG and RAW formats, here are some things to consider about each format. Because you can't easily add pixels and retain image quality, or remove the effects of compression after the fact, it's usually best to use the largest available JPEG size and the least compression available. If you have to reduce either, you can do so later using a photo-editing program. If you shoot the image at a lower quality setting, you can never really improve it much or get a large, sharp print if you want one. The only problem with this approach is that higher quality images have larger file sizes.

RAW images are always captured at the largest file size, and any compression used is lossless. Images in this format used to require an extra processing step but since the latest programs such as Aperture and Lightroom were designed from the ground up after RAW formats were introduced they handle them as easily as they handle JPEGs.

There are a number of advantages to using the RAW format:

• RAW lets you decide on most camera settings after you've taken the picture, not before. For example, when you shoot a JPEG image under fluorescent lights, the camera adjusts the image to remove the yellow-green tint. Any changes you make later are on top of this initial change. If you shoot the image in RAW format, the camera just captures the images as is and you decide what white balance setting to use later. You can even create different versions of an image, each with its own white balance.

• RAW images can be processed again at a later date when new and improved applications become available. Your original image isn't permanently altered by today's generation of photo-editing applications even if they don't support non-destructive editing.

• You can generate alternate versions of the same RAW image. For example, many photographers will adjust highlight and shadow areas and save these versions separately. Using a photo-editing program, they then combine the two images as layers and by selectively erasing parts of the top image layer let areas of the lower image layer show through so all areas have a perfect exposure.

Admittedly, there are drawbacks to using RAW images.

• RAW files are quite large. If you use this format a great deal you will need more storage space in the camera, and computer processing times may be slightly longer.

• When shooting images, you may have to wait longer between shots because the buffer gets filled more quickly and the camera is tied up longer processing the last image you took, and moving it from the buffer to the memory card.

• Since RAW images aren't processed in the camera, you have to process them on the computer and export them in a usable format when you want to e-mail them, post them on a Web site, print them, or import them into another program to create a slide show or publication. When you are done shooting for the day, there is still work to do.

• Since each camera company has defined its own proprietary RAW format, many operating systems and even photo-editing programs are unable to recognize some or all of these files. For this reason camera manufacturers always supply a program to process RAW images along with their cameras.

RAW images used to be hard to work with because they required some extra processing steps. The latest photo-editing programs such as Aperture and Lightroom make them as easy to work with as any other format.

IN-CAMERA IMAGE STORAGE DEVICES

The Kodak EasyShare has 256 Megabytes of internal storage that can hold up to 1500 of your favorite pictures so they are easy to share. This keeps them separated from those you capture and transfer to your computer. You can organize the pictures into albums with a stylus and touch screen menus.

With traditional cameras, the film both records and stores the image. With digital cameras, separate devices perform these two functions. The image is captured by the image sensor, then transferred to an in-camera storage device of some kind. These devices are only designed for temporary storage. At some point you transfer the images to a computer, erase the device, and reuse it.

Almost all but the cheapest digital cameras use some form of removable storage device, usually flash memory cards, but occasionally small hard disks. The number of images that you can store during a shooting session depends on a variety of factors including:

• The number of storage devices you have and the capacity of each (expressed in Kilobytes, Megabytes or Gigabytes).

• The resolution or image file format used to capture images.

• The amount of compression used.

The number of images you can store is important because once you reach the limit you have to move them to a computer, quit taking pictures, or erase some existing images to make room for new ones. How much storage capacity you need depends on the factors mentioned above and how prolific you are when photographing.

Flash chips courtesy of ST.com.

There is an old set up line for a joke that begins "I have good news and bad news." The good news is that we have these memory cards at all, especially at the prices they sell for. The bad news is that they come in a variety of formats that are not interchangeable. Once you have a sizable investment in memory cards, you are locked into using only cameras that support that format, or you are forced to buy a new set of cards.

Samsung developed the technology that makes 64 GB CompactFlash cards possible.

Over the past few years a variety of flash memory cards have come and gone. At the moment there are two types in widespread use—Compact Flash (CF) and Secure Digital (SD). These cards store your image files on flash chips that are similar to the RAM chips used inside your computer but there is one important difference. Your photographs are retained indefinitely without any power to the card. These chips are packaged inside a case equipped with electrical connectors and it's this sealed unit that is called a *card*. Flash memory cards consume little power, take up little space, and are very rugged. They are also very convenient; you can carry a number of them and change them as needed.

• **CompactFlash** (CF) was developed by SanDisk Corp and these cards are about the size of a matchbook.

• **Secure Digital** (SD) cards are smaller and thinner than CompactFlash cards and are used in many smaller cameras.

• **MultiMedia** (MMC) cards are even smaller cards used in a few pocket cameras.

Most cameras store images on a removable memory card that slides into a slot on the camera. Courtesy of Kodak.

Hitachi makes the Microdrive, a tiny high capacity hard drive.

• **Memory Stick™**, a proprietary format from Sony Corporation, is shaped something like a stick of gum. These cards are used only in Sony products.

• **Hard drives** such as Hitachi's Microdrive and Sony's Compactvault are high speed, high capacity hard disk drives. These drives are so small they can be plugged into a Type II CompactFlash slot on a digital camera or flash card reader. (Type I CompactFlash slots are thinner.)

• **One-time use flash cards have been** introduced with the idea that flash memory is so inexpensive you can leave your photos on a card instead of copying then to a computer. This is not recommended for serious photographers.

One thing to consider is the "speed" of a card. Many companies sell regular and more expensive high-speed versions. Unless you are missing shots because your camera can't move images from the buffer fast enough, you may be better off investing elsewhere in your system, especially since any bottleneck may be in your camera, not the card.

When you first buy a memory card or use it in a different camera you should format it. Every camera that accepts these cards has a *Format* command listed somewhere in its menus. Formatting prepares a card for use in a camera, and reformatting it when first using it in a specific camera ensures the card will be accurately written to and read in that camera. You may also find that formatting fixes a card that has developed problems. Just be aware that the *Format* command erases all of the images stored on a card. Should you ever do this by mistake, there is digital image recovery software available. To find it, just Google "digital photo recovery."

Some cameras come with software that lets you connect the camera to the computer (called *tethering* it) and operate it from the computer. When shooting this way, captured images can be stored on the computer's hard drive instead of on the camera's memory card. Although this approach is most often used in a studio setting, it's also occasionally used by landscape photographers when they want to immediately evaluate images on the computer's much larger screen.

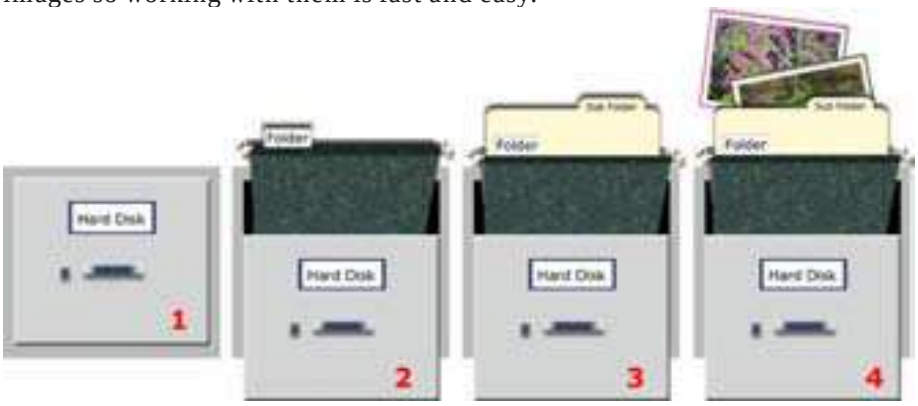
When you have more than one card, a case protects your spares. Courtesy of In Any Case at inanycase.com.

HOW PHOTOS ARE STORED IN YOUR CAMERA AND COMPUTER

DCF

DCF (Design Rule for Camera File System) defines the entire file system of digital cameras including the naming and organization of folders, file naming methods, characters allowed in file names, and file formats.

The photos you take are stored as files on your camera's storage device following rules spelled out in a variety of standards adopted by camera companies. These standards assure that files and storage devices can be moved among cameras and other digital imaging hardware and software. Since file storage and organization are so important you should understand how drives, folders, and files relate to one another. When someone takes up digital photography without having mastered these few simple concepts, they may not be able to locate the photos they want to use, or know how to organize their images so working with them is fast and easy.



A new hard disk drive (1), like an empty file drawer, has no files nor organization. Dividing a hard disk into folders (2) is like dividing a file drawer with hanging folders. Nesting subfolders inside folders (3) is like putting manila file folders into the hanging folders. Files, including images, can be stored in any of the folders or subfolders (4)—or even in the drawer outside of the folders, called the drive's root directory.

TIP

You may encounter the interchangeable terms *directory* and *folder*. When computers were used primarily by professionals, the term *directory* was introduced. As computers became more widespread, the more user-friendly *folder* was substituted. In photo sharing you'll also find the names *albums* and *galleries* used for the same things.

DRIVES

Almost all computers have more than one drive. To tell them apart, they are assigned letters or names such as *Macintosh HD*, and icons are used to identify their type. For example, the now defunct floppy disk drive was assigned both drive A and B and those drive letters now go unused. The hard drive that the computer looks to for the operating system when you turn it on is drive C. Additional drives vary from computer to computer but often include other hard drives, CD or DVD drives. When you attach your camera, a card reader, or even a digital picture frame to the computer, these too become drives. Many devices are recognized automatically when you plug them in, but a few require you to install small programs called *drivers* so the computer knows they are there.

Apple's Macintosh Hard drive icon.

FOLDERS

Folders are used to organize files on a drive. Imagine working in a photo stock agency where you're told to find a photo of "Yosemite" only to discover that all of the photos the agency ever acquired are stored in unorganized boxes. You have to pick through everything to gather together what you want. Contrast this with an agency that uses a well-organized file cabinet with labeled hanging folders grouping related images together. For example, there might be a hanging folder labeled *California National Parks*. If a further breakdown is needed, labeled manila folders are inserted into any

Click for a group of movies on folders.

of the hanging folders—basically, folders within folders. There might be one labelled *Yosemite* containing images of the park. With everything labelled and organized, it's easy to locate the images you need. The same is true of your memory cards and drives on your computer system. Both are equivalent to the empty file cabinet—plenty of storage space but no organization. The organization you need to find things on the camera's memory device (which we discuss here) is created by the camera, but on your computer, you have to create it yourself (as you will see later).

If you use operating system tools or applications to look at a storage device in the camera or card reader, you will find it is listed like the other drives on your system. If it contains more than one folder, the one photographers care about is named *DCIM* (for *Digital Camera IMages*). If you delete this folder, the camera will recreate it (but not any images it contained). The purpose of this folder, called the *image root directory,* is to keep together all of the images you capture with the camera. If you use the same card with other devices, there may also be other folders on the same card holding MP3 music or other files.

As you take pictures, your camera automatically creates and names subfolders within the *DCIM* folder to hold them (like placing manila folders in a hanging folder). The first three characters in a folder's name, called the *directory number*, are numbers between 100 and 999. The next five characters are known as *free characters* and can be any uppercase alphanumeric characters chosen by the camera manufacturer. When a new folder is created, as one is when the current folder is full, it is given a number one digit higher than the previous folder. Some cameras allow you to create and name your own folders, or select among folders the camera creates. This lets you route new images into a specific folder and also play back images from just one folder rather than the entire card.

Image files have an 8-character name followed by a period and a 3-character extension.

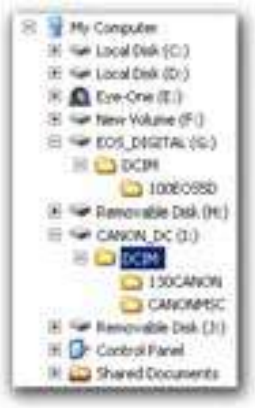
Filenames

When an image is saved, the camera assigns it a filename and stores it in the current folder. Filenames have two parts, an 8-character filename and a 3-character extension. Think of them as first and last names. The name is unique to each file, and the extension, separated from the name by a period, identifies the file's format. For example, a JPG extension means it's a JPEG image file, TIF means it's a TIFF image file.

Extensions play another important role. An extension can be associated with a program on your system so if you double-click a file, the associated program opens and then it in turn opens the file you clicked. Also, when you use an application program's *File > Open* command it often lists only those files with extensions that it can open. (You can list other file types but it usually requires an additional step or two.) If you change the extension, your system may no longer know what to do with the file.

The first four characters in an image file's name, called *free characters*, can only be uppercase letters A–Z. The last four characters form a number between 0001 and 9999 and are called the *file number*. Canon uses the first four free characters *IMG_* followed by the file number, Nikon uses *DSC_*, and Sony uses *DSC0*. Once transferred to your computer, or sometimes while

transferring them, you can rename images with more descriptive names.



A tree displayed by Windows Explorer indicates drives and folders with icons and labels. The - and + signs indicate if a drive or folder is expanded (-) to show subfolders, or collapsed (+) to hide them.

TREES

One way to illustrate the organization of folders on a drive is to display them as a tree. In this view, all folders branch off from the drive—something like an organization chart. If any of these folders contain subfolders, those subfolders are shown as a second branch from the first. When using a tree, you can expand and collapse the entire tree or any branch. This allows you to alternate between a summary of the computer's contents, and details of each drive or folder.

PATHS

With files stored in folders on a disk, you specify a *path* to get to them. For example, if a file named *IMG_4692.JPG* is in a subfolder named *146CANON* that's in a folder named *DCIM* on drive H, the path to that file is *H:\DCIM\146CANON\IMG_4692.JPG*. The key elements of a path—the drive, folder, subfolder, and filename—are separated by backslashes (\). You might be more familiar with paths from your Web browser that uses a similar approach using slashes. For example, the URL...

http://www.shortcourses.com/index.html

... is a path to a specific page on the Web. Normally you don't type in paths, you click drives or folders to open them. However, many programs display paths on the screen as a navigational aide and so it's easy to confirm the actual location of the file on your system.

Here is the path to the file IMG_4692.JPG in subfolder 146CANON that's in the DCIM folder on drive H. The drive, folder, subfolder, and filename are separated by backslashes.

Here is the path to an image as displayed in Lightroom.

TRANSFERRING IMAGES

Card readers are often connected to a computer's USB port, or may even be built in. Cards inserted into a slot are treated just as if they were removable hard drives. Cards vary in size and have different connections so many readers now have a variety of slots. Photo courtesy of PQI atpqi1st.com.

If a card is smaller than a slot, or if your notebook has an ExpressCard Slot you can usually find an adapter that mates your card to the slot. Here is Delkin's adapter that lets you read CF cards in an Expresscard slot. Some adapters accept a variety of cards Courtesy of Delkin.

Animation

Click for an animation on dragging and dropping files.

Some home printers, print kiosks in public locations, and even TV sets have slots that accept cards directly from your camera so you can view or print images without a computer. Courtesy of Hewlett Packard at hp.com.

Storage in the camera is only meant to be temporary. When you want to use or edit the images, or make room for new ones, you transfer the images on the card to the computer.

Almost all digital cameras come with software that will transfer your images for you as do newer photo-editing and image management programs. As useful as these tools are, you should also know how to use your operating system's tools. Here are some reasons why:

• **Availability**. Operating system tools are on every computer of the same type, anywhere in the world.

• **Change**. If you change applications, what you have learned about operating system tools remains useful. What you have learned about the old application might as well be forgotten.

• **Control**. Many programs have a mind of its own and rename and store files in a manner you may not choose were you given the choice. Operating system tools let you use your own file management system.

Regardless of how you transfer the files, you have to choose whether to move or copy them.

• **If you move files** from the camera's storage device, they are first copied to the computer and then deleted from the storage device. If anything goes wrong during the transfer you may loose image files.

• **If you copy files**, they are not automatically deleted from the storage device. You either have to do that using your computer or one of the camera's commands. Although deleting the images after the transfer is an extra step, this procedure is safer than moving files because if anything goes wrong you still have the original images on the card.

To transfer files you have to connect the camera or memory card to the computer or other device and there are a variety of ways to do this.

CARD READERS AND SLOTS

One of the most common ways to transfer images to a computer is using a card reader or card slot that accepts your card with or without an adapter. Card slots are increasingly being built into computers, printers, and even TV sets. If your system doesn't have one, there are inexpensive card readers that will plug into a USB port.

CABLE CONNECTIONS

Another popular way to transfer photos is by way of cables. The most popular connections at the moment are USB 2.0 and Firewire 800 (IEEE 1394b).

Almost all cameras come with a USB or Firewire (IEEE 1394) cable that connects it to a computer or printer. Courtesy of Canon at www.powershot.com.

Cable connections on the back of Apple's Mac Mini with USB and Firewire (IEEE 1394) logos and connectors are shown here circled in red. Courtesy of Apple at www.apple.com.

A dock lets you easily connect a camera to a printer or computer and even charge the camera's batteries. Unfortunately, docks are camera-model specific so if you buy another camera you'll need another way to make your connections. Courtesy of Kodak at www.kodak.com.

USB cables have a standard plug at the computer end but those on the camera end aren't standardized—a source of endless frustration for those with more than one camera. Luckily there are adapter kits like this one from www.wiredco.com.

Sandisk makes an SD card that folds to reveal a USB connector so it can be plugged in without using a slot or card reader.

WIRELESS CONNECTIONS

One of the latest trends is using wireless connections between your camera and you computer or printers, and between your camera and a network so you can immediately share your photos using e-mail, photosharing sites, or photo blogs. There are three basic approaches:

• **Infrared** connects line-of-sight devices where the infrared beam isn't blocked.

The Kodak EasyShare One's WiFi compatibility lets you post images on a Web site or e-mail them using a home network or public hot spot. Photo courtesy of Kodak at www.kodak.com.

• **WiFi** connects to wireless printers, kiosks and WiFi networks like those in home networks and public hot spots. It is built into a few cameras and can be purchased separately for others. Camera phones often send photos over the operator's network but you are at their mercy when it comes to pricing. Luckily, some camera phones also let you connect to WiFi networks so you can cut your transfer costs. These cameras adhere to the Digital Living Network Alliance (DLNA) standard, which works with WiFi 802.11b/g networking. This allows them to communicate with each other as well as a WiFi network and other entertainment devices in the home.

• **Bluetooth** is inexplicably named after Herald Bluetooth a 10th Century Danish king. It is relatively slow, much slower than WiFi. Initially developed to replace all of the cables hanging off your desktop, Bluetooth is finding a home in photography because it uses very little power, preserving battery life, and unlike infrared technology, Bluetooth devices don't have to be in line of sight contact with each other in order to transfer data. Photo kiosks are often equipped with Bluetooth so you can beam your photos to the printer. With both digital cameras and camera phones equipped with Bluetooth you can even take pictures with the camera and send them with the camera phone. There are also PC Card and USB adapters that let you use Bluetooth to wirelessly transfer images from your phone to your computer.

A Nikon camera with WiFi connectability.

STORING IMAGES—ON YOUR SYSTEM

Maxtor makes a line of inexpensive high-capacity hard disk drives that are ideal for digital photographers. Courtesy of Maxtor.

When you transfer images to your computer, it's usually to a hard drive. From there you may then copy or move them to CD/DVDs or even to another hard drive.

HARD DRIVES

When you move photos from a camera's storage device to a computer's hard drive they become available for organizing, editing and sharing. Hard drives have become so inexpensive, and their storage capacity so great, that you can have an almost endless supply of hard disk space on which to store images. Currently, affordable drives have capacities up to 500 Gigabytes—enough room to hold more than 33 thousand 15 Megabyte images. If these were film images at 50-cents a picture, you've have a small box of images worth over $16-thousand dollars! One way to think of this amazing capacity is by how long it would take you to fill a drive. If you shot a hundred 15 Megabyte photos a day, you could shoot for almost a year before filling a 500 Gigabyte drive. And forget backing these drives up to CDs or DVDs. It would take 106 DVD disks to back up a drive like this and over 700 CDs. Even tape backups have fallen far behind. The only affordable backup for entire libraries of photos is another hard drive.

Hard disks grouped together into a RAID configuration (Random Array of Inexpensive Devices) not only store information but automatically back it up. If one drive fails, it can be replaced and the damaged files are then automatically reconstructed from the remaining drives.

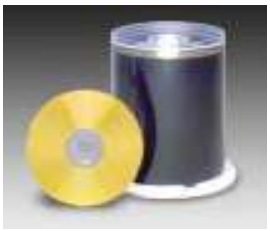
OPTICAL DISCS

Other than hard drives, the only other widely available storage device is the optical drive that *burns* and reads either or both CDs or DVD discs. These drives are common on almost all new computer systems and the discs are frequently used to backup important images to protect them, share them with others, and even to store slide shows that can be played back on a computer or DVD equipped TV set. (When a DVD device is attached to the TV it's called a *player* or *recorder*. When attached to a computer it's called a *drive* or *writer*.) There are major problems with these discs—their storage capacity is relatively low, their archival quality is questionable, and they are not always compatible.

• **Capacity**. CDs can store, at most, 700 Megabytes of data. In an era of 4 Gigabyte memory cards and 15 Megabyte RAW or TIFF image files created by some cameras, 700 Megabytes of storage looks small indeed. DVDs currently store 4.7 Gigabytes, more that 7 times the capacity of a CD. As two-sided discs become more common, the capacity climbs to 9.4 Gigabytes. Even newer devices based on blue lasers will eventually push these limits to almost 30 Gigabytes and beyond. As a place to store your digital images, DVDs have a promising future.

Mitsui Gold CD-R discs are considered one of the best storage CDs because of a real gold added to the reflective layer—others use silver which doesn't have the same archival properties. Courtesy of Diversified Systems Group.

• **Archival quality**. CD and DVD discs are both relatively new forms of storage. How long they will last before data is lost isn't yet known with any certainty. Most tests use accelerated aging that may or may not accurately reflect the future or your storage conditions. The consensus seems to be that they will last a few decades if manufactured and stored properly. Given the uncertainty, the best thing you can do is buy only name brands and store them in acid-free envelopes in a cool dark place such as a drawer or album. Discs that use a gold, rather than a silver recording layer, are generally considered to last longer.



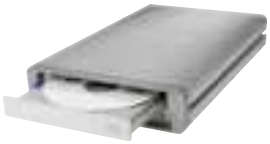
CDs and DVDs are less expensive when you buy them on spindles. You then use envelopes to store them in drawers.

Amazingly, one company ran a light fastness test that showed that gold discs could withstand sunlight for only 100 continuous hours without damage. Discs with the widely used cyanine dye began to deteriorate after only 20 hours and failed at 65 hours.

• **Compatibility** . The big problem with optical discs is summed up in the word "compatibility" defined by the dictionary as "existing or living together in harmony."

With CDs the problems are minimal. You can select either *CD-Recordable* (CD-R) discs that can be written to once or *CD-ReWriteable* (CD-RW) discs that can be recorded, erased, and reused, just like a hard disk.

With DVDs, the problems are more complex. Until recently you could select DVD+ (plus) or DVD- (dash) formats. Since the formats are incompatible, the industry solved the problem by having you pay for both in the form of a multiformat or dual DVD drive.



CD drive. Courtesy of LaCie.

Now the industry is introducing two more incompatible formats, the HD-DVD and Blu-ray DVD. Only time will tell if there is a clear winner or if they again solve the problem by charging you for both in the form of a combined drive.

CD/DVD BURNING SOFTWARE

There are many notebook computers that have built-in DVD drives, including this ultralight from Sony.

To copy files to a CD/DVD, you need recording—sometimes called *authoring* or *burning*—software. This software is readily available—for example, the latest Windows and Mac operating systems let you burn a CD/DVD directly from the operating system. In addition, there are programs such as Roxio's Easy Media Creator designed specifically for this task. The ability to burn CD/DVDs is increasingly being integrated into other applications. For examples, Apple's iPhoto and Aperture and Adobe's Lightroom all let you select images and burn them to a CD/DVD without leaving the application. Many applications also let you create a slide show of your images and burn the show to a DVD disc so it can be played on the computer, a CD player, and even a late model DVD player connected to the TV.

LABELING CD/DVD DISCS

When you burn a disc, you or your software can add a title that will be displayed by your computer when you access the disc in a drive on your system.

The name will also be used by image management software to keep track of your images. For example, with most image management programs, when you double-click the thumbnail of an image that isn't currently on-line, the name you assigned the disc on which it is stored is displayed and you are prompted to insert that disc.

You can add your own descriptive title such as *Florida Trip Disc,* or let the program automatically assign one based on the current date and time. For example, the number *070412_0849* indicates the disc was burned in the year 2007 on May 12 at 8:49 AM.

Even when a disc is labeled when burned, you still need to physically label it. Generally, the information should be on the disc itself, not on an envelope or insert. It's too easy for these to get separated from the disc. One way to label a disc is with a permanent marker pen that writes on the non-recording side of the disc with ink that won't rub off with use. For longevity reasons, the best choice is a pen that uses water-based inks. Some marker pens, such

When copying images between devices, USB flash drives come in very handy. You plug one into a computer's USB port and copy files to it. You then plug it into any other computer and copy the files from it. Courtesy of Lexarmedia at lexar.com.

as the Sharpie, use solvent-based inks and should be avoided. You can easily identify the pens not to use by their solvent odor. These solvents can attack the protective covering of the disc, even when you write just on the label side. Over a long period of time, possibly measured in decades, this can affect the data.

For a more professional look, you can buy press-on CD/DVD labels that you print with an inkjet printer and stick onto the surface of the disc. One major problem is alignment because once the label sticks, it's stuck. Unlike life, there are no second chances. To help you get it right the first time there are alignment gadgets that center the label as you press it onto the CD. When using these labels, apply them after recording the disc. If you apply one first and it's slightly off-center, it may affect the recording process.

Most CD/DVD burning applications include software you use to lay out and print labels and even jewel case inserts. This software, and applications available from others, usually has a number of backgrounds from which to choose (or lets you use your own photos as backgrounds), and text boxes into which you type your text. You don't have to be technically proficient or very artistic to get a decent design.

Neato makes an applicator that centers a label and the disc so the label goes on right the first time. Courtesy of neato.com.

Should you ever decide to ramp up your CD/DVD distribution efforts, the next step is a label printer. These printers print on special disks that have a water permeable coating on one side. If a disc doesn't have this special layer, the ink beads up on the surface of the disc and flakes off when dry. Inkjet printable discs are produced by several major companies and are available from office supply and on-line retailers. A number of photo printers from Epson have added the ability to print labels directly onto these printable disks. If the market supports this feature, it will become more common. These printers include software that you use to design and print your labels. When ready to print, you place the inkjet printable CD or DVD into a tray that protects it as the CD passes through the printer's straight-through paper path. There are also printers designed for the sole task of printing labels on discs and there are even robots available that will insert one disc after another into the printer so you can print a quantity of discs unattended.

If you ever need large quantities of a single disk, you may want to have them professionally duplicated and the labels silk-screened. You can also give your own discs a professional and personal appearance. Just have a supply of blank discs silk screened with professional graphics, leaving a space to write in specific information such as the discs's name or title.

Drives using Lightscribe technology can label Lightscribe discs as they are burned. Courtesy of Lightscribe.com.

STORING IMAGES—ON THE ROAD

Some iPods can both store and display photos.

The iPod Camera Connector provides a fast, easy way to transfer images from your digital camera to your iPod. Simply plug the iPod Camera Connector into the iPod dock connector, plug in your camera's USB cable, and watch your images make their way to your iPod.

The Epson P-5000 is a portable storage and viewing device with an 80 Gigabyte hard drive and a 4 inch screen.

Storing images at home is easy. When it's time to hit the road with your digital camera, the problems begin. With traditional cameras, you just stuff the bag with film and shoot till it runs out. Then you go buy some more. With digital cameras it isn't that easy. When you take a lot of photos or are on a long trip, you'll eventually reach the point where your memory cards are all full and you have to move images to another storage device. This is especially true when you capture high-resolution images or use file formats such as RAW or TIFF that give you the best image quality but create huge files—15 Megabytes and even larger in some cases. Here are your alternatives on an extended photo shoot or expedition:

• **Find a place to burn CD/DVDs for you**. This will now be done by most photo stores but they are often clueless. (One store used software that recognized and copied only JPEGs, leaving RAW images on the card where they could easily have been deleted since the reasonable assumption was that they has also been copied.)

• **Buy more or larger memory cards**. This is a common solution but it can be expensive if your trip is long or you are a prolific shooter.

• **Carry a notebook computer**. Not only may you already have one of these, but its large screen and ability to run your choice of applications provides you with a mobile version of the typical desktop system. However, a notebook computer isn't always the ideal portable device because of its size, weight, short battery life, and long start-up time. On a car trip it's perfect, especially with a *voltage inverter* so you can power it from the car's battery. On airline, hiking, or canoe trips it's difficult or impossible. On trips out of the country you may need voltage adapters or converters. If you attach a portable hard drive to the notebook, you can just plug it into your other system when you return home. You can then transfer the files or editing the images right on the portable drive.

• **Buy a portable storage device** based on a hard drive or a CD/DVD drive. Some of these devices have card slots or connect directly to the camera. After transferring your images you can then erase your card to make room for new images and resume shooting. When you get back to the setup you use for editing, printing, and distributing images, you copy or move the images from the portable storage device to that system. Many portable storage devices, including some models of Apple's iPod, also let you view your stored images on the device's LCD monitor or on a connected TV—and even pan, rotate, and zoom the images. Some also let you print directly to a printer without using a computer and combine digital photos, digital videos, and MP3 music. With a device such as this you'll be able to create slide shows with special transitions, pans, and accompanying music and play them back anywhere. If you consider one of these devices, be sure it can handle the image formats you use. RAW and other non-JPEG formats are often not supported.

• **Use file transfer**. A service called GoToMyPC is widely used by people to access and operate their home or office computer from other computers anywhere in the world even those in libraries and cyber-cafes. If you subscribe to this service you can also transfer files and folders between PCs, or an attached memory card or camera, simply by dragging and dropping between screens. There are also other peer-to-peer file transfer systems available.

ORGANIZING YOUR PHOTO FILES

Here is a tree from the Lightroom Library that shows two projects—one on Manchester-Essex Woods and one on Monarch Butterflies.

When you move your images from your camera to your computer and then to a CD/DVD disc, you need to do so in an organized way. It doesn't take long to be overrun with images; and all of them with meaningless names to boot. Luckily, with some planning, and the right tools and knowledge, you can work with thousands of images without getting lost.

Before transferring images from your camera to your computer, you should develop a system that lets you quickly find them later. Folders are the heart of any image management system. The best way to organize images on your computer is to create one or more folders for images and then subfolders that meaningfully identify the images stored in them. The thing to keep in mind is that your organization is not about storing images, but about finding them. Ask yourself, where you'd most likely look for pictures of interest a year from now, long after you've forgotten where you stored them.

There are a variety of ways to organize and name folders, depending on what kind of photos you take or how you use them.

• **A chronological organization** uses folders named with dates in the format yyyy-mm-dd. For example, a folder named 2008–02–10 would contain photos taken or downloaded on February 10, 2008. When using dates, be sure to add zeros to single digit months and days or the folders won't sort into a perfect chronological order. You can use hyphens or underscores between elements, but should avoid using spaces.

• **A subject organization** uses folders named after subjects, events, projects, or experiences. For example, a folder named *Christmas 2008* would contain images of that day. *Emilys Birthday 2008* would contain images of the birthday party.

> **TIP**
>
> Shorthand ways of ordering and separating days, months, and years vary from country to country. However, sorting on the computer works best when dates are in the format yyyy-mm-dd.

These two approaches aren't mutually exclusive. For example, if you organize images chronologically, you can add a comment after the date that indicates the subject or project. Although duplicating images should be avoided as much as possible, you can also create a chronological system, and then copy the desired images to separate subject or project folders. The chronological folders act as an archive of original images, and the subject or project folders become the versions you edit, print, or distribute. This system has the advantage that you never actually edit your original photos. The drawback is that you can have different versions of the same image in more than one folder. As you'll soon see, the latest image management programs give you the same advantages using collections or albums (based on the same concept as iTunes playlists), and non-destructive editing so you never need more than one master copy of any photo on your system, because each master can have many exported variations.

Once you have developed an organizational system that works for you, you need to decide what folders and files should be moved to CD/DVDs or other form of long term archival storage. In most cases they would be images you anticipate no longer wanting to look at, edit, or use. If you ever do need them, they are still accessible.

The tools you use to create folders, and view, transfer, and manage images include those that come with your computer as part of the operating system. However, image management applications store thumbnails and descriptions in a database so you can even locate images that are stored on CD/DVDs in a drawer. We'll explore these tools in the sections that follow.

IMAGE MANAGERS

TIP

A thumbnail image is actually created at the time you take a picture. In a JPEG image it is stored in the image file as metadata and goes anywhere it goes.

Windows XP has a filmstrip view that lets you look at thumbnails, with the currently selected one enlarged.

Windows Vista has added a variety of new ways to view and manage your photos.

If you've set up your folders systematically, it's not hard to locate images taken on a certain date or during a certain period. However, you need to see the actual images to choose the specific ones that interest you. You can do so with any program that displays your images as small thumbnails. Viewing thumbnails is so important this feature has been integrated into operating systems and almost every digital camera and photography program. However, thumbnails are only one resource offered by programs designed specifically to manage large collections of images. These *image management programs* not only let you view thumbnail images and information about the images, they permanently store this information in a *database*, often called a *library*. What is a database? In one respect it's just a collection of facts. You interact with databases every day without even knowing it. For example, when you use Google to search for the phrase "digital cameras," you are searching Google's database for Web pages in which that phrase appears. Another familiar database is iTunes' Library where music and information about it are stored. In a database, data (facts) are stored in a very structured way using tables with rows and columns much like a spreadsheet.

Although you never see that actual database, it has one row or *record* for each image in the library. Each record contains a number of columns or *fields* that contain specific facts about the image. Typical fields might be the date the picture was taken, the camera used to take it, the size of the image in pixels, and the name of the file. The record for each image has the same fields, and this is what makes the database so powerful. You can sort the table based on the contents of any field. For example, you can sort it by the date pictures were taken, by their size, or format. You can also search the database by specifying what field to search in and what fact to find. For example you can search the date fields for pictures taken or modified on a certain date. Any images that contain the specified facts in the specified fields are listed. Databases also let you view the information in different ways. You can have it display just thumbnails; or thumbnails, filenames, and image sizes. Another view might include the Exif information so you can see what shutter speeds or lens focal lengths were used for each image.

Lightroom creates a record for each of the images in its database called the Library. *You then use Lightroom to view this data, including thumbnails and Exif information, in a variety of ways.*

File Name	File Size	File Color Space	Color Dept	Shutter	Aperture	Flash
IMG_1000.JPG	13 MB	SRGB	24 Bits	1/200	f/8.0	On
IMG_1001.JPG	11 MB	SRGB	25 Bits	1/800	f/11.0	On
IMG_1002.JPG	12 MB	SRGB	26 Bits	1/500	f/5.6	Off
IMG_1003.JPG	15 MB	SRGB	27 Bits	1/600	f/11.0	Off
IMG_1004.JPG	10 MB	SRGB	28 Bits	1/125	f/16	Off
IMG_1005.JPG	11 MB	SRGB	24 Bits	1/500	f/2.8	Off

In an image database there is a record (red row) for each image and a number of fields (blue column).

Click for a movie on Portfolio, and asset manager from Extensis.

Many image management applications also index and catalog other kinds of files such as movies, sounds, and the like. For this reason, these programs are called by the more inclusive name *asset managers*—each file on your system from a Quark document to a digital image being an asset.

Database-backed image managers are used to manage small and large collections of images. Their features only grow in importance as the number of photos on your system increases. Here are some of the most important features.

LIBRARIES

The database in which image information is stored is called a *library* or *catalog*. Once a photo has been added to the library, all of the image management and editing tools can be used on it. Some early applications forced you to copy the original image files into the Library so the Library could never be larger than the drive it was stored on, and as the library got larger it got slower. Newer applications let you copy or move photos into their libraries if you want, but also let you reference photos anywhere on your system and even those stored off-line. For example, you can take a CD/DVD or external hard drive out of a drawer, add its contents to your library, and return it to the drawer. You can then view thumbnails and even larger previews of the images even though they are no longer on the system—called *off-line*. This is because you are actually viewing thumbnails and previews stored in the database when the images were added to the library. Each thumbnail or preview in the library is linked to its full-size image or points to it. If you double-click a thumbnail or preview of an image that's still on the system, the image opens full-size. If you double-click a thumbnail or preview of an image that is on a CD/DVD or hard disk drive in a drawer, the program gives you the name of the disc on which it's stored and prompts you to insert the disc or connect the drive.

If your library ever does get too large or too slow you can create more than one library—perhaps one for professional work and another for personal. However, you can't work on both libraries at the same time so this approach has limits.

In Lightroom you can mark images with different colors and then locate all of the images with any of the colors you assigned.

TRACKING

Photographers often like to move photos around, rename them, and delete them. If you do this from within the image manager the program keeps track of and accurately reflects the changes.

WATCHED FOLDERS

You can specify that certain folders be watched so when you copy or move files into these folders without using the image manager to do so, they are automatically added to the library. The contents of the folder and the library are synchronized.

The Sort menu choices in Adobe's Lightroom.

In Lightroom you can rank images with 1–5 stars and when you select the picture its ranking is displayed.

Pick and reject flags.

The header is an area of the file separated from the image data.

Exif metadata is displayed for a selected file in Lightroom.

SORTING

You can sort your images in a number of ways including by the date they were taken, their filenames or extensions, and the date they were imported into the database. Sorts can be in ascending or descending order.

RANKING

Most of the photos we take turn out to be disappointing so we usually focus on just a few photos. For this reason programs let you assign a ranking to images. The best might get a 5-star ranking while the next best 4-stars and so on. Variations of this are to mark them with pick or reject flags or with color labels to which you can attach meanings. Once ranked in one of these ways, you can display, sort, or search using one or more of these criteria.

KEYWORDING

You can assign keywords to images or groups of images to make it easier to find them later. Keywords can refer to such things as the location, subject, people, and so on. If you are consistent with keywording, you will be able to easily find all of the photos of "Emily" that you took in "Santa Barbara" over the years.

FILTERS

When you have a large number of photos in your library, you may only want to work with a small subset. To determine which images are displayed, you can use filters. For example, you can tell the program to only display pictures taken this week, this month, or on any given day. You can also display just those that have a five star rank or all photos that have been assigned any rank up to a certain level. Filters vary from program to program but all serve the same function—filtering out photos that don't interest you so you can zero in on the ones that do.

METADATA

When you take a picture, the camera stores information about it along with the image data. You can also add additional information using some cameras and photo-editing or image management applications. The more information you have to work with, the easier it will be to find an image later.

• **Exif** (Exchangeable Image File Format) is a specification that spells out how information about a JPEG image is stored in the same file as the image. This information, including a thumbnail image, describes the camera settings at the time the picture was taken, and even the image's location if the camera supports GPS (Global Positioning System). Digital cameras record this information as *metadata* in an area of the image file called the *header*. This information isn't just for managing images, it can also be used by some printers to give you better results. Basically, any camera control set to auto at the time the image was taken can be manipulated by the printer or other device to improve results. Those set to one of the camera's manual choices is considered to be a deliberate choice and is not manipulated.

Metadata can sometimes be lost if the file is opened and then saved in another file format. (Or even lost when using the camera's own rotate, crop, or other commands that write to the disk.) However, most applications now preserve this information, although camera companies sometimes store secret metadata that can be lost.

METADATA?

Metadata is data about data. In digital photography it's information inserted into the header of an image file that describes what the contents of the file are, where it came from, and what to do with it. You are already familiar with two examples, an image file's name and the date it was created. Other metadata includes the Exif data created by most digital cameras that tells what camera was used, what the exposure was, and whether a flash was used.

• **IPTC**. Using an image management application, you can add information to an image such as keywords, a copyright notice, or a caption. The problem is that when you send the image to someone else, that information is usually not sent along because it's stored on your computer in the database and is not part of the image file as Exif information is. (As you will see shortly, one solution to this problem is the xmp file.) To solve this problem, the International Press Telecommunications Council (IPTC) defines a format for exchanging such information. Programs that support this standard let you add, edit, and view this information that's embedded in a file just as Exif information is.

PREVIEWS

When reviewing your images in detail, you'll generally find thumbnail images too small and full-sized images too slow to open. For this reason image management programs will normally generate full-screen preview images that are then stored in the database. These need only be as large as the screen to be useful. In fact, on some applications you are normally viewing and editing a preview image. You only see the original image when you enlarge the preview past the size where it fills the screen. Since the preview is so much smaller than the original image this increases the application's response time.

IPTC metadata is displayed for a selected file in Lightroom.

COLLECTIONS

One rule of all databases is that an image should only be stored once. When you need the same image to appear in a number of projects, you don't create duplicates. Instead, you create *collections*, sometimes called *albums* or *projects*, of related images. The same image can appear in any number of such collections even though there is only one copy of the image on the system. (If you are familiar with the iPod, this is exactly how playlists work.) When you assign an image to a collection, the program just copies its thumbnail and information about it and adds a link to the full-size image. For example, if you have an image that you want to use in both a book and a calendar, you would create collections for each of these projects and add the image to both.

STACKS

Stacks are sets of related photos such as a series shot in continuous mode or using autoexposure bracketing. By grouping images in stacks you can collapse a stack so only the image you specify as representative of the stack is displayed, or expand the stack when you want to view and compare all of the images it contains. If nothing else, stacks reduce the clutter on your screen because you don't have to scroll through all of the stacked images unless you choose to. Ideally, the application will use metadata, such as how close together photos were taken, to automatically combine some images into stacks.

LIGHT TABLE

When working on a project such as a slide show, Web site, or publication, there comes a point when you'd like to see the photos you've taken arranged more like they will appear in the finished work. Film photographers did this by arranging slides on a light table so they could experiment with combinations that would create a particular visual effect. In an image management program an area of the screen provides the digital equivalent; a freeform canvas on which you can place, align, resize and group images in an unconstrained way.

TIP

Non-destructive editing means that at any point you can undo any changes you have made to an image.

EXPORTING

With RAW images or non-destructive editing the original file is never changed. Your edits are applied when you export an image into another format, to a different folder, or to a file with a different filename. When you do so you can also resize the image, attach a color space, specify a file format and amount of compression.

XMP

The latest photo applications use what's called *non-destructive editing* so an original image is never changed. Instead, your edits are stored in the database and reapplied whenever you reopen the file. When you send one of your edited images to someone, or copy/move it to another system, the edits are left behind in the database. If you want to share the edits along with the image, programs such as Aperture and Lightroom use Adobe's Extensible Metadata Platform (XMP) to embed editing metadata into the image file itself or in a separate "*sidecar*" file with the same filename as the image but the extension *xmp*. The metadata can include the list of editing changes you have made to the image as well as Exif and IPTC metadata. Other applications that support XMP can access and use the metadata so you can see the editing changes on other systems.

ARCHIVING

When you are finished with photos but want to save them, you should be able to archive them along with their metadata. Ideally you can easily select the images and burn them to a CD/DVD or copy them to a backup drive or network volume, and they remain listed in the library so you can see their thumbnails, previews and metadata. If you select an image that's off-line you will be prompted to insert the disc on which it's stored.

If you want offsite backup, so the same accident can't affect your originals and your backups, on-line storage may be the answer. Two sites, Carbonite.com and Mozy.com, will backup some or all of your files. Each service installs a small program on your system. When you change or add files, they are marked for backup and this is then done in the background while you work on other projects. The only problem with this form of backup is that it can be very slow even with a fast Internet connection. However, after the initial backup of all important files, backups of those files that have changed will go much faster.

USING ALL OF THE FEATURES—THE WORKFLOW

When a photographer returns from a shoot, their goal is to process images as quickly as possible. Here are some of the workflow steps many photographers might follow in a program such as Lightroom.

1. Adds the photos to the library.

2. Selects all of the images and adds a copyright notice to each.

3. Selects all of the images and adds keywords.

4. Scrolls through the images and ranks them using stars, colors, or pick/reject flags.

5. Delete the rejects, then edits images to be used immediately and exports them in the desired format.

6. Shares or publishes the photos.

EVALUATING YOUR IMAGES—BASICS

TIP

Without you even being aware of it, your camera is making changes to your JPEG images that cannot be undone. These include such things as sharpness, white balance, and contrast. If you want to adjust these yourself, use the camera's RAW format if it has one.

When you open an image on the computer, you really get to see it for the first time. The display on the camera's monitor is so small, captured images are hard to evaluate. So what do you look for when deciding if the image you are looking at can be improved? In this section we'll try to get you started. As you learn to identify characteristics that can be improved, you'll also discover there is frequently more than one way to adjust them. Many people start with the automatic adjustments because they are so easy. However, it won't be long before you find yourself migrating to more powerful tools that take more practice, but which give results that make the extra effort worthwhile.

To properly evaluate images your system should be color managed, as we discuss later. At times you should also enlarge images to 100% (sometimes called 1:1 or Actual Size) or use a digital loupe to zoom in to examine details.

As you examine your images, here are some things to look for.

Animation

Click for a movie on adjusting tonal ranges.

EVALUATING IMAGE SIZE AND ORIENTATION

The initial size and orientation of an image is determined by what the camera captured. There are situations in which you may want to change these characteristics.

Animation

Click here for a PDF extension on pixels and read Part 5 on changing image sizes.

• **Resizing** can be done in two ways, by changing the number of pixels in the image, called its *pixel dimensions*, through a procedure called *resampling*. This process adds or removes pixels to make the image larger or smaller. You might want to do this to reduce the size of images you will be sending by e-mail or posting on the Web. You might also want to increase the size of the image when making large prints. However, increasing the number of pixels in an image doesn't always make the image better. In fact it usually has the opposite effect. You can also change the size of the image without changing the number of pixels it contains, called its *document size* by specifying the pixels per inch. You normally do this when making a print or exporting an image to another application.

Cropping (top) is one way to emphasize the key parts or make it fit a format, perhaps in a magazine layout.

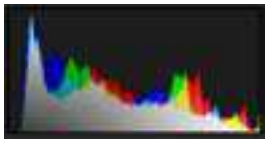
• **Cropping** removes distracting or unimportant parts of an image. You might also want to crop if the image has to fit into a specific design such as a newsletter or greeting card.

• **Rotating** an image may be necessary if you turned the camera vertically to capture a picture, or if the horizon line is tilted.

EVALUATING THE TONAL RANGE

Dynamic range in music is the range between the faintest and loudest sounds that can be reproduced without distortion. In photography the dynamic range, called the *tonal range* or *contrast*, indicates the range of brightness in an image between pure white and pure black. There are two ways to evaluate the tonal range of an image—visually and using a histogram (discussed in the next section). You should use both approaches because they are not mutually exclusive. Foe example, you can analyze an image visually and then learn why it's the way it is by checking its histogram.

Visually, images that use the full tonal range look rich and crisp, with vibrant colors and smooth transitions in tones. Those that don't use the full range lack contrast, often looking flat and dull. Details may be missing in highlight



One way to evaluate the tonal range is with a histogram that charts the various levels of brightness in the image.

and shadow areas or the image may be too dark or light. In these cases you may want to adjust or expand the image's tonal range.

EVALUATING COLORS

The human eye perceives color in terms of three characteristics—hue, saturation, and brightness and there is even a color model based on these characteristics, called HSB. The color monitor uses a different color model called RGB because images are displayed using varying amounts of red, green, and blue light. When evaluating images, you can think in terms of these two models—one to evaluate colors and the other to look for color casts.

To evaluate colors in an image, think of them in terms of hue, saturation, and brightness because these three aspects can be adjusted.

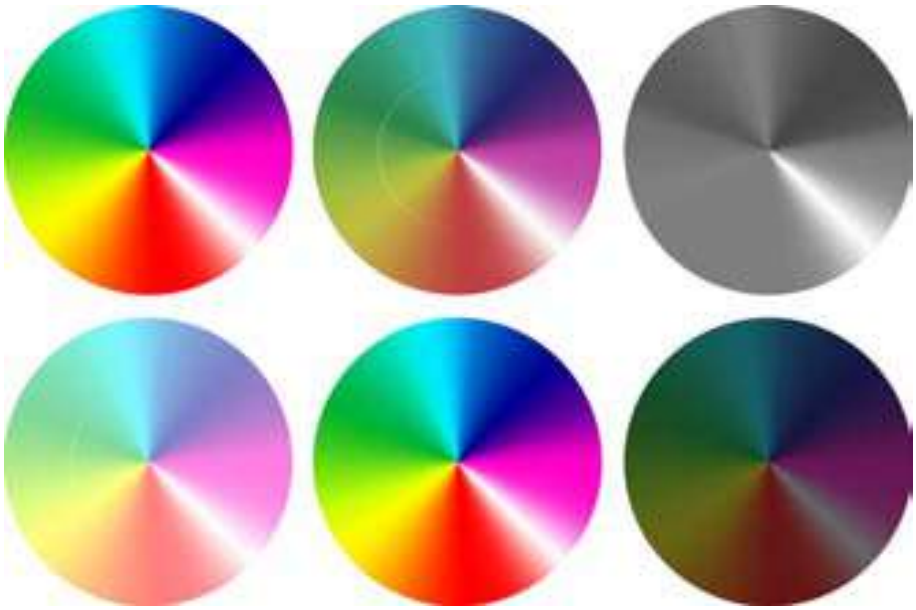
Hues can be arranged on a color circle or wheel.

• **Hue** is unique in one respect, it is the actual color, as measured by its wavelength, while the other two characteristics (saturation and lightness) modify the hue in some way. The hue can be red, orange, yellow, green, blue, purple, or any intermediate color between those pairs.

• **Saturation**, sometimes called *chroma*, is the strength or purity of the color. If you adjust saturation through its entire range, colors go from rich and vibrant to dark gray.

• **Lightness,** also called *luminance* or *brightness*, is the relative lightness or darkness of the color. Brightness is reduced by adding black to the color mix and increased by adding white. If you adjust brightness through its entire range, colors go from white to black. This is the only one of the three color attributes that gray scale images have.

As you decrease saturation (top), colors become muddier and finally gray. As you decrease lightness (bottom), colors become darker and eventually black.



Animation

Click for a movie on adjusting hue, saturation and brightness.

TIP

A neutral color has equal amounts of red, green, and blue and appears as a shade of gray.

A color cast is usually caused when one or more of the three color components (red, green, and blue) are too high or low over the entire image. This can be caused by not setting white balance correctly, by photographing a scene illuminated by more than one type of light source, or even a subject picking up reflections from a colored surface. Color casts are very noticeable when shooting during sunrises and sunsets—but there we usually like the effects. It's easiest to identify a color cast by looking at areas that should be neutral white or gray. If these areas have any colors mixed in, the image has a

As you point Lightroom's white balance selector tool at a pixel in an image, the pixel's color mix is displayed. If you click that pixel, it and all like it will become neutral.

color cast that you should remove. Pure white areas should have R, G, and B settings of 255. Gray areas should have R, G, and B settings that are equal, for example, 128, 128, and 128 for middle gray. Pure black areas should have R, G, and B settings of 0. Regardless of which neutral tone you are examining, if one or more of the RGB values is higher or lower than the others, these tones won't be neutral and will have a color cast.

EVALUATING DETAILS

When examining an image, look for small imperfections that can be retouched. The sensor may have dust that shows up on the image as dark spots. A portrait subject might have a small blemish that will be very noticeable when you enlarge the image. There may be reflections, or even telephone wires you want to remove. Small areas may benefit by being made a little lighter or darker than their surroundings. Portrait subjects may have red-eye caused by flash in a dark room.

EVALUATING SHARPNESS

The apparent sharpness of an image depends a great deal on how much contrast there is along edges and lines. If an image looks soft, it can often be improved by sharpening, a process (technically called *unsharp masking*) that adds contrast along lines and edges. Many photographers sharpen almost every image, ignoring this aspect only for images such as fog scenes that are deliberately soft.

Sharpening (right) increases the contrast between light and dark areas to make the edges appear sharper.

Animation

Click for a movie on sharpening an image.

Noise can significantly degrade smooth tones.

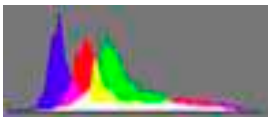
EVALUATING NOISE

If you used a long shutter speed or high ISO setting to take a photo, it may contain noise. Look in dark areas for randomly colored pixels that look like grain.

GLOBAL VS LOCAL EDITING

You may have noticed that some of the adjustments discussed in this section affect the entire image and others affect just specific areas. These are referred to as *global and local adjustments* and are discussed in sections that follow.

EVALUATING YOUR IMAGES—HISTOGRAMS

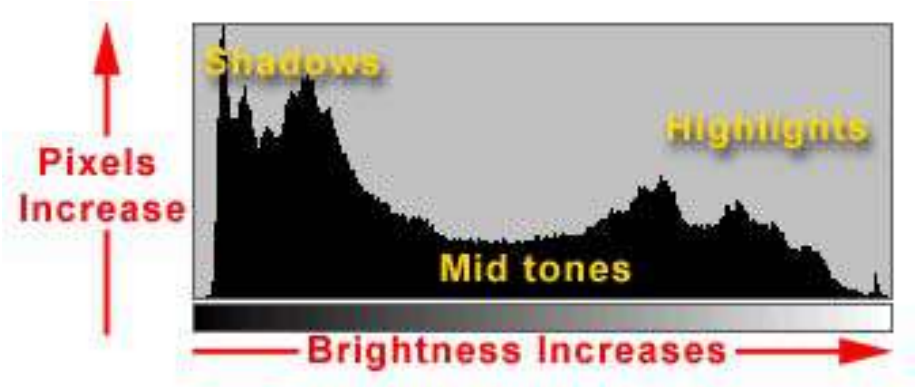


There are two kinds of histograms. Most cameras show one of the gray scale brightness levels. A few display an RGB histogram showing the brightness of each of the three colors, red, green, and blue.

Most serious photo-editing programs let you use a histogram as a guide when editing your images. However, since most image corrections can be diagnosed by looking at a histogram, it helps to look at it while still in a position to reshoot the image. It's for this reason that many cameras let you display histograms on the monitor in playback mode or while reviewing an image you have just taken. A few cameras even let you see a histogram as you are composing an image so you can use it as a guide when adjusting the camera settings you'll use to capture the picture.

EVALUATING HISTOGRAMS

As you've seen, each pixel in an image can be set to any of 256 levels of brightness from pure black (0) to pure white (255) and a histogram graphs which of those levels of brightness are in the image and how they are distributed. The horizontal axis of a histogram represents the range of brightness from 0 (shadows) on the left to 255 (highlights) on the right. Think of it as a line with 256 spaces on which to stack pixels of the same brightness. Since these are the only values that can be captured by the camera, the horizontal line also represents the image's maximum potential tonal range or contrast.



The vertical axis represents the number of pixels with each of the 256 brightness values. The higher the line coming up from the horizontal axis, the more pixels there are at that level of brightness.

To read the histogram, you look at the distribution of pixels. Here are some things to look for.

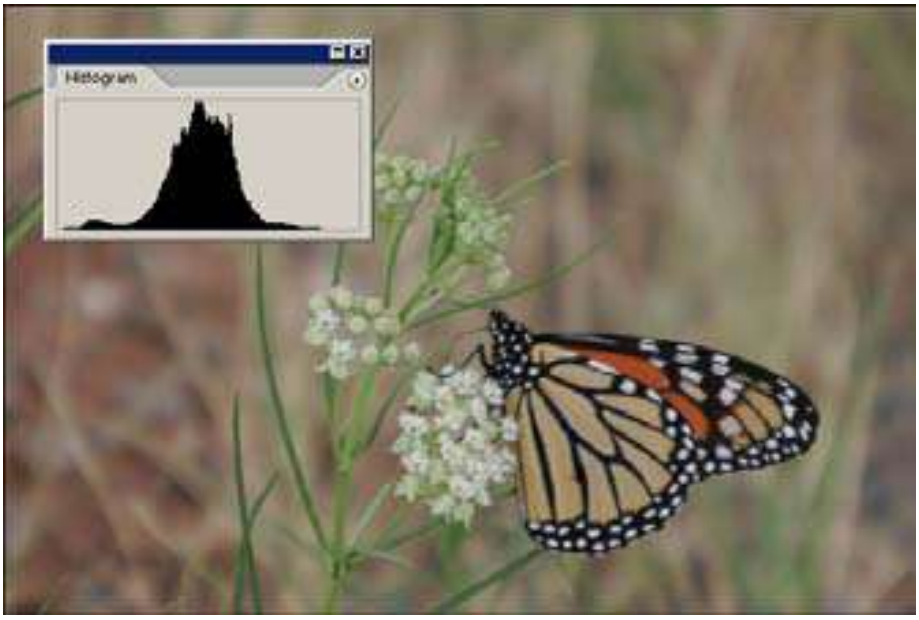
• Many photos look best when there are some pixels at every position because these images are using the entire tonal range.

• In many images, pixels are grouped together and occupy only a part of the available tonal range. These images lack contrast because the difference between the brightest and darkest areas isn't as great as it could be. However, this can be fixed in your photo-editing program by using commands that spread the pixels so they cover the entire available tonal range. These controls allow you to adjust the shadow, midtone, and highlight areas independently without affecting the other areas of the image. This lets you lighten or darken selected areas of your images without loosing detail. The only pixels that can't be fixed in this way are those that have been "clipped" to pure white or black.

When adjusting the histogram at the time you are taking photos, here are some things to keep in mind:

• If the histogram shows most pixels toward the left (darker) side of the graph, use exposure compensation (discussed in the next chapter) to add exposure.

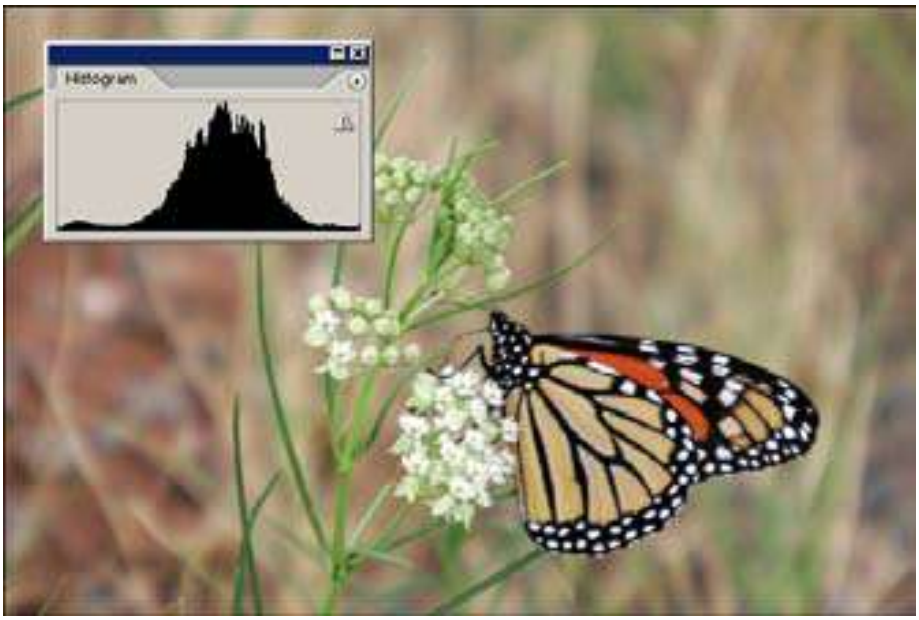
• If the histogram shows most pixels toward the right (lighter) side of the graph, use exposure compensation to reduce exposure.



The original image (top) is flat and its histogram indicates only part of the tonal range is being used. A photo-editing program was then used to expand the tonal range (bottom). You can see the change in both the image and in the histogram.

Animation

Click to explore histograms.



Animation

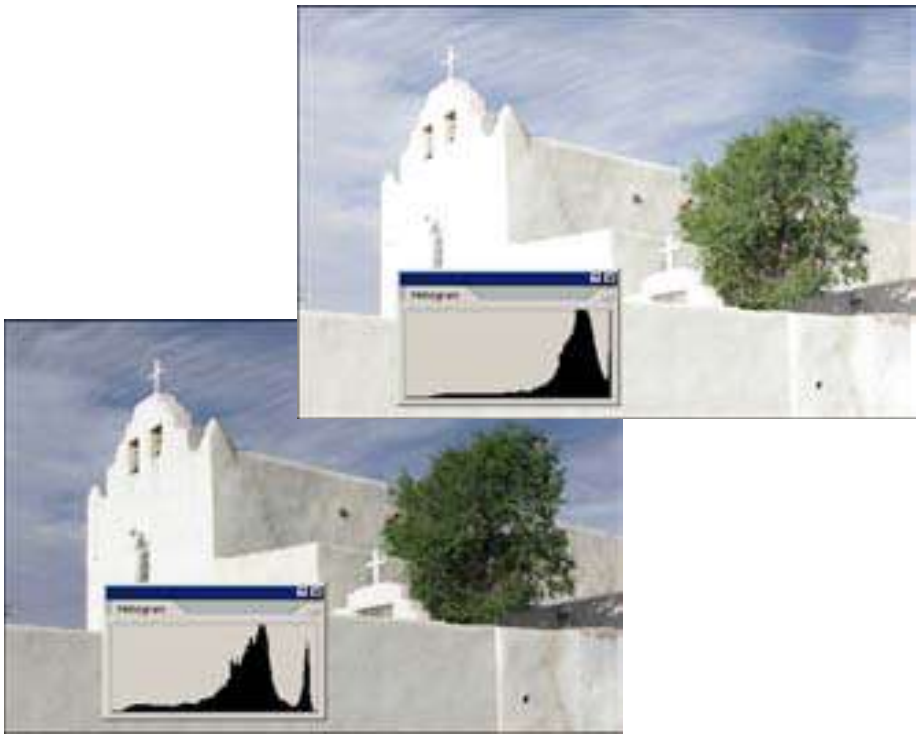
Click to explore how overexposed highlights blink.

HIGHLIGHT WARNING

One thing you want to avoid is overexposing highlights so they become so bright, or "clipped", they loose details. To help you avoid this many cameras display a highlight warning when you review or compose your images. Areas that are so overexposed they have no detail blink or are outlined in color.

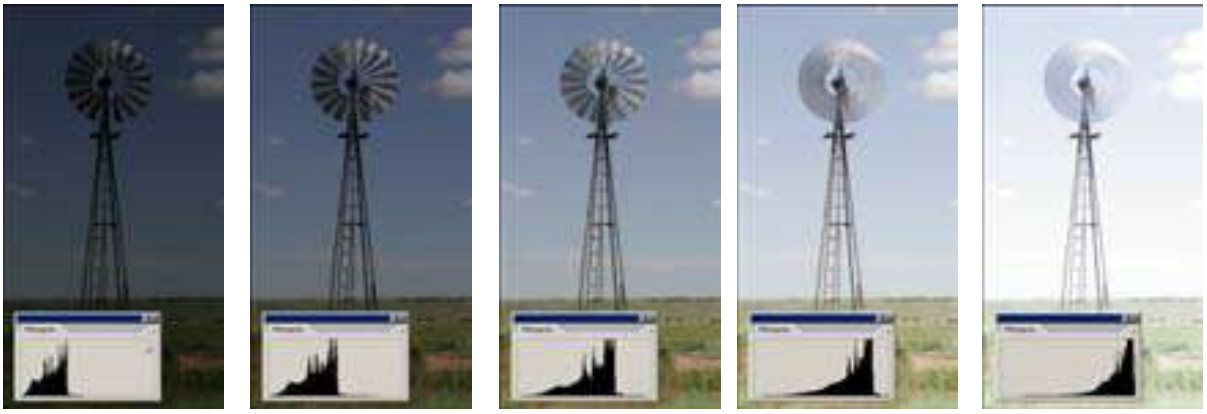
CLIPPED PIXELS

When a histogram shows pixels at the extreme ends of the range, in the 0 and 255 positions, it means details in those tones are lost or "clipped" in your image. These extremes should be reserved for specular highlights (reflections) and small dark shadows. When large areas lack detail an image suffers.



In the top image you can tell from the histogram that some of the highlight pixels are pure white and hence clipped. There is nothing you can do later to display details in the area of these pixels. However, if you reshoot the scene at a different exposure you can shift the pixels to the left and avoid the clipping (bottom).

To avoid clipping and better place the tonal values in subsequent shots, you use exposure compensation. Increasing exposure shifts pixels to the highlight, or right end of the histogram. Decreasing exposure shifts them the other way. Unless you are deliberately trying to get pure whites or pure blacks, you should shift the pixels if any are being clipped. This then gives you a chance to correct the image in your photo-editing program.



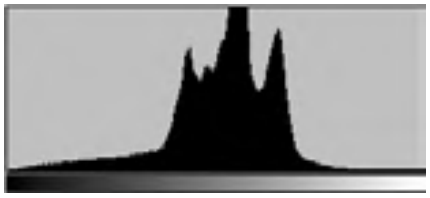
This series of photos was taken one stop apart using exposure compensation. As the exposure increased, pixels on the histogram shifted right. You can tell from the way the fan blades blur that the shutter speed was changed to change the exposure. In the image where it was faster, the image is darker and the blades are frozen. As slower speeds were used to increase the exposure, the images get lighter and the blades more blurred.

SAMPLE HISTOGRAMS

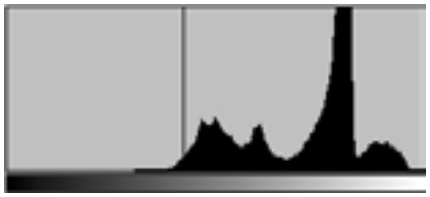
The way a histogram looks depends on the scene you're shooting and how you expose it. There's no such thing as a good or bad histogram other than one that shows unwanted clipping. Whether a particular histogram is good or bad depends on what you are trying to accomplish. If fact, you may prefer to trust your visual reaction to the image more than the very numeric image data provided by a histogram. However, even if you never use a histogram, you can learn about digital photography by understanding what a histogram can show about an image. Following are some histograms from good images along with a brief summary of what each histogram reveals.

In this well exposed portrait there is a fairly even distribution of values in both the shadow and highlight areas of the image. There are no pure blacks in the image as shown by the gap at the far left end of the scale.

This brown moth on a gray card has most of its values in the midrange. That's why there are a number of high vertical lines grouped in the middle of the horizontal axis.



This high-key fog scene has most of its values toward the highlight end of the scale. There are no really dark values in the image. The image uses only a little more than half the camera's dynamic range.



The distinct vertical line to the left of middle gray shows how many pixels there are in the uniformly gray frame border added in a photo-editing program.

This low-key scene has the majority of its values in the shadow area with another large grouping around middle gray. There are wide levels of brightness that have only a few pixels.

PHOTO-EDITING—GLOBAL EDITING

The Lightroom History Panel in the Develop module.

In 1932 a group of young photographers including Ansel Adams and Edward Weston started a group they called f/64 that championed straight photography over the heavily manipulated pictorial photographs so in vogue at the time. The movement grew and when Edward Steiglitz published the work of another straight photographer, Paul Strand, in his magazine Camera Work he wrote "*... The work is brutally direct. Devoid of flim-flam; devoid of trickery and any 'ism'; devoid of any attempt to mystify an ignorant public, including the photographers themselves. These photographs are the direct expression of today...*" This movement became known as "straight photography" and there are still echoes of the arguments it generated. The pictorialists of today are those who use Photoshop to heavily manipulate their images so they fall out of the field of photography and into the realm of the graphic arts. There is an entire industry of these people offering newsletters, Web sites, workshops, conventions, videos, books, and magazines, all devoted to proselytizing obscure techniques. For many of these gurus an image's content is less important than its manipulation and they spend so much time on manipulating the images they already have that they almost stop taking new ones. It's helpful to understand these arguments because Apple's Aperture and Adobe's Lightroom are really tools for straight photography and straight photographers and it helps you to put them in a historic context.

Click for a movie on improving a photo.

Straight photography doesn't mean you don't try to improve an image, in fact it's the rare image direct from a digital camera that doesn't need some tweaking. However Photoshop has become so complex, and has so many graphic arts features, that there was an opening for a program that was both simpler and more photographic in philosophy. Serious amateurs needed one that was more intuitive and easier to learn. Professionals needed one that would allow them to work faster and more efficiently—especially when dealing with a large number of images. Thus were born Aperture and Lightroom, programs that emphasize global procedures that affect the entire image.

Click for a movie on changing a photo into something quite different.

THE GOOD OLD DAYS?

In the days of film, control over prints in the darkroom was limited. You could control contrast by your choice of paper and with filters. You could make local changes by dodging to lighten areas or burning to darken them. When making color prints you could adjust color balance using filters. Before getting too carried away with the things you can now do, keep in mind that almost all of the greatest photos in the history of photography were made with these few adjustments.

One interesting aspect of Lightroom and Aperture is that any changes you make don't alter the original pixels in your image so you can undo any edit at any time. This *non-destructive editing* is accomplished by storing a list of your edits in the database along with the image itself. When you open the image in Lightroom, it uses that stored list to reapply the edits so they are used when you display, print, or export the image. In essence these programs treat your images as digital negatives or masters and preserves them as such. If you ever want to return the image to its original form, you just click the *Zero'd* choice on Lightroom's Presets panel.

Lightroom and Aperture are designed to make working with RAW images as easy as working with JPEGs. You can display, zoom, adjust, add keywords, print, and create Web page layouts using both formats without intermediate format conversions. Both programs also let you work in the same way with other image formats including TIFF and Photoshop's native PSD.

THE ANATOMY OF LIGHTROOM

When you first start Lightroom, you'll notice it's divided into sections.

1. **The menu** at the top of the screen offers access to commands. The commands change as you change modules.

2. **The module picker** in the top right of the screen is where you select *Library* so you can import, organize and select photos for editing, *Develop* so

you can perform image adjustments, *Slideshow* so you can create slideshows for on-screen viewing and exporting as PDF files, *Print* so you can set up your printouts, and *Web* so you can create Flash or HTML web galleries. On the left side of the screen is an identity plate and progress monitor.

3. **The grid view or image display area** in the center of the screen is where selected images are displayed in all modules.

4. **Panels** to the left and right of the image area contain tools, layouts, and information you use when working with images. The available panels change as you change modules so you always have access to just those tools you need for the immediate task. In most situations panels on the left contain content and preset browsers, while panels on the right contain the tools you need for the current task. Clicking a panel's header collapses and expands it.

5. **The toolbar** has buttons you can click and these perform different functions in different modules. You can display and hide this toolbar by pressing T. In the Library and Develop modules clicking the drop-down arrow on the right end of the toolbar lets you specify which buttons are displayed.

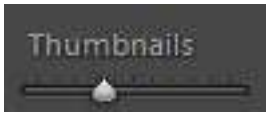
6. **The filmstrip** at the bottom of the screen shows the photos in the select folder, a collection, a quick collection, or a keyword set and they remain displayed when you change modules. Unless photos are in the filmstrip, they cannot be accessed from the other modules. The only way to change which images are displayed is to return to the Library.

THE LIBRARY MODULE

The first time you use Lightroom, you open the Library and import photos from drives on your system or directly from a camera or memory card. You have the choice of leaving the original images where they are (as you might when importing from folders on your system) or moving them into a folder you specify.

TIP

One of the best things about Aperture and Lightroom is the way they retain your workspace when you end a session. There is no need to save your work. It's all saved automatically and the next time you start the application everything is the same way it was when you quit. If you were editing 100 photos for a book, they are all right there. There is no need to open each of the images before you get started.



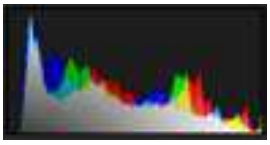
In grid view dragging the thumbnail slider adjusts the size of the images.

In survey view Ctrl-clicking images displays them for comparison.

Icons you click to change the content area to grid, loupe, compare or survey views.

Modules in the left (top) and right (bottom) panels.

The metadata browser.



The histogram is a good way to locate the white and black points.

Buttons in the navigator panel let you specify the size of the image you are editing.

The red eye and remove spots tools are the only local editing tools in Lightroom. All other tools are for global editing.

• **The grid view or image display area** has four modes between which you switch by clicking buttons on the toolbar (below): *grid* for thumbnails, *loupe* for full screen or zoomed display of an image, *compare* with two images side by side, and *survey* to compare one image against any number of others. In grid view thumbnails can be set to various sizes from extra small to extra large. To compare two or more images more closely you can Ctrl-click them to display them in the Grid.

• **The toolbar** in the library module has buttons that change the view in the contents area, stars to rank photos, pick and reject flags, and rotate buttons.

• **Filmstrip buttons** above the thumbnails change the view in the content area, navigate through images, and turn filters for stars, flags and colors on and off. Photos that don't meet the criteria are filtered out and not displayed.

• **Navigator** panel lets you scroll around zoomed images.

• **Library** panel lets you specify if all photos are listed or just those in the quick collection or previous import.

• **Find** panel searches for photos using the text and date range you specify.

• **Folders** panel is where imported photos are listed. Each photo can be in only one shoot.

• **Collections** panel lets you gather together related photos for a project.

• **Keyword Tags** panel is where you click keywords you have assigned to images so just those images are displayed.

• **Metadata Browser** panel lets you quickly locate images with matching metadata such as the camera used.

• **Histogram** panel shows the distribution of tones in the selected image and a few of the camera settings used to capture it. You can adjust the displayed tonal range with sliders or by dragging the histogram itself.

• **Quick Develop** panel lets you make adjustments to your images. The choices are described in the section on "The Develop Module."

• **Keywording** panel lets you add keywords to selected photos.

• **Metadata** panel lists Exif and IPTC metadata for the selected image and lets you enter additional IPTC metadata.

THE DEVELOP MODULE

For a complete discussion of all Lightroom features, you need a book devoted to the program. However, here are the procedures listed in Lightroom's *Basic* editing section—the ones almost every photographer thinks about for almost every image.

• **Navigator** panel lets you specify the size of the image and scroll around images larger than the screen display.

• **Presets** panel lists stored settings you can apply to images. You can create and save your own presets and they are added to the list.

The Lightroom Basic Panel in the Develop module.

Presets, either those that come with the program or those you create and save yourself can be applied to all selected images with a click of the mouse.

Lightroom's white balance selector tool shows the colors of the pixels that it points to.

TIP

While dragging the *Exposure* and *Blacks* sliders to adjust the tonal range, you can see the levels where black or white details begin to emerge in the image if you Alt+drag the sliders.

• **Snapshots** panel lets you name and save a photo at any point in the editing process so you can return to that version just by clicking its name.

• **History** panel lists changes you made to images so you can undo them.

• **Histogram** panel shows the distribution of tones in the image.

• **Basic** panel contains sliders you use to adjust the colors and other characteristics of your images. (This section is discussed in more detail shortly.)

• **Tone Curve** panel lets you adjust the tones in the image: highlights, lights, darks, and shadows.

• **HSL/ Color /Grayscale** panel adjusts hue, saturation and luminance; colors, and the grayscale mix.

• **Split Toning** lets you set adjust hue and saturation independently in highlights and shadows.

• **Detail** has controls to sharpen, smooth and de-noise an image.

• **Lens Correction** reduces fringe effects and controls vignetting.

• **Camera Calibration** lets you calibrate your own cameras if you find that Lightroom's generic profile doesn't meet your needs.

DEVELOPING IMAGES

Most of the changes you make to an image will be done using the Basic section in the Develop module so it's worth a closer look. Here are what each of the controls does.

• **Color/Grayscale** converts the selected photos to grayscale and back to color.

• **White balance selector tool** (the eyedropper icon) lets you click a neutral pixel in the photo to remove color tints throughout an image. As you move it about the image it enlarges the pixels under and around it and displays the center pixel's RGB values so you can find a neutral pixel to click.

• **White balance**, **temp** and **tint** can be adjusted so that white or neutral gray areas don't have a color tint. *Temp* adjusts the color from blue to yellow, while *Tint* adjusts from green to magenta. The *WB* drop-down menu lets you select from a standard selection of white balance presets. The default is *As Shot*.

• **Tone's** *Auto* button sets the sliders to maximize the image's tonal scale and minimize highlight and shadow clipping.

• **Exposure** adjusts the tonal range or contrast of the image by changing the *white point* to brighten or darken an image. *The white point* is where tones become pure white with no detail (255). As you adjust, watch the histogram.

• **Recovery** lets you restore clipped highlights without darkening the rest of an image.

• **Fill light** lightens shadow areas without lightening other areas.

• **Blacks** adjusts the tonal range by changing the *black point* to brighten or darken an image. *The black point* is where tones become pure black with no detail (0). As you adjust, watch the histogram.

• **Brightness** adjusts the *midtones* (sometimes called *gamma*) to lighten or darken the overall image without affecting the black and white tones and the details they contain. By default, the Brightness slider has a value of +50.

Web gallery templates are listed by name and when you point to one a preview is displayed in the Preview panel.

• **Contrast** adjusts the white and black points simultaneously to increase contrast in the image.

• **Vibrance** adjusts the saturation of primary colors while leaving skin tones and other secondary shades unaffected. This allows you to boost saturation without unrealistic hue shifts.

• **Saturation** adjusts the saturation of all colors in the image.

OTHER MODULES

In addition to the Library and Develop modules discussed above, Lightroom also has modules devoted to outputting your images in various formats.

• **Slideshow** lets you create slideshows to display on the screen, or export as PDFs.

• **Print** lets you layout and print selected images.

• **Web** lets you create HTML or Flash galleries using templates supplied with Lightroom.

EXPORTING

When working on images in Lightroom, your changes do not permanently affect the image. However, the changes are made permanent on versions of the image that you export. At the time you export images, here are just some of the choices you can specify:

• **Color Space** attaches an sRGB, Adobe RGB or ProPhoto RGB color space to the image. (Color spaces are discussed later in this chapter in the section on color management.)

• **Constrain Maximum Size** lets you resize and image by specifying that the width or height is not to exceed a specified number of pixels.

• **Format** lets you specify what format the image is saved in—JPEG, PSD, TIFF or DNG.

• **Post Processing** lets you see an exported image in Explorer or Finder, burn selected images to a CD/DVD, or go to an export action folder.

AUTOMATION

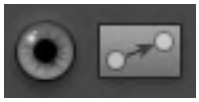
When it comes to efficiency there is nothing like automation to save you time. Lightroom lets you select a group of images and add keywords and perform other tasks. You can also make edits to one image and apply the same changes to other images in two ways.

Sync buttons lets you copy edits or metadata from one image to many images.

• **Sync** lets you select an image you have edited, then select others. When you then click the *Sync Settings* or *Sync Metadata* button the edits or metadata in the first image are copied to the others.

• **Presets** are stored settings that are added to a Presets menu. You can select other images and click the preset on the menu and the stored settings are applied.

PHOTO-EDITING—LOCAL EDITING



The red eye and remove spots tools are the only local editing tools in Lightroom. All other tools are for global editing.

Local editing lets you change selected areas of the image. The latest programs such as Aperture and Lightroom focus on global changes so to make most local changes you have to export a photo to Photoshop or similar program. When you export an image you can specify what format it will be in. For example, when exporting an image to Photoshop, you would probably export it in Photoshop's native format, PSD. It is then this PSD file that you edit and when finished, reimport into Lightroom.

When using a program such as Photoshop here are some of the things you can do to an image that you can't do in Aperture or Lightroom.

• **Selecting**. If you first select an area of the image, you can edit just that area without affecting other areas. You can also copy, move, or delete selected areas, perhaps to create a collage or remove a background.

Click for a movie on changing perspective in a photo.

• **Compositing**. You can cut out a selected part of one photo and paste it into another to create a composite image.

• **Healing and cloning**. Many images have small imperfections such as a small blemish on a portrait, reflections, or even telephone wires you want to remove. Small areas may benefit by being made a little lighter or darker than their surroundings. Portrait subjects may have red-eye caused by flash in a dark room. The Healing Brush works by blending the area you sample seamlessly into the background so the texture, lighting, transparency, and shading aren't changed. You can either paint with pixels sampled from the image or select a pattern to paint with. In Lightroom the Remove Spots tool lets you repair a selected area of a photo with a sample from another area. Clone copies the sampled area of the photo to the selected area. Heal copies just the texture, lighting, and shading of the sampled area to the selected area.

Photoshop's toolbox contains many of the tools used to make local adjustments. These include healing, dodging, burning, cloning, and painting tools.

• **Dodging and burning** to lighten or darken areas of a print have been the most popular darkroom techniques since the first prints were made from negatives. Dodging was done using a piece of cardboard or other tool to block light from certain areas of the image to make them lighter. Burning was done with a piece of cardboard with a hole cut in it that let light through to darken selected areas. In Photoshop you do the same thing by dragging a brush over the area of the image you want to adjust.

• **Adding text** to images is usually the realm of graphic designers, more so than photographers. However, you should be able to so to create title slides for your slide shows, add copyright notices to your images, or just invent ways to combine text and images in creative ways.

• **Layers**. When you first open a digital photo, it has only one layer—the background layer containing the image. Any changes you make to this layer become part of the image and permanently change its pixels. To avoid permanent changes, you add additional layers and make your changes on those layers. It's as if you were covering an original photo with sheets of glass on which you drew, painted, made adjustments to the image below, entered text, or added fills.

• **Blending modes** determine how a color you apply with a tool interacts with the colors you paint over or how the colors on one layer interact with colors on the layers below.

• **Transformations** let you scale, rotate, skew, distort and add perspective to selections.

• **Effects** let you add drop shadows to text, bevel the edges of an image, or add a frame. You can also combine effects, using first one and then another. For example, you may soften a portrait to make it look more romantic, vignette it, and then add a frame around it.

• **Masking** confines adjustments to selected area of an image. Unlike a selection, a mask is a grayscale image just as your images are. This means you can edit one just like you edit images; using brushes, erasers, fills, filters, and almost every other tool and technique you have learned. Having all of these tools at your disposal means you can create more complex selections than you can with just selection tools. Because masks make precise selections possible, they lie at the heart of compositing—the creation of a new image by piecing together parts of other images. You can either cut and paste selected areas or make some areas transparent so layers below show through. Once you master a few basic tools, the possibilities are endless.

• **Animated GIFS** can be created by layering images on top of each other. When then saved as an animated GIF and posted on a Web site, the images play back like frames in a movie.

• **Stitching panoramas** from a series of side by side images lets you create seamless panoramas that capture a broad sweep of the landscape.

The background of the monster has been selected and removed (top), a new photo opened (middle) and then the monster copied in (right) to create a composite image.

The background of the original image (left) has been selected and removed (right).

COLOR MANAGEMENT—COLOR MODELS AND COLOR SPACES

Animation

Click to explore how sRGB and Adobe RGB color spaces compare when it comes to the number of colors they can capture.

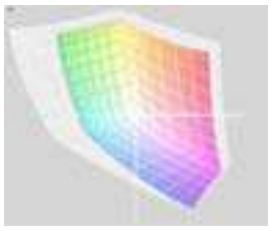
Animation

Click to explore how red, green and blue can create full color images.

Animation

Click to explore how cyan, magenta and yellow can also create full color images.

If you align the letters CMY under RGB, you have a guick guide to how CMY works. Cyan creates red (directly above it) by absorbing the other two colors, green and blue; Magenta creates green by absorbing red and blue; and yellow creates blue by absorbing red and green.



Here is the sRGB color space superimposed over the larger Adobe RGB color space (shown here ghosted). You can see how much smaller its gamut is.

As you've seen, the image sensor in a digital camera captures just red, green and blue (RGB) light. RGB is what we call a *color model* and it's based on the way the human eye perceives full-color images by blending various proportions of red, green and blue light. The RGB model used in display devices creates an image with transmitted red, green, and blue light; and the CMY model used in printers creates it with cyan, magenta, and yellow inks that absorb colors so only red, green and blue are reflected.

COLOR MODELS

Color models are fairly basic in that all they tell you is what amount of each color needs to be blended to create a third color.

• RGB specifies the amount of each color in units between 0–255.

• CMY specifies the amount of each color as a percentage between 0–100%.

For example, if you start with pure red its RGB values would be R:255 G:0 B:0 indicating that the color's red component is 256 (remember, we count from 0, not 1) and both green and blue components are zero. This sounds like a detailed description of a color but it isn't because it doesn't refer to a specific color as you would perceive it, it just tells a device such as a display screen or printer to generate all of the red it's capable of. (One expert calls these RGB values "input signals".) The most fully saturated red could be bright and vibrant on one device and dull and muddy on another. It's as if a driver's manual told you that to reach a specified speed you press the accelerator down 1 inch. However, if you follow this instruction in a Ford, you might go 35 miles per hour, while following it on a Ferrari would have you going 135 miles per hour. In digital photography what's needed is a way to make the values refer to a very specific color and that's where color spaces come in.

COLOR SPACES

A *color space* plots each of the millions of possible colors on a three-dimensional chart in such a way that their positions and spacing show how they relate to one another—often called *scaling*. Each color can be specified or located by its coordinates in this space.

One of the key features of a color space is its *gamut*—the range of colors it represents. Different color spaces have different gamuts as do different devices. It's not at all uncommon to have a color in an image that is within the gamut of the display but not of the printer and vice versa. When a color falls outside of a color space's gamut in this way, it can't be reproduced by the device and is called *out-of gamut*. In the next section you'll see how a color management system can bring such colors back into the gamut of a device. One thing to keep in mind is that a wider gamut doesn't mean more colors. The only way to do that is to capture images in the RAW format rather than JPEG. A wider gamut just spreads out the available colors.

In digital photography you will find references to a variety of *RGB color spaces*. Here are the most common:

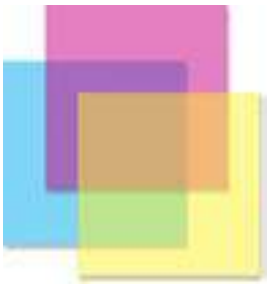
• **sRGB** has the smallest gamut of the spaces discussed here, but is ideal for images that will be displayed on a screen or projected. Almost all cameras assign this as the default space for JPEG images. Almost all browsers and display devices are set to display this color space most accurately.

TIPS

• In color management, the term "space" is so widely used that it's lost any specific meaning other than the distribution of RGB or CMYK colors into a three dimensional chart that shows their relationships.

• The CMY color model is more often called CMYK with the "K" standing for black. Black is needed because although mixing CMY at 100% should create black, it's a muddy black.

sRGB's gamut plotted against the larger CIE LAB.



CMYK uses cyan, magenta, yellow (and black) to form all other colors.

• **Adobe RGB** has a wider gamut than sRGB and is often used when the goal is making high-quality prints. One drawback is that images using this color have subdued colors when displayed on a display because almost all displays are based on the sRGB color space. However, if you use this space, Photoshop, Lightroom and other products can convert it to sRGB without any loss in quality.

• **ProPhoto** is the largest color space currently used in digital photography and the only one that has a gamut that includes all of the colors a camera can capture. This color space can cause problems when used with 8 bit JPEG images. There are so many fewer levels of tones (256 versus a RAW image's 65,536) that if you make any large adjustments to the image you may get *banding,* noticeable transitions in what should be smooth gradations.

• **CIE LAB** (pronounced "see-lab"), and its very closely related CIE XYZ, are different but important kinds of color spaces although you don't interact with them directly. Unlike the other color spaces CIE LAB arranges colors based on how we perceive them rather than on any particular device. For this reason this color space is called "*device-independent*" (although if there were a device, it would be the human eye). The space contains almost all of the colors a human can perceive. (Interestingly, the actual CIE LAB color model can't be accurately printed or displayed because no device has all of the required colors.) In the section that follows on color management you'll see how this color space plays an important role in moving images from the camera to the screen and then to the printer while keeping colors constant on all of these different devices.

• **Working space**. When editing an image, the editing application lets you select a *working space* so the colors are what you expect to see when you display or print the image. The working space can be sRGB, Adobe RGB, ProPhoto RGB or any other space supported by the application.

Although a color space is initially embedded in a JPEG image by the camera that captured it there are two ways to change the color space.

• **Attaching a new color space** changes the look and colors of the image without changing the color values of each pixel.

• **Converting to another color space** keeps the image looking the same, but converts the color values of each pixel to fit into the new color space.

When using Photoshop you can assign different profiles and watch the image change appearance as you do so. This is a good way to find the space that works best for a particular image. The widest possible gamut isn't always the best choice. A smaller gamut such as sRGB has smaller spaces between the colors so smooth gradations, such as those found in skin tones, are reproduced more faithfully. However, if the center of interest in the image is a fluorescent orange traffic cone, most of its colors might be outside of the sRGB's gamut so ProPhoto would be a better choice.

COLOR MANAGEMENT—THE WORKFLOW

One thing that's often overlooked is a consistent viewing area. Color experts recommend a neutral colored room with diffuse fluorescent lighting with complete spectrum tubes and ideally egg-crate lighting diffusers. If you don't have the money for a new room, a color viewing booth is a less expensive alternative. Courtesy of Just-Normlicht.

If you don't do anything about controlling color, it's amazing how good your results are with most camera, screen and printer combinations. If nothing else, the colors are pleasing if not accurate—mainly because so many cameras and other devices have been designed to display and print sRGB images. In fact, other than skin tones, color accuracy is rarely important to most people. If the yellow flower in the scene is yellow on the screen or in the print, that's good enough—who cares, or can even tell, that it's not the exact same yellow as the subject's. However, photography is a visual art and when you start using RAW image formats and other color spaces, you soon notice things about colors that you never noticed before, and for many people accurate colors become more important.

As you prepare your images to be displayed and printed, you move them through the workflow. As you do so, colors rarely remain predictable and consistent. The image on the display differs from the original scene, and the printout differs from both. When you then share images with friends, they look different on their screens or printouts than they do on yours. To see this for yourself, visit an electronics super store and look at the walls of TV sets, all with slightly different colors. If you post your images on the Web, they will vary just as widely when displayed on other systems.

Color management systems (CMS) are designed to help you keep the colors in your images as consistent and predictable as possible as they pass through the various stages of the workflow. Although you can't control other people's display devices (or even many of your own, such as the TV or digital frame) you can ensure that your image colors are as close to perfect as they can be. To accomplish this, a color management system adjusts colors between devices that have different gamuts so the colors remain consistent. For example, a scene will have one gamut, an image of it another, the display and printer still others. As your interest in this area grows, you'll find that color management systems are a great deal easier to use than they are to understand or pay for. There are only two steps, creating profiles of your devices and using those profiles to display or print images.

TIPS

- Profiles have their limits since there are many devices such as TVs, cell phones, and digital picture frames that don't recognize them. The same is true of applications such as Web browsers.
- Printers at most commercial labs, including those that make prints for most photo-sharing Web sites shine light on traditional silver-based photographic paper to create prints. These work best with sRGB images.
- Inkjet printers and printing presses create images with ink so work best with wider gamut color spaces such as Adobe RGB and ProPhoto.

GETTING READY TO COLOR MANAGE—CREATING PROFILES

The first step in color management is to measure how much your devices vary from a known standard. The differences are measured and stored in text files, called *profiles*, with the extension .ICC or .ICM. The color management system uses the information stored in these profiles to determine what color adjustments are required to make the colors in an image display or print as accurately as possible. There are various kinds of device profiles:

- **Image profiles** have been developed for sRGB and other color spaces. These profiles define the colors in an image in a generic fashion and are embedded in the image at the time it's captured. In some cases these profiles (rather than input profiles discussed below) are used by color management systems.
- **Input profiles** for specific digital cameras are fraught with complications because the camera heavily manipulates JPEG images and RAW converters do the same to RAW images. Unless you are photographing under a very controlled studio situation it's better to use the profile for the image's color space, rather than a profile for the camera.

> **TIP**
>
> Profiles are not permanent. They need to be redone periodically because hardware colors drift as a device ages. They also need to be redone if any settings or parts are changed.

• **Display profiles** for CRT and LCD flat panel displays. To profile a display, you attach a color measuring device called a *spectrophotometer or colorimeter* to the display screen. Profiling software then flashes a number of known colors on the display while the device reads each colors' values. The differences between the known and measured results are stored in the display's profile. Some color management systems let you create a display profile visually without using an expensive color measuring device. This software walks you through adjusting brightness, contrast, and color balance as you create the profile step by step. Although not as accurate as a profile done with an instrument, it's better than nothing.

• **Output profiles** for devices such as printers and projectors. To profile a printer, you open an image of a color chart with known color values and print it out. You then use a *spectrophotometer* to read each color patch in the printout. Profiling software compares the known and printed values for each patch and stores the differences in the device's profile.

When you buy a printer, it often comes with a number of profiles created by the manufacturer for various papers. Since these profiles are generic, the ones you create for your specific printer will be more accurate but you have to create a profile for every ink/paper combination you use. Although inconvenient, you have to do this to get the best possible results on your specific printer and whenever you use paper or ink from a third-party.

Sony's Artisan Color Reference System has integrated profiling hardware and software.

To simplify the use of profiles, the International Color Consortium (ICC) has defined a widely accepted format for them so they can all work together. This makes it possible to move images with *embedded ICC profiles* (called *tagged images*) between different applications, hardware, and even operating systems while retaining color fidelity. If an ICC profile isn't assigned to an image, you can use an application such as Photoshop to assign one.

One interesting use of profiles is in a process called *soft proofing*. The purpose of this proofing is to show on the screen what your image will look like when printed on a specific type of paper. When you soft proof, the program uses the printer's profile, normally used as an output profile, as the input profile. When paired with the display's output profile, you get a close approximation on the display of what the printed image will look like.

ColorVision's PrintFix has a target that you open on your computer and print out. You then scan the printout and the printed colors are compared to the known colors in the target. The differences are stored in the new printer profile.

COLOR MANAGING—USING PROFILES

When you are ready to pass an image between two devices, you need both an input and output profile. A single profile describes a device but doesn't affect it. The various profiles that can be paired up include the following:

• **The image or input profile** is embedded in the image by the camera, or you can embed one using a photo-editing application. Many photo-editing applications also let you select a working space profile, which is then paired with the display profile.

• **The display profile** can be changed using an operating system dialog box.

• **The output profile,** often specific to a paper, is specified at the time you print using your photo-editing application's print dialog box.

Once you have specified a pair of profiles, the color management system works as follows:

1. It looks up each color value in the image in the input profile and adjusts it as specified in that profile.

2. It looks up the adjusted color in a *Color Matching Method* (CMM) that

A color management system uses an input profile, a profile correction space and an output profile to adjust colors as they are moved from one device to another.

includes a device independent color space such as CIE LAB, called a *profile connection space*. This gives it a device independent color value to use in the next step.

3. It looks up the device independent CIE LAB color value in the output profile and uses the adjustment found there to determine what color value to send to the output device.

This three-step process, called *rendering*, converts the color values found in the source image into the color values needed to obtain accurate colors in the output. As this process takes place, there may be colors that one device can reproduce that the other device can't because they are out-of-gamut. When this happens the input color value is changed to a color that is in gamut on the output device. The rules that govern this adjustment when using ICC profiles are known as *rendering intents* and there are four of them to choose from.

• **Perceptual** is the most commonly used intent in digital photography and is based on the fact that relative color values are more important to a viewer than absolute values. This intent adjusts the entire gamut of the image so it fits the gamut of the destination device. Even colors that were in-gamut are adjusted so the relationships between colors remain the same and the overall look of the image is preserved.

• **Colorimetric** comes in two versions, relative and absolute (the difference is based on whether the *white point* is adjusted or not). In digital photography the relative version is sometimes used and the white point of the source color space is changed to the paper white of the output device so whites in the original image remain white in the output. This intent to retain a near exact relationship between in gamut colors, even if this clips out of gamut colors. In contrast, perceptual rendering tries to also preserve some relationship between out of gamut colors, even if this results in inaccuracies for in gamut colors. If you use the colorimetric rendering intent when converting to a smaller color space you may see banding, posterization and other artifacts into the image.

• **Saturation** is designed to produce saturated colors without trying to be accurate. This intent is never used in digital photography but is best when printing or displaying pie charts and other solid colors found in business graphics.

PROFILES IN PHOTOSHOP

When an image is opened in Photoshop, if its profile doesn't match the working space you are often given choices. They include:

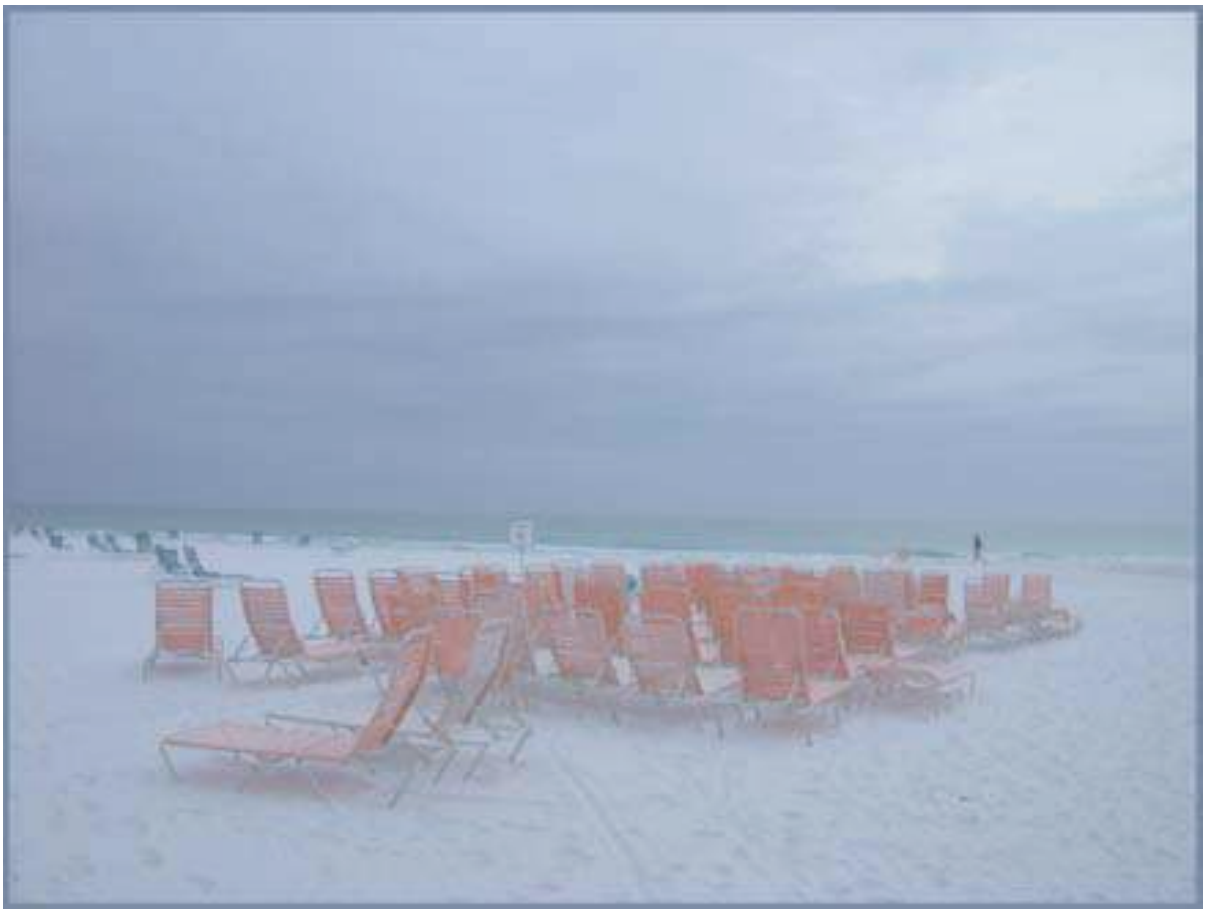
• Use the embedded profile (instead of the working space).

• Convert to the working space.

• Discard the embedded profile and don't color manage.

Instead of choosing a profile blindly, you can select the last choice to discard the embedded profile. When the image opens, you can then use the *Edit > Assign Profile* command to assign other profiles to it to see which has the best effect on the colors. When you then save the file you can embed the new profile.

Chapter 3
Controlling Exposure



Longue chairs on a Florida beach, illuminated by the soft light of dawn.

Automatic exposure control is one of the most useful features of a digital camera. It's great to have the camera automatically deal with the exposure while you concentrate on the image. This is especially helpful when photographing action scenes where there isn't time to evaluate the situation and then set the controls manually.

You shouldn't, however, always leave the exposure to the automatic system. At times the lighting can fool any automatic exposure system into producing an underexposed (too dark) or overexposed (too light) image. Although you can make adjustments to a poorly exposed image in a photo-editing program, you've almost certainly lost image information in the shadows or highlights that can't be recovered. You will find it better in some situations to override the automatic exposure system at the time you take the picture.

Situations in which you might want to override automatic exposure often involve scenes with interesting or unusual lighting. For example, you need to take control when you photograph into the sun, record a colorful sunset, show the brilliance of a snow-covered landscape, or convey the dark moodiness of a forest. In this chapter you'll learn how to use your camera controls to get just the exposure you want.

THE IMPORTANCE OF EXPOSURE

Animation

Click to explore how exposure determines how light or dark an image is.

Photography begins with an exposure when you press the camera's shutter button. The shutter opens and light reflected from the scene enters through the lens and strikes the image sensor to create the image. By controlling how much light reaches the sensor you control how light or dark the picture is—one of the most important aspects of photography. When a scene has both very light and very dark areas, getting the perfect exposure is a lot like parking a large car in a small garage—there isn't a great deal of room for error. Your goal is to retain details in both the darkest and lightest areas so pure white is used only for spectral highlights such as reflections, and pure black is used only for those few areas of the scene that are black with no details.

In this scene there are details in all of the whites that give them texture and form. The small white square has been added to give you a reference to what pure white would look like.

One of the things that makes an Ansel Adams print so stunning was his ability to hold details in both the brightest and darkest parts of a scene. To do this with film he developed the Zone System *that guided him in adjusting exposure and development times for the best results. Today the adjustments are made with a photo-editing program.*

In this scene there are details in the darkest shadows. The small black square has been added to give you a reference to what pure black would look like.

How Exposure Affects Your Images

When you take a photograph, the exposure isn't uniformly distributed over the sensor's surface—unless you are photographing a subject that is absolutely uniform in tone. Highlights (brighter areas) in the scene reflect the most light, and the areas of the sensor onto which they are focused are exposed a great deal. Darker areas, such as shadows, reflect much less light, so the areas of the sensor onto which they are focused receive much less exposure. The perfect exposure retains details in both the highlights and shadows. If there is even a little too much exposure, the image is too light and details are lost in the highlights. If there is too little exposure, the image is too dark and details are lost in the shadows.

As you'll see, one way to ensure you get the best exposure is to take three pictures—a procedure called *bracketing*. The first is taken at the recommended setting. The second is lighter and the third darker than the first.

In this series of photographs you can see the effect of exposure on the image. The top photo is correctly exposed. The bottom left photograph was overexposed and is too light. The bottom-right photo was underexposed and is too dark.

EXPOSURE CONTROLS—THE SHUTTER AND APERTURE

It's not just old cameras that use waterhouse stops. The Lensbaby, "a selective focus SLR camera lens", comes with four apertures you can insert into the lens.

The most important exposure controls on your camera are the shutter speed and aperture because both affect the total amount of light reaching the image sensor. However, they do more than just control the exposure. As you'll see shortly they can also be the most creative controls you have.

• **The shutter** opens to begin an exposure and closes to end it. The shutter speed setting determines how long the shutter remains open to expose the image sensor.

• **The aperture** is the hole through which light enters the camera. Its size can be changed to control the brightness of the light allowed through to the image sensor.

If you strip away all of the modern technology and look at the earliest cameras, you will find the same controls in much simpler, and perhaps easier to understand, versions.

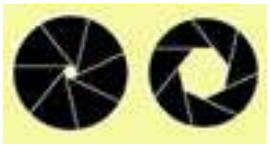
In the early days of photography, a plate called a waterhouse stop*, was inserted into a slot in the lens. Selecting one of the holes was much like selecting an f/stop today. A lens cap was removed and then replaced to begin and end the exposure—a primitive version of a shutter. This vintage camera is surrounded by waterhouse stops (apertures) and a lens cap (the shutter) leans against it.*

Less light makes an image darker (left) and more light makes it lighter (right).

Exposure Controls—Why So Many Choices?

Many digital cameras let you set the shutter speed and aperture to a range of settings. Since you only need one combination of these settings for a good exposure, why are there choices? It's because they give you creative control. By selecting the right combination you can make the background in a portrait sharp or blurred or freeze or blur motion.

A small aperture increases depth of field so foreground and background are sharp (top) and a large aperture decreases depth of field so the foreground and/or background is soft (bottom).



In this book and its animations, apertures are represented by these realistic icons with a small aperture (left) and a large one (right).

In this book and its animations, shutter speeds are represented by these symbolic icons with a fast shutter speed (left) and a slow one (right). The cutout "pie slice" indicates how far an imaginary second hand would sweep.

A fast shutter speed freezes a spinning amusement park ride (right) and a slow shutter speed blurs it (left).

EXPOSURE MODES

Click to explore the exposure modes available on many cameras.

Digital cameras usually offer more than one way to control the aperture and shutter speed—called *exposure modes*. All modes give equally good results in most situations. However, in specific situations, each of these exposure modes may have certain advantages. Here are modes you may encounter:

• **Automatic mode** (full auto) sets the shutter speed and aperture without your intervention. This allows you to shoot without paying attention to settings so you can concentrate on composition and focus. In this mode you can't change many camera settings.

• **Scene modes**, which go by a variety of names (Nikon calls them *Digital Vari-program modes*), automatically adjust settings for specific situations such as landscapes, portraits, night portraits, sports, and close-up photography. On some cameras the number of these settings has gotten a bit out of hand since there are so many you have to select them from a menu.

Modes and how they are designated on the camera vary from model to model. Modes that give you the most control, available only on more advanced cameras, are usually indicated with letters. Those that are fully automatic, often called scene modes, are indicated with icons like those shown on this Canon mode dial.

• **Programmed AE (auto exposure) mode** is just like full auto in that it sets the aperture and shutter speed for you, but unlike full auto it lets you change many of the camera's settings. In this mode, many cameras also let you select from a series of paired aperture and shutter speed combinations that yield the same exposure as that recommended by the camera. This gives you control over how depth of field and motion are captured. One of the best things about this setting is that it prevents you from inadvertently selecting an exposure setting that exceeds the camera's range.

• **Shutter-priority AE mode** lets you choose the shutter speed and the camera automatically selects the aperture needed for a good exposure. You select this mode when the portrayal of motion is most important. For example, when photographing action scenes, such as those encountered by wildlife photographers, sports photographers, and photojournalists, shutter-priority mode might be best. It lets you be sure your shutter speed is fast enough to freeze the action or slow enough to blur it

• **Aperture-priority AE mode** lets you select the aperture and the camera automatically selects the shutter speed needed for a good exposure. You select this mode whenever depth of field is most important. To be sure everything is sharp, as in a landscape, select a small aperture. The same holds true for close-up photography where limited depth of field is always a major concern. To throw the background out of focus so it's less distracting as in a portrait, select a large aperture.

• **Manual mode** lets you select both the shutter speed and the aperture. The two are not linked as they are in all other modes. You normally use this mode only when the other modes can't give you the results you want. Some cameras have a bulb setting in this mode that lets you capture time exposures such as light trails at night. In bulb mode the shutter remains open as long as you hold down the shutter button.

On some cameras you select exposure modes using buttons or a menu.

• **Custom settings mode** on high-end cameras lets you store personal settings. This is as simple as setting the camera the way you want it and then selecting the menu's command that assigns them to the custom setting. Some cameras let you save one or more sets and then instantly access them at any time just by turning a mode dial. If you use the same settings over and over again, this is a great way to save them. For example, you can save one group of settings to capture macro subjects, and then use any of the normal exposure modes to capture other scenes.

Using Scene Specific Exposure Modes

Portrait and Landscape mode icons.

Close-up and sports mode icons.

Night portrait and night landscape mode icons.

> **TIP**
>
> It would be nice if camera companies told you more about what settings they were manipulating in these scene modes, but none that I know of do so.

Sepia makes an image look like an albumen print from the 1800s.

Scene modes work just like full auto, but each draws on a library of settings designed for specific situations. For example, in Portrait mode the camera selects settings for a shallow depth of field so the background is softer. In Landscape mode, it does the opposite and selects a small aperture for maximum depth of field. (For more on the concepts of depth of field, see Chapter 4.) Here are the modes you are most likely to encounter.

• **Portrait** sets the camera for minimum depth of field so a portrait has a soft, and less distracting, background. To maximize the effect, zoom in on the subject, or use a long focal length lens (a telephoto) so the subject fills most of the viewfinder, and make sure there is as much distance as possible between the main subject and the background.

• **Landscape** sets the camera for maximum depth of field so as much of the scene as possible is sharp from foreground to background. Since a slow shutter speed may be used in this mode, you may need to support the camera. This mode works best with a short focal length (wide-angle) lens and the built-in flash is usually turned off so it won't fire.

• **Close-up** is used to capture flowers and other small objects but on SLR cameras this mode isn't a substitute for a macro lens. This mode works best when subjects are at the lens' minimum focusing distance.

• **Sports** mode is ideal for action sports and other fast-moving subjects because the shutter sped is set as fast as possible to freeze action. On some cameras, the autofocus mode is set to automatically keep a moving subject in focus, and continuous mode is selected so you can take pictures one after another as long as you hold down the shutter button. For best results use a long focal length lens.

• **Night Portrait** or **Twilight** mode is designed for photographing people or other nearby subjects at twilight, night, or dawn. The flash fires to illuminate foreground subjects and the shutter speed is set slow enough to lighten the background. Since it's likely a slow shutter speed will be used, you need to support the camera. Also, the shutter may remain open after the flash goes off so be sure to hold the camera still until the shutter closes, and if there are people in the foreground, ask them to freeze until a few seconds after the flash has fired.

• **Night landscape** doesn't fire the flash and instead uses a slow shutter speed to capture a landscape, and especially a cityscape, in the light of dawn, dusk, or night. Since a slow shutter speed will almost certainly be used in this mode, you need to support the camera. If the scene includes foreground subjects, you may want to consider using night portrait as well as this mode.

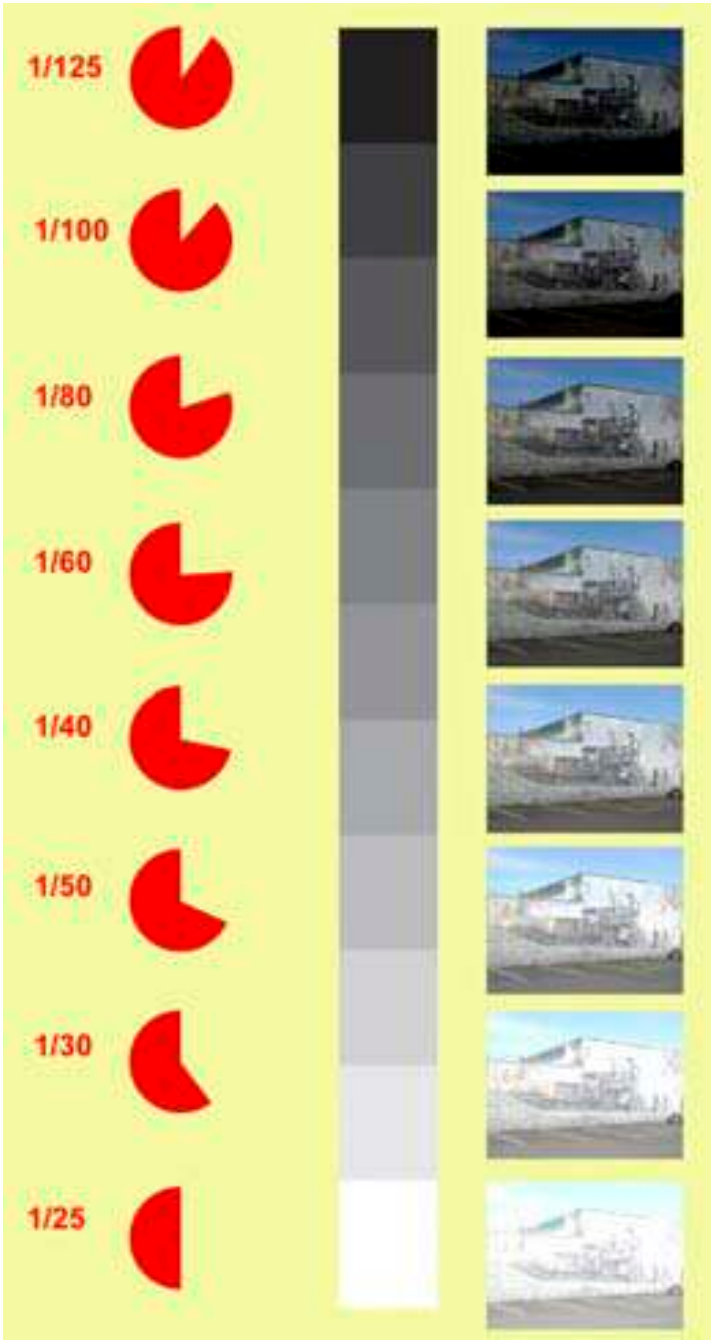
• **Black and White** or **Sepia** modes capture grayscale images. In sepia mode images are given a reddish brown tone to mimic old albumen prints.

• **Panoramic** mode, also called stitch-assist, helps you align a series of images so they can be stitched together on your computer using a panoramic stitching program. Some cameras will even stitch a panorama together in the camera but you can get better results, and much larger images, doing it on your desktop.

• **Other** scene modes you might encounter include party/indoor, beach/snow, sunrise/sunset, museum, fireworks, copy and backlight.

THE SHUTTER CONTROLS LIGHT AND MOTION

The shutter is normally closed to keep light out of the camera but opens during an exposure so light can expose the image sensor. In respect to just exposure, faster shutter speeds let less strike the image sensor so the image is darker. Slower speeds let in more light so an image is lighter.



As the shutter speed gets slower, the image gets lighter. The reason you don't usually see this effect in your images is because in most exposure modes when you or the camera change the shutter speed, the camera changes the aperture to keep the exposure constant.

Animation

Click to explore the effect of shutter speed on exposure.

In addition to controlling exposure, the shutter speed is the most important control you have over how motion is captured in a photograph. The longer the shutter is open, the more a moving subject will be blurred in the picture Also, the longer it's open the more likely you are to cause blur by moving the camera slightly. Although you normally want to avoid blur in your images there are times when you may want to use it creatively.

TIPS

- Depending on the available light, you may have access to only some of the camera's shutter speeds. To access faster shutter speeds, increase the ISO. To access slower shutter speeds, use a neutral density filter.
- The term "stop" goes back to the earliest days of photography. When there was too much light, plates with holes drilled in them were inserted into the lens to "stop" some of the light from entering.

A fast shutter speed (top) opens and closes the shutter so quickly a moving subject doesn't move very far during the exposure. A slow speed (bottom) allows moving objects to move sufficiently to blur their image on the image sensor.

Animation

Click to explore how the shutter speed affects the capture of moving subjects.

At slow shutter speeds, especially with point and shoot cameras, noise can build up and degrade image tones.

Shutter Speeds

1	0"8	0"6
	0"7	
1/2	0"4	0"3
	0"3	
1/4	1/5	1/6
	1/6	
1/8	1/10	1/13
	1/10	
1/15	1/20	1/25
	1/20	
1/30	1/40	1/50
	1/45	
1/60	1/80	1/100
	1/90	
1/125	1/160	1/200
	1/180	
1/250	1/320	1/400
	1/350	
1/500	1/640	1/800
	1/750	
1/1000		

Shutter speeds

Although digital cameras can select any fraction of a second for an exposure, there are a series of settings that have traditionally been used when you set it yourself (which you can't do on most point and shoot cameras). These shutter speed settings—called *stops*—are arranged in a sequence so that each setting lets in half as much light as the next slowest setting and twice as much as the next fastest. Some of the traditional shutter speeds are listed in the first column in the table to the left although many cameras have both faster and slower speeds.

• Speeds faster than 1 second are fractions of a second and many cameras display them without the numerator. For example, 1/2 second is displayed as *2*.

• Speeds of 1 second or slower are whole seconds and many cameras indicate them with quotation or inch marks ("). For example, 2 seconds is displayed as 2".

A leaf shutter.

Many high-end digital cameras have added one or two settings between each of the traditional ones. This allows you to adjust exposure in one-half or one-third stop increments for finer exposure control. In the table on the previous page one-half and one-third stops are shown in the second and third columns in the table.

TYPES OF SHUTTERS

There are three different kinds of shutters used in digital cameras—leaf, electronic, and focal plane. Leaf and focal plane shutters are both mechanical and have moving parts—leaves or curtains.

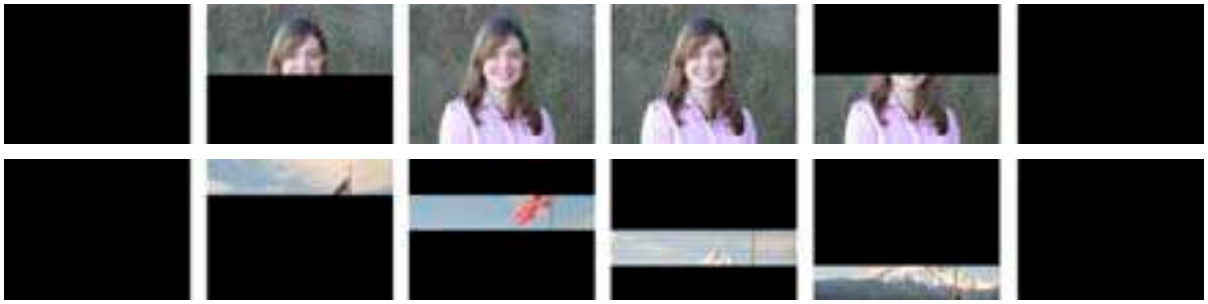
Animation

Click to explore the different types of shutters used in digital cameras.

• **Leaf shutters**, alone or combined with an electronic shutter, are used on some point and shoot cameras. On some inexpensive cameras, the shutter also acts as the aperture by varying how far it opens.

• **Electronic shutters** simply turn the sensor on and off to capture the exposure. It's like turning a vacuum cleaner on to start accumulating dust and off to stop. These shutters are found in the cheapest cameras, but ironically also in the most expensive. When precision designed they can be exceptionally accurate.

• **Focal plane shutters**, found in all digital SLRs open one curtain to begin an exposure and close another curtain to end it. On newer cameras the curtains run vertically. This makes them faster than older shutters that ran horizontally because they have less distance to cross. This faster speed makes it possible to have a faster flash sync shutter speed.



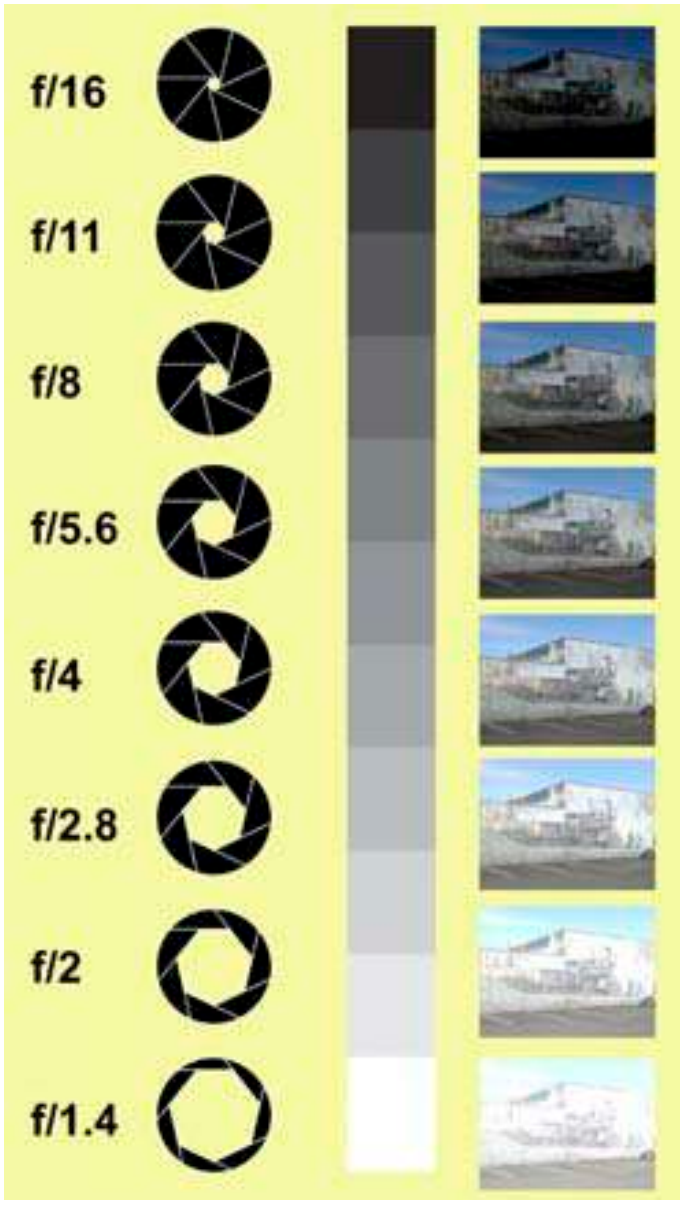
At slow shutter speeds (above, top) the first curtain fully opens to expose the sensor before the second curtain closes to end it. At high shutter speeds (above, bottom), the second curtain starts to close before the first curtain has fully opened so there is a slit between the two curtains moving across the image sensor (below, bottom).

On the Great Plains a slow shutter speed was used to blur the blades on a spinning windmill.

The Aperture Controls Light and Depth of Field

The size of the aperture can be adjusted to control the brightness of the light reaching the image sensor. The aperture can be opened up to let in more light or closed (stopped down) to let in less. In respect to just exposure, smaller apertures let less light strike the image sensor so the image is darker. Larger apertures let in more light so the image is lighter.

In better cameras, the aperture is a series of overlapping leaves located between the glass elements in the lens.



As the aperture number gets smaller (for example, from f/16 to f/11) the aperture opening gets larger and the image gets lighter. The reason you don't usually see this effect in your images is because in most exposure modes when you or the camera change the aperture, the camera changes the shutter speed to keep the exposure constant.

As with the shutter speed, the aperture also affects the sharpness of your picture, but in a different way. Changing the aperture changes the *depth of field*, the depth in a scene from foreground to background that will be sharp in a photograph. Smaller apertures increase depth of field while larger ones decrease it. For some pictures—for example, a landscape—you may want a smaller aperture for maximum depth of field so that everything from near foreground to distant background is sharp. But perhaps in a portrait you will want a larger aperture to decrease the depth of field so that your subject is sharp but the background is soft and out of focus.

Animation

Click here to explore the standard series of apertures and the aperture's effects on exposure.

A small aperture increases depth of field so foreground and background are sharp (top) and a large aperture decreases depth of field so the background is soft (bottom).

Animation

Click here to explore how the aperture affects depth of field.

TIP

Depending on the available light, you may have access to only some of the camera's apertures. To access smaller apertures, increase the ISO. To access larger apertures, use a neutral density

Apertures

f/1.4	f/1.6	f/1.7
	f/1.8	
f/2.0	f/2.2	f/2.5
	f/2.6	
f/2.8	f/3.2	f/3.5
	f/3.5	
f/4.0	f/4.5	f/5.0
	f/4.5	
f/5.6	f/6.3	f/7.1
	f/6.7	
f/8.0	f/9.0	f/10
	f/9.5	
f/11	f/13	f/14
	f/13	
f/16	f/18	f/20
	f/19	
f/22		

Aperture settings are called *f/stops* and indicate the size of the aperture opening. Each f/stop lets in half as much light as the next larger opening and twice as much light as the next smaller opening. From the largest possible opening to increasingly smaller ones, f/stops have traditionally included those shown in the first column in the table to the left with the largest at the top. No lens has the full range of settings; for example, the standard lens on a digital camera will range from about f/2 to f/16. Note that as the f/stop number gets larger (f/8 to f/11, for example), the aperture size gets smaller. This may be easier to remember if you think of the f-number as a fraction: 1/11 is less than 1/8, just as the size of the f/11 lens opening is smaller that the size of the f/8 opening. Many high-end digital cameras have added one or two settings between each of the traditional ones. In the table to the left one-third and one-half stops are shown in the second and third columns.

How wide you can open the aperture depends on the len's *maximum aperture*—its widest opening. The term "fast lens" usually applies to lenses that can be opened to a wide maximum aperture. For example, a lens with a maximum aperture of f/1.8 opens wider, and is faster, than a lens with a maximum aperture of f/2.6. Faster lenses are better when photographing in dim light or photographing fast moving subjects. With most, but not all, zoom lenses the maximum aperture changes as you zoom the lens. It will be larger when zoomed out to a wide angle, and smaller when zoomed in to enlarge a subject.

USING SHUTTER SPEED AND APERTURE TOGETHER

Many cameras display the current aperture and shutter speed settings on the monitor, in the viewfinder, or on a separate LCD panel when you press the shutter button halfway down.

As you've just seen aperture and shutter speed settings are arranged so that a change of 1 stop in either lets in half or twice the light of the next setting. This relationship means a change in one setting can be offset by a change in the other. This is exactly what happens in aperture and shutter priority modes where a change in one setting is offset by a change in the other. If you make the shutter speed 1 stop slower (letting in 1 stop more light), and the camera automatically selects an aperture 1 full stop smaller (letting in 1 stop less light), the exposure doesn't change. However, the pictures may differ. These changes increase the depth of field and the possibility of blur from camera or subject movement. Lets look at two analogies.

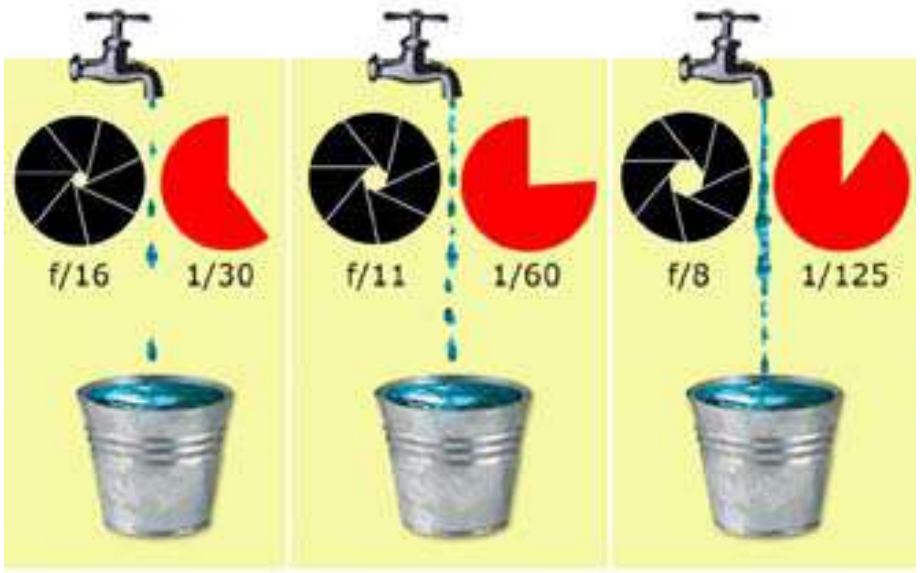
EXPOSURE—FAUCETS & BUCKETS ANALOGY

One way to think of the relationship between apertures and shutter speeds is to use the analogy of a faucet for the aperture and a timer for the shutter speed.

• When you open a faucet all the way, water gushes out so you fill a bucket in a very short time. This is the same as pairing a large aperture with a fast shutter speed to let in bright light for a short time.

• When you open a faucet just a little, water trickles out and so it takes a much longer time to fill a bucket. This is the same as pairing a small aperture with a slow shutter speed to let in dim light for a longer time.

No matter which combination you choose, the bucket is filled the same amount. Likewise, an image in a camera can be exposed the same amount by various aperture and shutter speed combinations while using their side effects to also control motion and depth of field.



1. Lets assume you start with the aperture set to f/16 and the shutter speed to 1/30.

2. When you open the aperture one stop to f/11 the shutter speed has to decrease to 1/60 to keep the exposure the same. This change decreases depth of field slightly and freezes action better.

3. When you open the aperture another stop to f/8 the shutter speed has to decrease another stop to 1/125. This change decreases depth of field even more and freezes action even better.

TIPS

• To be sure you are always using the fastest possible shutter speed, set the camera to aperture-priority mode and select the aperture needed for depth of field. The camera will then always select the fastest possible shutter speed.

• To be sure you are always using the largest possible aperture, set the camera to shutter-priority mode and pick the shutter speed you need to freeze or blur motion. The camera will then always select the largest possible aperture.

Animation

Click to explore the relationship between the aperture and shutter speed.

EXPOSURE—SEESAW ANALOGY

Another way to think of exposure is as a seesaw. As one child rises a given distance, the other descends by the same amount, but their average distance from the ground remains the same. In photography, when you or the camera change the aperture or shutter speed to let in more or less light, you or the camera must also change the other setting in the opposite direction to keep the exposure constant.

The illustrations below show how a change in the aperture setting must be matched by a change in the shutter speed and vice versa. As these offsetting changes are made, the exposure stays constant but depth of field changes slightly and subjects are more or less likely to be blurred.

1. Here the aperture is f/4 and the shutter speed is 1/125.

2. If you reduce the aperture one stop to f/5.6 the shutter speed has to decrease one stop to 1/60 to keep the exposure the same.

3. If you reduce the aperture one more stop to f/8 the shutter speed has to decrease one more stop to 1/30 to keep the exposure the same.

How Your Exposure System Works

Animation

Click to explore how your exposure system "sees" a scene.

All digital camera exposure systems operate on the same general principles. A meter continuously measures the light reflecting from the subject and uses this measurement when you press the shutter button halfway down to calculate and set the shutter speed and aperture.

Your camera's meter measures some or all of the light reflecting from the part of the scene shown in the viewfinder or on the monitor. The coverage of the meter (the amount of the scene that it includes in its reading) changes just as your viewfinder image changes when you change your distance to the scene or change the focal length of the lens. Suppose you move close or zoom in and see in your viewfinder only a detail in the scene, one that is darker or lighter than other objects nearby. The suggested aperture and shutter speed settings will be different for the detail than for the overall scene.

Meter averaging and middle gray

Your exposure meter doesn't "see" a scene the same way you see it. Its view is much like yours would be if you were looking through a piece of frosted glass.

Your meter "sees" scenes as if it were looking at them through a piece of frosted glass. It doesn't see details, just averages.

Where you see a checkerboard-like pattern (top), your camera sees only an average gray (bottom).

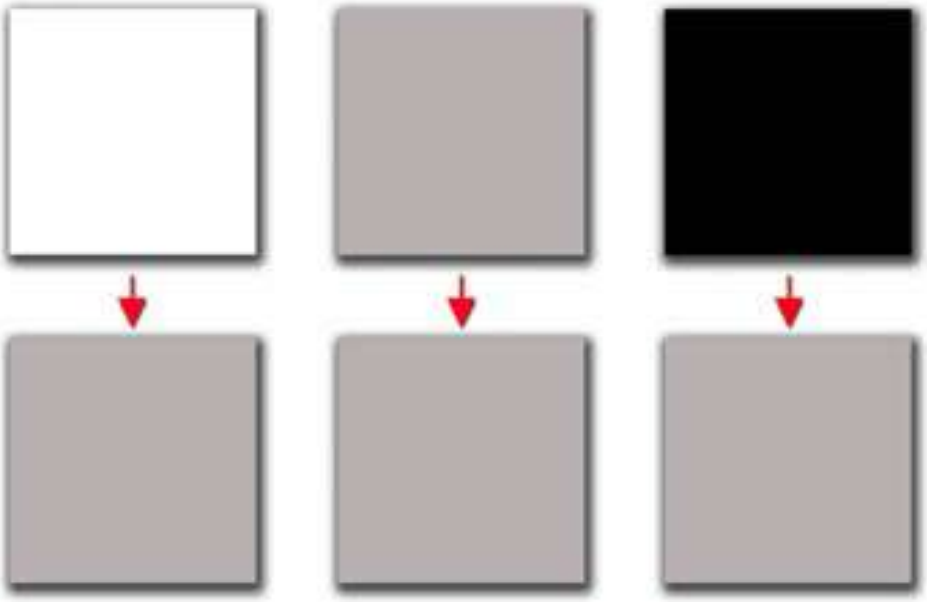
Every scene you photograph is something like a checker board pattern on the buildings (left), but often more complex. Portions of most scenes are pure black, pure white, and every possible tone in between.

The camera's exposure meter and exposure control system can't think. Regardless of the scene, its subject matter, color, brightness, or composition, the meter does only one thing—it measures the average brightness, or how light or dark the scene is. The automatic exposure system then calculates and sets the aperture and the shutter speed to render this level of brightness as "*middle gray*" in the photograph. Most of the time this works very well because most scenes have an overall brightness that averages out to middle gray. But some scenes and situations don't average out to middle gray and that's when autoexposure will lead you astray. Let's see why.

Most scenes contain a continuous spectrum of tones, ranging from pure black at one end to pure white at the other—the *gray scale*. When shooting JPEGs there are 256 tones in the scale (2^8) and when shooting RAW images there are up to 65,536 (2^{16}). The tone in the middle of these ranges is *middle gray* and reflects exactly 18% of the light falling on it.

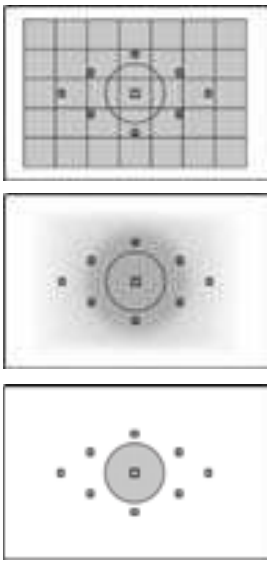
The gray scale captured in an image is a range of tones from pure black to pure white.

When you photograph a subject, your camera's autoexposure system sets the exposure so the average brightness in the image is middle gray regardless of the scene's actual brightness. As a result, when you photograph a scene with an average brightness lighter or darker than middle gray, the image will be darker or lighter than the scene. For example, if you photograph a white card, a gray card, and a black card, and each completely fills the viewfinder when the exposure is calculated, each of the cards will be middle gray in the captured image.



Because of the way your exposure system works, if you photograph a white card, a gray card, and a black card (top row), the exposure system sets the camera to capture each as middle gray (bottom row).

To realistically capture a scene that doesn't average out to middle gray, you have to use exposure compensation or some other form of exposure control to lighten or darken the picture.



Metering patterns include matrix (top), center-weighted (middle) and spot (bottom). The small squares are focus areas from which you can choose.

Types of metering

All parts of a scene are often not equally important when determining the best exposure to use. In a landscape, for instance, the exposure of the foreground is usually more important than the exposure of the sky. For this reason some cameras offer more than one metering method including the following:

• **Matrix metering**, sometimes called *evaluative*, divides the image area into a grid and compares the pattern of measurements against a library of typical scenes to select the best possible exposure for the current scene. This mode is often programmed to ignore sections of the grid, such as the reflection from a mirror, that would otherwise throw off the measurement.

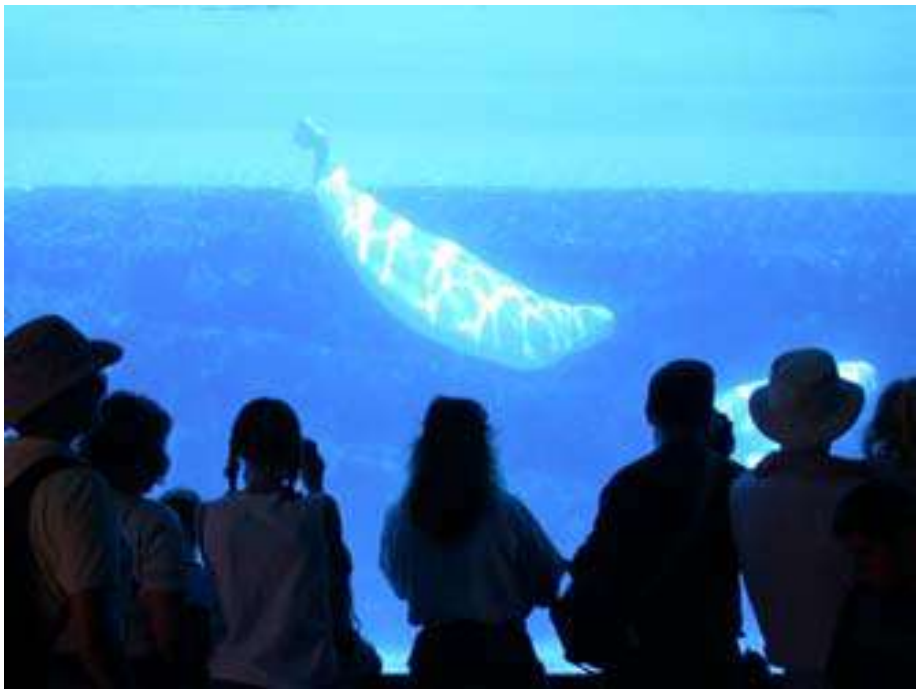
• **Center-weighted** meters the entire scene but assigns the most importance to the center of the frame where the most important objects usually are located.

• **Spot**, or slightly larger *partial metering*, evaluates only a small area of the scene. This allows you to base your exposure on a specific part of the scene rather then relying on an average reading. This mode is ideal when photographing a subject against a bright or dark background. On some cameras the spot that's metered is fixed in the middle of the viewfinder or monitor. On others you can move it, to meter other areas of the scene.

• **Spot AF** links spot metering to the same focusing area you have selected for focusing. Since many high-end cameras have a number of focus areas from which you can choose, this allows you to base an exposure and focus on an off-center subject.

Meter weighting can cause a few problems. For instance, a dark object located off center against a very light background may not be exposed properly because it is not located in the area the meter is emphasizing. Or, in some cases, holding the camera vertically may give undue emphasis to one side of the scene. These occasions are uncommon, but when they occur you can use exposure lock or exposure compensation to get a good exposure. These techniques are discussed later in this chapter.

By controlling metering the exposure of this scene was based on the aquarium tank so the people in the foreground are underexposed.



Zones	
0	Pure black
I	Black with detail
II	Textured black
III	Very dark gray
IV	Dark gray
V	Middle gray
VI	Light gray
VII	Very light gray
VIII	Near white
IX	Pure white

To guide film photographers, the Zone System divided the gray scale into nine zones from pure black to pure white. Each zone has one stop more or less exposure than the ones next to it. The camera will normally expose the scene so it is Zone V.

PLACING A VALUE

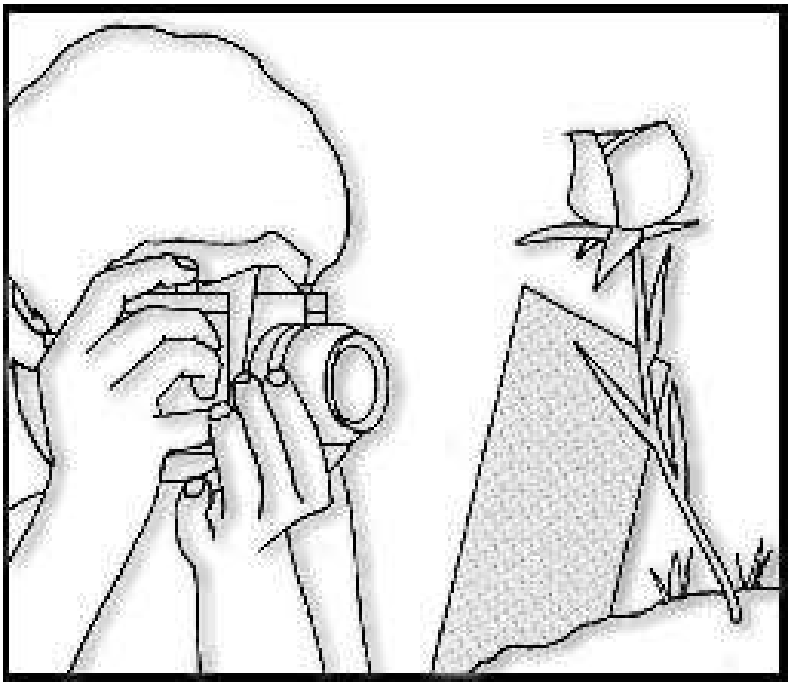
If you have ever seen an original Ansel Adams print, you probably marveled at the way he used the entire tonal range to capture detail in both the highlights and shadows. His prints reflect the incredible control he had over his images using the Zone System he developed. By exposing and developing the film correctly, he could expand or contract the tonal range of the negative to match the tonal range of the scene. Although Ansel's system was very scientific and quite technical, much of what he was able to accomplish can be accomplished with a digital camera and a photo-editing program such as Lightroom or Photoshop. Ansel's system is based on the general principle that you expose for the shadows and develop for the highlights. In digital photography, you expose so pixels aren't clipped and many cameras, including all SLRs, display a histogram so you can confirm that you have done this. You then use a photo-editing program to adjust the tones so they fall in the desired zones.

To begin, you use exposure compensation to "place a value." To do this, you select the most important part of the scene and meter it from close up or use spot metering mode. The key to metering a specific value is to have the area of the scene being metered fill the camera's metering area. You then decide what tone you want this area to have in the final image. Since autoexposure will make it middle gray, you may have to change the exposure to move it to another zone. In manual mode you can do this by changing the shutter speed or aperture. In other modes, you use exposure compensation to move it up to two zones in either direction.

GRAY CARDS

Since the exposure system is designed to set the exposure to capture a middle gray, Zone V, scene you can get perfect exposures in many situations by using a gray card. When you fill the viewfinder or spot metering area with a gray card and press the shutter button halfway down, your camera will indicate the best exposure regardless of how light or dark the scene is. You can then use AE Lock to use this setting to take the picture.

When you fill the viewfinder or metering area with a gray card and press the shutter button halfway down, your camera will indicate the best exposure regardless of how light or dark the scene is.



When Automatic Exposure Works Well

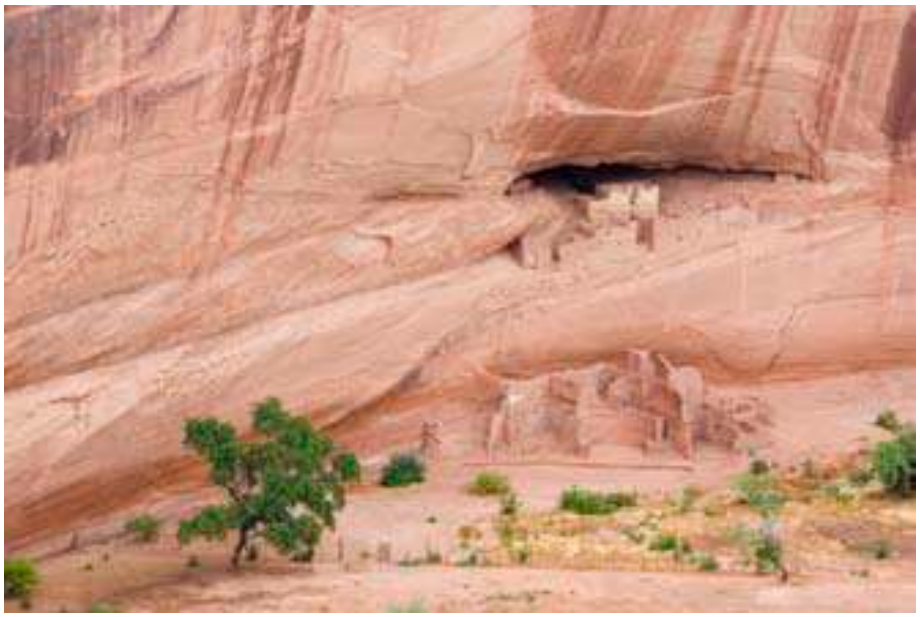
Most scenes that you photograph have an overall brightness of middle gray. Some areas of the scene may reflect 90% of the light and other parts may reflect 5%, but overall the average amount of light reflecting from the scene is 18%, the amount reflected by a middle gray subject.

Whenever you photograph a normal scene with this average brightness, your automatic exposure system exposes it correctly. Typical middle gray scenes include the following:

• Scenes in bright sunlight where the subject is illuminated with the sun behind you as you face the scene.

• Scenes on overcast days or under diffused light, such as in the shade or in evenly lit scenes indoors.

This landscape of Canyon de Chelly was taken on an overcast morning using autoexposure.



This portrait, taken under a cloudy bright sky is perfectly exposed using autoexposure.

When to Override Automatic Exposure

Not all scenes average out to middle grey. Let's take a look at some of the most common situations where your automatic exposure system will have problems and you'll need to override the suggested exposure settings.

Scenes lighter than middle gray

Scenes lighter than middle gray, such as beach scenes, or bright sand or snow covered landscapes, reflect more than 18% of the light falling on them. The autoexposure system doesn't know the scene should look bright so it calculates a middle gray exposure that produces an image that is too dark. To lighten the image so it matches the original scene, you must override the camera's automatic exposure system to add exposure.

The snow scene here is typical of scenes that are lighter than middle gray. Most of the important tones in the scene are at the lighter end of the gray scale. The overall "average" tone would be about one stop brighter than middle gray. For a good picture you have to increase the exposure by one stop (+1) to lighten it. If you didn't do this, the snow in the scene would appear too gray (bottom).

Scenes darker than middle gray

Scenes that are darker than middle gray, such as deep shadows, dark foliage, night scenes and black cloth, reflect less than 18% of the light falling on them. If you photograph such scenes using automatic exposure, they will appear too light. The meter cannot tell if the scene is dark or just an ordinary scene with less light falling on it. In either case it increases the exposure to make the scene a lighter middle gray. To produce a picture with an overall tone darker than middle gray, you need to override the autoexposure system to decrease the exposure.

The black cat is between one and two stops darker than middle gray. To darken the scene so the cat's not middle gray, exposure must be decreased by one (-1) or two (-2) stops.

Here the scenes were underexposed to silhouette the people in the foreground. To show detail in the people, exposure would have had to have been increased two stops (+2).

Subject against very light background

Subjects against a very light background, such as a portrait against a bright sky or light sand or snow, can confuse an automatic exposure system, particularly if the subject occupies a relatively small part of the scene. The brightness of the background is so predominant that the automatic exposure system reduces the exposure to render the overall brightness as a middle gray. The result is an underexposed and too-dark main subject. To render it realistically you have to increase the exposure.

Dark subjects against bright backgrounds will be too dark without exposure compensation.

SUBJECT AGAINST VERY DARK BACKGROUND

When a small light subject appears against a large dark background, your autoexposure system increases the exposure to produce a middle gray tone. Since this tone is lighter than the scene, the main subject is also lighter. To capture the scene the way you see it, you have to decrease the exposure to make it darker.

The early morning sun illuminated this Ibis wading in a pond. If the exposure hadn't been reduced the background would be too light and the white bird would have been too white. A scene like this is a great place to use spot metering.

The archway was in the shadows and dark while the cathedral was brightly lit by the sun. Both couldn't be exposed properly, so the archway was left as a solid black frame.

SCENES WITH HIGH CONTRAST

Many scenes, especially those with brightly lit highlights and deep shadows, have a brightness range that exceeds the range an image sensor can capture. When confronted with such scenes, you have to decide whether the highlight or shadow area is most important, then set the exposure so that area is shown accurately in the final picture. In high contrast situations such as these:

• Meter and base the exposure on the most important area and let the rest of the scene be under or over exposed.

• Lighten the shadows by adding fill flash or using a white reflector card. For example, a portrait lit from the back or side is often more effective and interesting than one lit from the front. But when the light on the scene is contrasty, too much of the person's face may be in overly dark shadow. In this case use fill flash or a white reflector card will fill and lighten the shadows.

• In high contrast settings, some cameras let you decrease contrast at the time you take the picture.

Hard to meter scenes

Occasionally it's not convenient or even possible to meter a scene. Neon street signs, spotlit circus acts, fireworks, moonlit scenes, and many similar situations are all difficult and sometimes impossible to meter. In these cases, it's easiest simply to experiment with the exposure controls on your camera. For example, after taking a picture at the suggested exposure, use exposure compensation or autoexposure bracketing to take other exposures both lighter and darker than the suggested settings.

This scene has a bright sky and one brightly illuminated fisherman against a dark background. A scene such as this is hard to meter because of the variety of lighting.

A relatively small subject against a wide expanse of sky will almost always be underexposed unless you use exposure compensation.

HOW OVERRIDING AUTOEXPOSURE WORKS

Underexposing by 2 stops kept the background dark while correctly exposing the spotlit areas.

When a scene is lighter or darker than middle gray you need to adjust the exposure to capture the scene the way it looks in real life. To do so many cameras let you increase or decrease exposure in autoexposure modes by two stops or more. Here are some typical settings where you'd make these changes.

• **+2** is used when the light is extremely contrasty and important shadow areas are much darker than brightly lit areas.

• **+1** is best for sidelit or backlit scenes, beach or snow scenes, sunsets and other scenes that include a bright light source, or very light objects, such as a white china on a white tablecloth.

• **0** (the default) is best for scenes that are evenly lit and when important shadow areas are not too much darker than brightly lit areas.

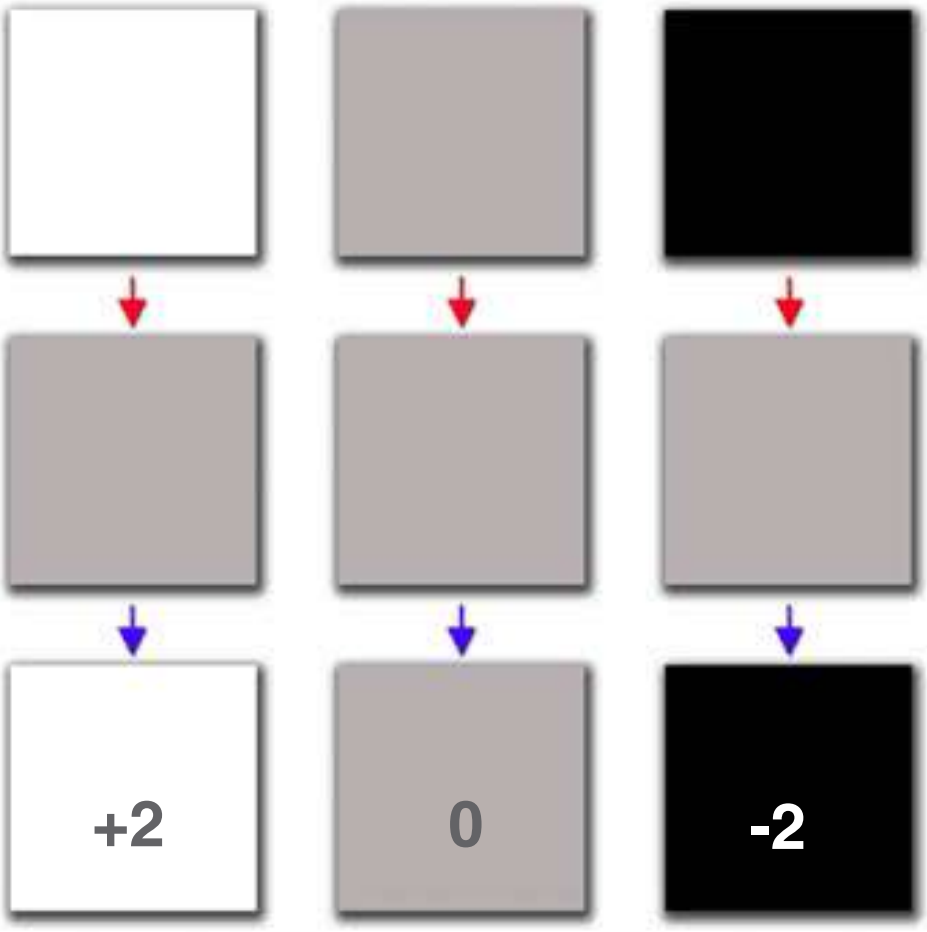
• **-1** is for scenes where the background is much darker than the subject, such as a night scene or a portrait in front of a very dark wall. Also good for very dark objects, such as black china on a black tablecloth.

• **-2** is for scenes of unusual contrast, as in night scenes where an extremely dark background occupies a very large part of the image and you want to retain detail in the brighter parts of the scene.

1. Here are three cards that you photograph with each filling the viewfinder at the time you take the picture.

2. The camera's exposure system makes all three cards appear gray in the photographs. Only the middle gray card in the center is exposed correctly.

3. Increasing the exposure for the white card and decreasing it for the black card captures them as they really appear. Only the middle gray card in the center doesn't need the exposure adjusted manually.



How to Override Automatic Exposure

> **TIP**
>
> Many digital cameras let you select 1/3 or 1/2 stop increments for exposure settings. Setting it to 1/3rd stops gives you finer control over the exposure.

The universally recognized icon for exposure compensation.

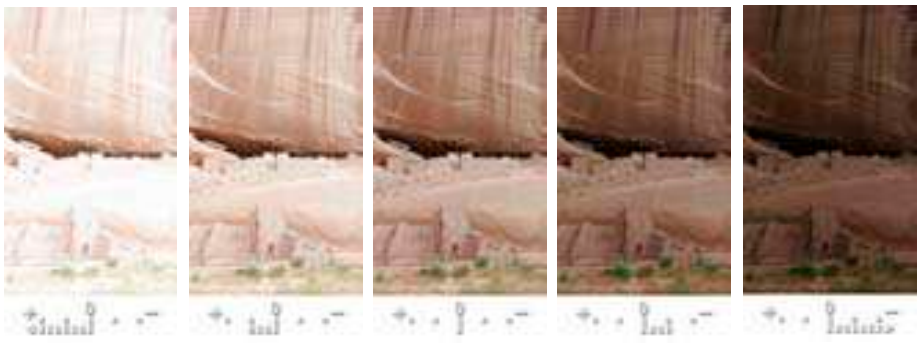
Click to explore exposure compensation.

Many digital cameras display an exposure scale when you use exposure compensation.

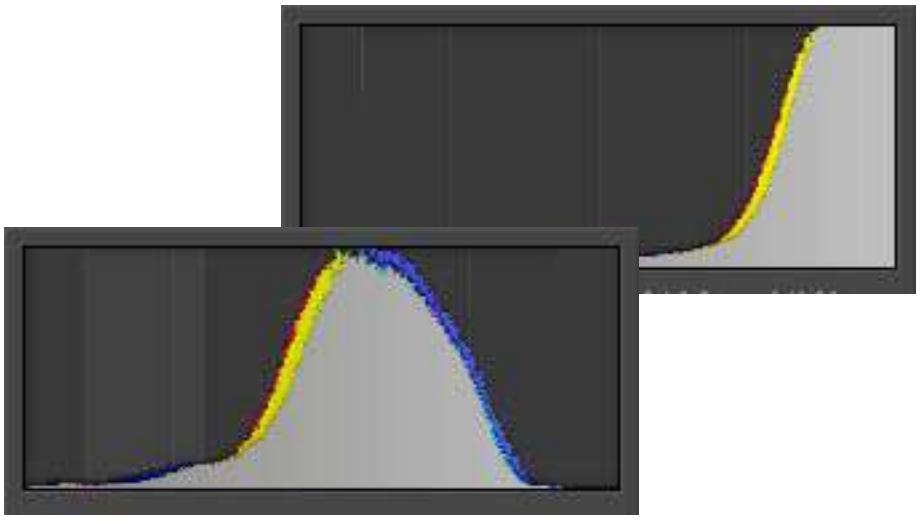
Most digital cameras provide ways to override the automatic exposure system to get the exposure you want. The most common choices are exposure compensation, exposure lock, and autoexposure bracketing.

Exposure compensation

You can't make an image lighter or darker by changing the shutter speed or aperture in any mode but manual. This is because when you change one of the settings, the other changes automatically to keep the exposure constant. Exposure compensation is the feature you use to capture an image that's lighter or darker than one the camera would produce automatically. To lighten a picture, you increase the exposure; to darken it, you decrease the exposure. The amount you increase or decrease the exposure is specified in stops. If you select a + value, the image will be brighter. If you select a – value it will be darker. It's easy to use exposure compensation because most cameras display a scale to guide you and you can preview the effects of your changes on the monitor, if the camera lets you use it to compose images. You can also check an image in review or playback mode and even examine its histogram on many cameras.



When you adjust exposure compensation you can do so in full stops and even finer increments—usually one-third or one-half stops. On most cameras you will see a scale displayed when you use this command. The "0" indicates the exposure suggested by the camera. As you adjust the exposure toward the plus (+) side of the scale the image gets lighter. As you adjust it toward the minus (-) side it gets darker. Here you see the results as it's adjusted from +2 (left) to -2 (right). The effect of the changes on the image are dramatic.



The histogram on the right shows that the image is overexposed and pixels at the far right end (the highlights) are being clipped. Using exposure compensation at the time the photo was taken shifted the histogram to the left (bottom left). With this adjustment no details are lost in the shadows or highlights.

Pressing the shutter button halfway down locks exposure and pressing it all the way down takes the picture.

Animation

Click to explore exposure lock.

AUTOEXPOSURE LOCK (AE LOCK)

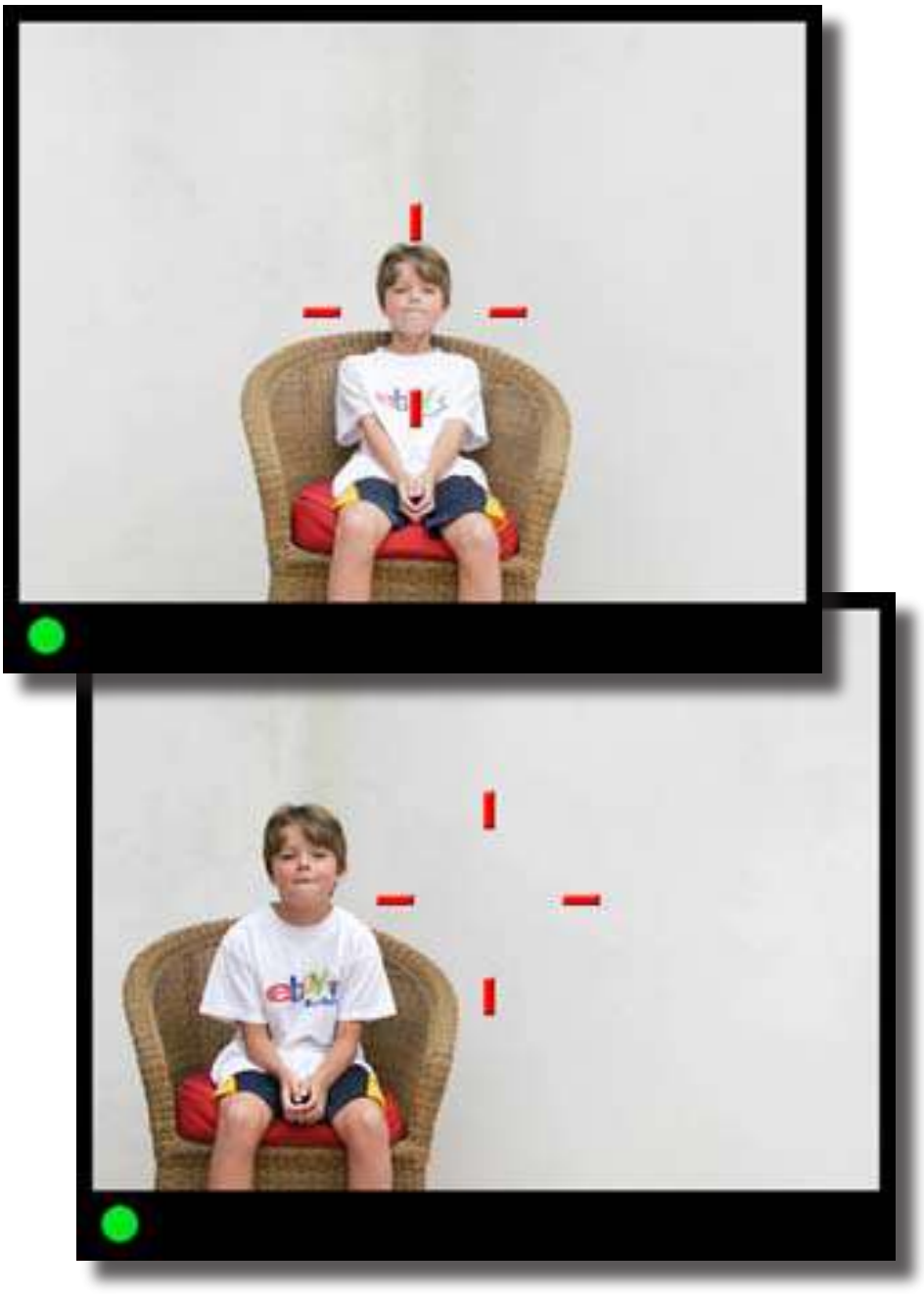
You can adjust exposures with a procedure called *autoexposure lock* (AE Lock). You point the camera so the part of the scene on which you want to base the exposure is metered (spot metering works best) and press the shutter button halfway down to calculate the exposure (and focus) and lock them in. While continuing to hold down the shutter button, you recompose and shoot the picture using the locked in settings.

Some cameras also have an AE Lock function that lets you lock exposure independently of focus. First you press the shutter button halfway down to lock exposure, then press the AE Lock button to keep it locked until you take a picture. You can then release the shutter button, recompose the scene, then press the shutter button halfway down again to lock just focus.

1. Point the camera so you are metering the area on which you want to base the exposure—in this case the subject in the cross hairs. Press the shutter button halfway down to lock exposure (and focus).

A common icon for AE Lock buttons.

2. Without releasing the shutter button, compose the image the way you want it and press the shutter button the rest of the way down to take the photo.



If you took the picture without first locking exposure, it would be too dark because the background influenced the exposure.

Animation

Click to explore autoexposure bracketing.

Autoexposure bracketing (AEB)

To be absolutely certain you have the best exposure, *autoexposure bracketing* (AEB) takes a series of photos—each at a slightly different exposure. This process is basically an automated form of exposure compensation. Some cameras let you specify both the number of exposures, usually 3 or 5, and the change in exposure between each shot. Some cameras take all of the pictures with a single press of the shutter button. With others you have to press the shutter button once for each picture. Some cameras use this same approach to bracket white balance and even focus.

Bracketing gives you a series of images at different exposures.

Some cameras let you select the number of shots and the exposure increment between each. Here the scale has no bracketing (top) followed by settings for one, two, and three stops difference between exposures.

The standard icon for auto exposure bracketing.