



PHOTOGRAPHY

E I G H T H E D I T I O N

Barbara London
John Upton
Jim Stone
Kenneth Kobre
Betsy Brill



PRENTICE HALL
Upper Saddle River, New Jersey 07458

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ANDREAS FEININGER
Photojournalist, 1955

*A merging of
photographer and
camera. Notice how
the dark shadows iso-
late and emphasize the
important part of the
picture. "Making a
good photograph
requires genuine inter-
est in the subject,"
Feininger said.
"Without it, making
a photograph sinks
to the level of boring
routine."*

This section describes your camera's basic controls and what they do.

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Most cameras fall into three basic categories: view camera, rangefinder/viewfinder, and single-lens reflex.

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How do you keep your camera steady so that camera motion doesn't blur your picture?

Keeping the Camera Steady	35
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Getting to the front line of action—and getting out again with photographs—is more than just a job for James Nachtwey.

Photographer at Work:	
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Why do you need to know how a camera works? Much of modern camera design is based on one of the earliest camera slogans, "You press the button, we do the rest." Automatic-exposure cameras set the shutter speed, aperture, or both for you. Automatic-focus cameras adjust the lens focus. But, no matter what technological improvements claim to make a camera "foolproof" or "easy to use," there are still choices to make before you take a picture. Either you make them or the camera does, based on what the manufacturer calculates will produce the best results for an average scene.

But average results may not be what you want. You have the freedom to interpret what you see. Do you want to freeze the motion of a speeding car or let it race by in a blur? Do you want to bring the whole forest into sharp focus or isolate a single flower? Only you can make these decisions.

If you are learning photography, most instructors recommend using manual operation at first because it will speed your understanding of basic camera controls. If you do have a camera with automatic features, this book tells not just what those features do, but even more important, when and how to override an automatic mechanism and make the basic choices yourself.

The basic controls on any camera are similar, helping you to perform the same actions every time you take a picture. You'll need to see the scene you are photographing, decide how much of it you want to include, focus it sharply—where you want it to be sharp, and use the shutter speed (the length of time the shutter remains open) and aperture (the size of the lens opening) to expose the film to the correct amount of light.

One of the most popular camera types is shown here—the 35mm single-lens reflex. Other basic camera designs are described later in this chapter.

As the camera's settings change, the picture changes also. What will a scene look like at a faster shutter speed or a slower one? How do you make sure the background will be sharp—or out of focus—if you want it that way? Once you understand how the basic camera controls operate and what your choices are, you will be better able to get the results you want, rather than simply pressing the button and hoping for the best.



MANUAL CAMERA

Manually adjusted controls on this 35mm single-lens reflex camera let you set the shutter speed (the length of time the shutter remains open), select the lens aperture (the size of the lens opening), focus on a particular part of the scene, and change from one lens to another.



AUTOMATIC CAMERA

On automatic cameras, control keys often replace adjustable knobs or rings. This model automatically adjusts the focus, shutter speed, aperture, and lens focal length and fires a built-in flash when necessary. You can override the automatic features if you want to adjust the camera's settings yourself.

More about . . .
• Digital cameras and how they work, pages 202–205

Viewfinder
image



The viewfinder shows you the entire scene that will be recorded on the film and indicates which part of the scene is focused most sharply. The viewfinder may also display exposure information—here the shutter speed (right) and aperture (below).

Slow shutter speed

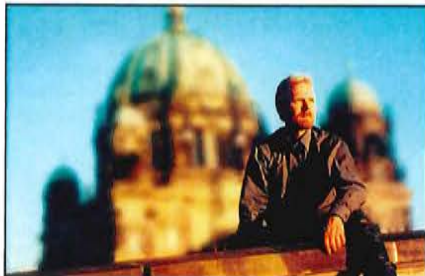


Fast shutter speed

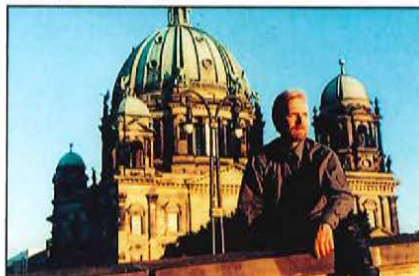


The shutter-speed selector controls the length of time that the shutter remains open. A shorter time decreases the likelihood that a moving object will appear blurred.

Large aperture opening



Small aperture opening



The aperture selector adjusts the size of the lens opening—the diaphragm. The smaller the aperture opening, the greater the depth of field (the part of the scene from near to far that will be sharp).

Short-focal-length lens



Long-focal-length lens



Interchangeable lenses let you select the lens focal length, which controls the size of objects in the picture and the extent of the scene recorded on the film.

More about . . .

- Aperture and depth of field, pages 26–27
- Aperture, shutter speed, and exposure, pages 28–29
- Focusing, pages 52–55
- Lens focal length, pages 42–43
- Shutter speed and motion, pages 20–21

Two controls adjust the amount of light that reaches the film: the shutter, described here, and the aperture (pages 24–25). The combination of an aperture and a shutter speed is an exposure, which must be a correct one so your picture is neither too light nor too dark.

The shutter controls the amount of light that reaches the film by the length of time it remains open. Doubling the amount of time it is open gives one stop more exposure—twice the amount of light. Halving the amount of time gives one stop less exposure—half the amount of light. Each full stop shutter setting is half (or double) the time of the next one and is marked as the denominator (bottom part) of the fraction of a second that the shutter remains open: 1 (1/1 or one second), 2 (1/2 second), 4 (1/4 second), and so on through 8, 15, 30, 60, 125, 250, 500, and on some cameras up to 8,000 or faster. B (bulb setting) keeps the shutter open as long as the release button is held down. T (time setting) opens the shutter with one press of the release, and closes it with another.

Electronically controlled shutters can operate at any speed, for example, 1/38 second. These “stepless” speeds are set by the camera in automatic exposure operation; some cameras allow you to dial them in yourself—others don’t.

Some digital cameras use a shutter for exposure. Others control exposure by turning their sensor chips on and off for the same amount of time that a traditional shutter would stay open.

NOTE: The term “stop” in photography refers to a change in illumination, whether the shutter speed or the aperture is changed to achieve it. To give one stop more exposure means to double the amount of light reaching the film either by doubling the exposure time or by doubling the size of the aperture (see page 25). To give one stop less exposure means to cut the light reaching the film in half by halving the exposure time or by halving the size of the aperture.

WHERE SHUTTER SPEED SETTINGS ARE DISPLAYED ON VARIOUS CAMERAS



In the camera's viewfinder



On the shutter-speed dial



In the data-panel readout

For the above examples, each camera is set to 1/500 sec. Notice that the camera displays only the bottom number of the fraction.

SHUTTER SPEEDS—WHAT YOU SEE AND WHAT YOU GET

Cameras used to provide shutter speeds only in full stops. This is because older mechanical shutters could only let in light for double the amount of time of the shutter speed before it or half that of the one after it. Cameras today with electronically-controlled shutters will also set shutter speeds in between. The camera will display increments of one-half or one-third stops, and may allow you to choose which of those you see. This chart shows how long each full stop remains open, plus how your camera may display fractional stops.

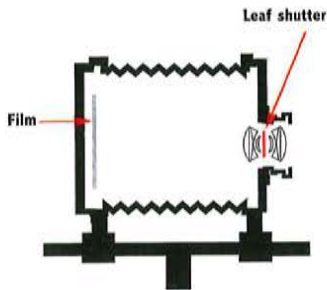
Many of these numbers are rounded off. Don't be surprised by inconsistency in shutter speeds among camera manufacturers. For example, a half-stop setting between 1 and 2 should actually be the square root of two, approximately 1.4142. One camera displays this as 1.4, another as 1.5.

NOTE: Don't confuse 2, meaning 2 seconds, with 2, meaning 1/2 second; 4, meaning 4 seconds, with 4, meaning 1/4 second, and so on.

If your camera allows you to choose among different ways to set shutter speeds, use full stops while learning photography. Do the same with aperture settings (see page 24).

Actual time in seconds	Shutter speeds your camera may display		
	FULL STOP	1/3 STOP	1/2 STOP
1 sec	1	1 1.3 1.6	1 1.5
1/2 sec	2	2 2.5 3	2 3
1/4 sec	4	4 5 6	4 6
1/8 sec	8	8 10 13	8 11
1/15 sec	15	15 20 25	15 20
1/30 sec	30	30 40 50	30 45
1/60 sec	60	60 80 100	60 90
1/125 sec	125	125 160 200	125 180
1/250 sec	250	250 320 400	250 350
1/500 sec	500	500	500

HOW SHUTTERS WORK

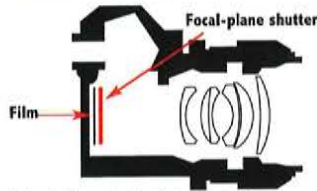


A leaf or between-the-lens shutter is generally located inside the lens itself. All view cameras, many medium-format cameras, and most point-and-shoots use leaf shutters. The leaf shutter consists of a number of small overlapping metal blades. As shown at right, when the shutter is released, the blades open up for an amount of time determined by the selected shutter speed, then shut again. The total amount of light admitted during this cycle produces the fully exposed photograph (see top photograph).

Advantages/Disadvantages. A leaf shutter is quieter than a focal-plane shutter and can be used with flash at any shutter speed. But since the leaf shutter has to open, stop, and then reverse direction to close again, most have top speeds no higher than 1/500 second. If your interchangeable-lens camera uses leaf shutters, the shutter is probably built into the lens. The cost of a shutter adds to the price of each lens. Also, actual shutter speeds might be a little slower or faster than each other. Generally, the difference is small, but it could be enough to make a noticeable difference in exposure when changing from one lens to another.

More about . . .

- Aperture and light, pages 24–25
- Relationships between shutter speeds and f-stops, pages 28–29
- Sync speed and flash, page 266



A focal-plane shutter is built into the camera body and is located directly in front of the film. The shutter consists of two overlapping curtains. When the shutter is released at slow shutter speeds, the first (opening) curtain moves across the film, revealing a window through which the film is exposed. The shutter waits for the correct amount of time, then it closes the second (following) curtain to stop the exposure. At higher shutter speeds, the following curtain begins to close before the opening curtain has completed its travel. The film is exposed through what appears to be a slit moving across the film. As the shutter speed increases, this slit becomes narrower.

The series to the right shows how the film is exposed at fast shutter speeds. The narrow slit exposes only part of the film at any one time, but every part of the film receives light for the same amount of time. Above, see the effect of the entire exposure, with all sections of the film having received the proper amount of light.

The shutter shown here moves from side to side across the length of the film. Some cameras have another type of focal-plane shutter (called a guillotine) that moves from top to bottom.

Advantages/Disadvantages. Interchangeable lenses for a camera with a focal-plane shutter can be less expensive than those for cameras requiring leaf shutters, since a shutter does not have to be built into each lens. And focal-plane shutters can reach higher speeds than leaf shutters—as high as 1/8,000 sec.

Generally, however, you can't use electronic flash when both shutter curtains are moving at the same time. The highest shutter speed at which the opening curtain has completed its travel before the following curtain begins to move—called sync speed—may be as slow as 1/60 second. At any faster shutter speed than a camera's sync speed, a flash will illuminate only the slice of the film revealed by the slit at the moment the flash is triggered.

Because you must use a relatively slow shutter speed with flash, existing (or ambient) light may register on the film as well as light from the flash. This can leave a "ghost" or second image in the picture.



The faster the shutter speed, the sharper a moving subject will be. A blurred image can occur when an object moves during an exposure, because its image projected onto the film by the lens will move during the time the shutter is open. If the object moves swiftly, or if the shutter is open for a relatively long time, this moving image will blur and be indistinct. But if you increase the shutter speed, you can reduce or eliminate the blur. You can control this effect and use it to your advantage. A fast shutter speed can freeze a moving object, showing its position at the instant of exposure (see opposite page). You can use a slower shutter speed to increase blurring and accentuate the feeling of motion (see pages 22 and 23). Generally, the amount of motion blur will double if you increase the shutter speed by one stop (toward a longer time).

Shown below are the effects of varying shutter speed and camera movement. In the picture at far left, the bicycle moved enough during a relatively long exposure of 1/30 second to leave a broad blur on the film. In the next photograph, at a shutter

speed of 1/500 second, the bicycle is much sharper. A moving subject may vary in speed and thus affect the shutter speed needed to stop motion. For example, motion slows and sometimes stops at the peak of a movement that reverses, such as the peak of a jump just before descent (opposite page), and even a relatively slow shutter speed will record the action sharply.

Other factors besides shutter and subject speed also affect the amount of blurring in a photograph. What matters is how far an image actually travels across the film during the exposure. In the photograph below of the rider moving directly toward the camera, the bicycle's image remains in virtually the same position on the film. Thus there is far less blurring even at 1/30 second. A subject close to the camera that is moving slowly, such as a cyclist 10 feet away, will cross more of the film and appear to blur more than the same subject moving at the same speed but farther away.

A long-focal-length lens magnifies objects and makes them appear closer to the camera. A moving subject will appear

more blurry when photographed with a long lens than it would if photographed with a normal lens used at the same distance.

Panning keeps a moving subject sharp while blurring the background. In the picture below, right, the camera was moved (panned) in the same direction the bicycle was moving. Since the camera moved along with the bicycle, the rider appears sharp while the motionless background appears blurred. Successful panning takes both practice and luck. Variables such as the exact speed and direction of the moving object make it difficult to predict exactly how fast to pan. Decide where you want the object to be at the moment of exposure, start moving the camera a few moments before the object reaches that point, and continue the motion after the exposure (follow-through) as you would with a golf or tennis stroke. The longer the focal length of the lens, the less actual camera movement will be necessary.

DIRECTION OF A MOVING OBJECT AFFECTS THE AMOUNT OF BLUR

1/30 second



When a subject is traveling parallel to the plane of the film, considerable movement is likely to be recorded on the film. The subject will be blurred, unless the shutter speed is fast.



1/500 second



1/30 second



If the subject is moving directly toward or away from the camera, there is no sideways movement recorded on the film and so a minimum of blur is produced, even at a relatively slow shutter speed.



1/30 second, camera panned



During panning, the camera is moved in the same direction as the subject. The result is a sharp subject and a blurred background.

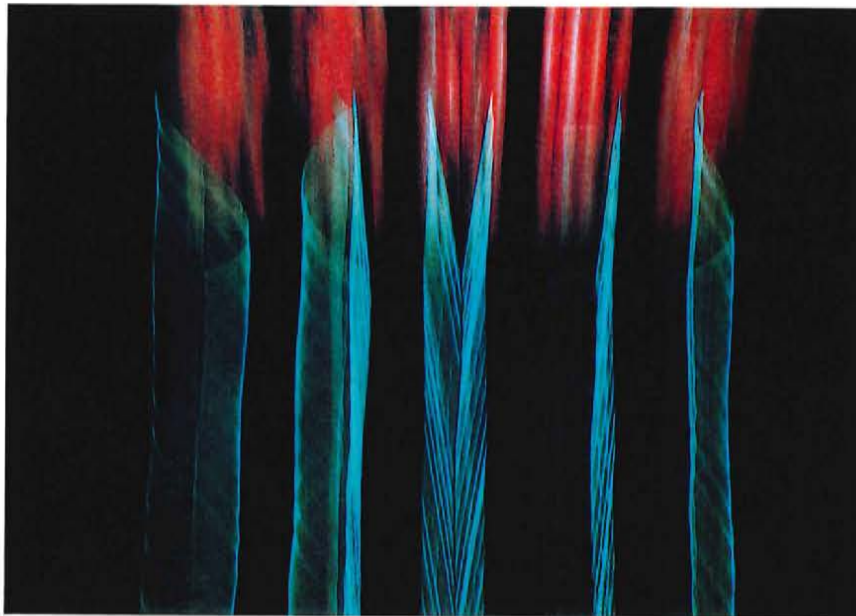


CLIFFORD OTO Slam Dunk, 1990

Motion slows at the peak of an action that reverses, such as this leap into the air. At that moment of slower movement, the shutter speed doesn't have to be as fast to show the motion sharply. Here the boy jumps from an overturned garbage can for a slam dunk.

The key word in photographing action is anticipation. What direction is the subject moving? Where should you be focused? When might an interesting moment occur? Think about what is going to happen, rather than trying to catch up to what has already happened.

SHUTTER SPEEDS TO STOP ACTION PARALLEL TO THE FILM PLANE				
Type of Motion	Speed	Camera-to-Subject Distance		
		25 feet	50 feet	100 feet
Very fast walker	(5 mph)	1/125	1/60	1/30
Child running	(10 mph)	1/250	1/125	1/60
Good sprinter	(20 mph)	1/500	1/250	1/125
Speeding car	(50 mph)	1/1000	1/500	1/250
Airplane		_____	_____	1/1000

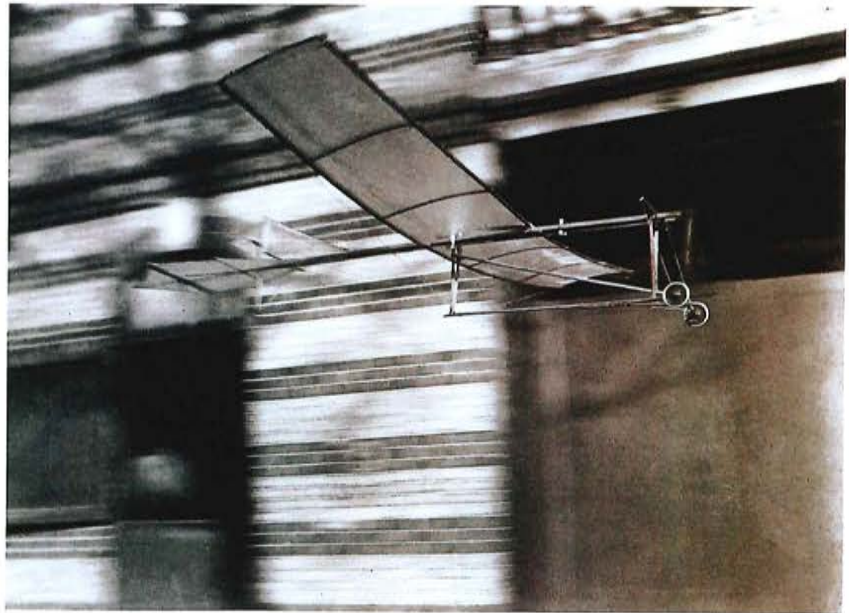


HARRY CALLAHAN
Untitled, c. 1941

An inveterate experimentalist, Callahan used camera movement and long exposures at night to explore an entirely abstract world of color and shape. Made at the very beginning of his long career, this color work went unseen for decades during which the art world was unwilling to take color photography seriously. (©The Estate of Harry Callahan, Courtesy Pace/MacGill Gallery, New York.)

JACQUES-HENRI LARTIGUE
Un modèle réduit en vol, Paris, 1909

Early photographers had no choice but to pan the camera to stop fast-moving objects. Film and cameras available to Lartigue, just fifteen when he made this photograph, didn't permit fast shutter speeds. To stop the action here he swung the camera from left to right with the subject as he released the shutter. The early airplane model was recorded in focus, while the stationary wall behind it blurred.



in used camera
to explore an
ape. Made at
his color work
the art world
y seriously.
easy



THOMAS STRUTH Stanza di Raffaello II, Rome, 1990
A long exposure blurred the people who were moving, while rendering sharply those who were standing still. Struth used the chaos of the group below to contrast with the calm orderliness of the figures painted on the walls.



NUBAR ALEXAMIAN
Patty Larkin,
Philadelphia, 1994

A fast lens, one that opens to a wide aperture, is useful in dim light, such as indoors. A wide aperture lets you set a shutter speed fast enough so that you don't have to use a tripod to keep the camera steady. It is also useful when photographing action by letting you shoot at a fast enough shutter speed to show moving subjects sharply.

The aperture (the size of the lens opening) controls the brightness of the light that reaches the film. The aperture works like the pupil of an eye; enlarging or contracting the aperture admits more light or less. In a camera lens, the diaphragm—a ring of thin, overlapping metal leaves located inside the lens—is the mechanism that controls the size of the aperture. Its movable leaves can be opened wide to let in more light or closed down to let in less (see opposite).

The size of an aperture is indicated by its **f-number or f-stop**. On early cameras the aperture was adjusted by individual metal "stop" plates that had holes of different diameters. The term stop is still used to refer to the aperture size, and a lens is said to be "stopped down" when the size of the aperture is decreased.

Part of the standardized, full-stop series of numbers on the f-stop scale is shown in the box, right. The smaller numbers correspond to the larger apertures, and admit the most light. Each larger-numbered full f-stop (shown in bold face) admits half the light of the previous one. A lens that is set at **f/4** admits half as much light as one set at **f/2.8** and only a quarter as much as one set at **f/2**. (Notice that f-stops have the same half or double relationship that full-stop shutter-speed settings do.)

The full-stop numbers continue in both directions. Wider apertures, for example **f/1** or **f/0.7**, are possible but such lenses are too expensive for general use. Smaller ones—**f/32**, **f/45**, **f/64**, **f/90**—are seen only on specialized lenses. The change in light over the full range of f-stops is large; a lens whose aperture is stopped down to **f/64** admits less than 1/4000 of the light that comes through a lens set at **f/1**.

Few lenses provide a range of apertures greater than eight stops. A general-purpose lens for a 35mm camera, for example, might run from **f/1.4** to **f/16**. A camera lens designed for a large view camera might stop down to **f/64** but open up only to **f/5.6**. **NOTE:** The widest possible aperture on your lens may not be a standard full stop. A lens's f-stops may begin with a setting such as **f/1.2**, **f/3.5**, or **f/7.7**, then proceed in the standard full-stop sequence.

Lenses are often described as fast or slow. These terms refer to the width of the maximum aperture for the lens. A lens that opens to **f/1.4** opens wider and is said to be faster than one that opens only to **f/2**. Faster lenses allow you to shoot more easily in low light or at higher shutter speeds. They also are more expensive than slower lenses.

F-STOPS: CONTROLLING THE SIZE OF THE LENS APERTURE

Lenses come with a limited range of apertures (f-stops) usually marked in full stop increments. Each full stop lets in half the amount of light as the one before it and double that of the one after it. (Note that the smaller the f-number, the larger the lens opening.) Apertures are continuously variable, meaning they may be set anywhere in between full stops. But your lens or display may only indicate one-half or one-third stop increments.

This chart shows a range of full and fractional aperture openings. Not all cameras number the fractional apertures exactly as shown. If your camera allows you to choose among different ways to set apertures, using full stops will be less confusing while you learn photography.

Apertures in full stops	1/2 stop	1/3 stop
f/1.4	f/1.4 f/1.7	f/1.4 f/1.6 f/1.8
f/2	f/2 f/2.3	f/2 f/2.2 f/2.5
f/2.8	f/2.8 f/3.4	f/2.8 f/3.2 f/3.5
f/4	f/4 f/4.7	f/4 f/4.5 f/5
f/5.6	f/5.6 f/6.7	f/5.6 f/6.3 f/7.1
f/8	f/8 f/9.5	f/8 f/9 f/10
f/11	f/11 f/13	f/11 f/13 f/14
f/16	f/16 f/19	f/16 f/18 f/20
f/22	f/22 f/27	f/22 f/25 f/28

More about . . .

- Fast lenses, page 64
- Relationship between f-stops and shutter speeds, pages 28–29

SIZE

Size of aperture in full stop
 The amount of light that passes through the lens opening is controlled by the f-number. The higher the f-number, the smaller the opening and the less light that is let in. On this lens, f/2.8 is the largest opening and lets in the most light. As the numbers get bigger (4, 5.6, 8), the aperture size gets smaller and the amount of light admitted decreases.

1/3 stop

f/1.4
 f/1.6
 f/1.8
 f/2
 f/2.2
 f/2.5
 f/2.8
 f/3.2
 f/3.5
 f/4
 f/4.5
 f/5
 f/5.6
 f/6.3
 f/7.1
 f/8
 f/9
 f/10
 f/11
 f/13
 f/14
 f/16
 f/18
 f/20
 f/22
 f/25
 f/28

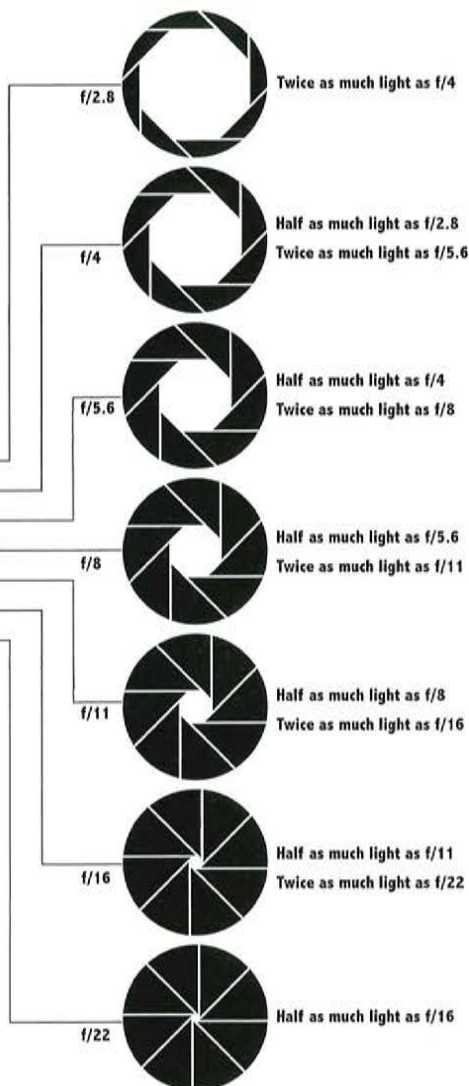
About . . .
 See, page 64
 ship between
 and shutter
 pages 28–29

The size of the lens opening—the aperture or f-stop—controls the amount of light that passes through the lens. The lens shown here has apertures from f/2.8 to f/22. Each setting is one stop from the next; that is, each lets in twice as much light as the next smaller opening, half as much light as the next larger opening.

The higher the f-stop number, the smaller the lens opening and the less light that is let in. On this lens, f/2.8 is the largest opening and lets in the most light. As the numbers get bigger (4, 5.6, 8), the aperture size gets smaller and the amount of light admitted decreases.



NOTE: Some lens barrels no longer display the apertures as shown above. Rather than twisting a ring on the lens to set the aperture, you dial in the setting on the camera body. Regardless of how you change the aperture, though, you are still changing the size of the lens opening and thus the intensity of light that strikes your film or computer chip.



WHERE APERTURE SETTINGS ARE DISPLAYED ON VARIOUS CAMERAS



In the camera's viewfinder



In the data-panel readout



On the lens barrel



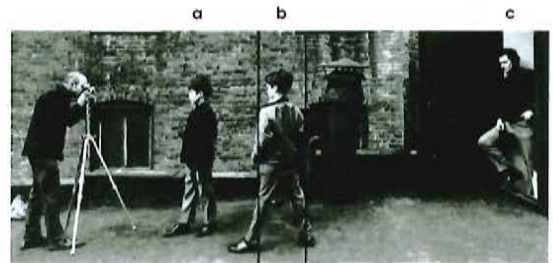
LARGE APERTURE, LESS DEPTH OF FIELD



The smaller the aperture size, the more that a scene will be sharp from near to far. As the aperture is stopped down and gets smaller, more of the background and foreground in a given scene becomes sharp. The area of acceptable sharpness in a picture is known as the depth of field.

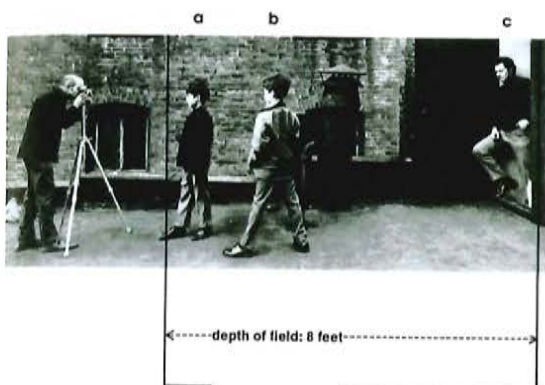
The two larger photographs shown on these pages were taken under identical conditions but with different aperture settings. In the photograph above, the diaphragm was opened to its widest aperture, $f/2$, and the lens was focused on the boy (b) about seven feet away (see side view of photographer Duane Michals and his subjects, above right). The resulting photograph shows a shallow depth of field; only the middle boy (b) is sharp, while both the boy in front (a) and the man behind (c) appear out of focus. Using a small aperture, $f/16$, gives a different picture (opposite page). The lens is still focused on the middle boy, but the depth of field has increased enough to yield sharp images of the other figures as well.

Some types of cameras let you see the extent of the depth of field. With a view camera, you look directly through the lens. As the lens is stopped down, the increasing sharpness is visible on the ground-glass viewing screen. A single-lens reflex camera also allows you to look directly through the lens. But most models, regardless of which aperture is selected, will automatically show the scene through the widest aperture. They are designed this way because looking through the lens at its widest aperture gives you the brightest possible view for framing and focusing.



Depth of field is the area from near to far in a scene that is acceptably sharp in a photograph. As the aperture changes, the depth of field changes too. If your lens has a depth-of-field scale (many do not), you can use it to estimate the extent of the depth of field. On this lens, the bottom row shows the aperture (f-stop) to which the lens is set. The top ring shows the distance on which the lens is focused. The paired numbers on the middle ring correspond to f-stops and show the nearest and farthest distances the depth of field covers when the lens is set at various f-stops.

Here, the lens is set to its widest aperture, $f/2$, and focused on the middle boy (see side view of scene above), who is at a distance of 7 ft. The depth of field extends from more than 6 ft to less than 8 ft; only objects within that distance will be acceptably sharp. If depth of field is shallow, as it is here, a lens can be sharply focused on one point and still not produce a picture that is sharp enough overall.



When the lens is stopped down to its smallest aperture, here $f/16$, the depth of field increases. Almost the entire scene—everything between about 5 ft and 13 ft—is now sharp at the same focusing distance of 7 ft. **NOTE:** The bigger the f -stop number, the smaller the lens opening (you can see this illustrated on page 25); $f/16$ is a smaller aperture than $f/2$.

More about . . .

- Depth of field, pages 56–61
- Camera types, pages 30–33



SMALL APERTURE, MORE DEPTH OF FIELD



Looking through the widest aperture also means you see the scene with the least possible depth of field. Some cameras provide a depth-of-field preview button that stops down the lens so that the viewfinder image shows the depth of field at the aperture you have selected. However, stopping down the lens reduces the brightness of the viewfinder image; in dim light or at a very small aperture, that image may become too dark to be seen clearly.

Other camera designs show the scene differently. Rangefinder and point-and-shoot designs have a window in which you frame your shot. Through this simple viewfinder, objects at all distances appear equally sharp. Twin-lens reflex cameras show depth of field at the fixed aperture of the viewing lens. Only single-lens reflex and view cameras give you a way to check depth of field visually at all apertures.

Some lenses have a depth-of-field scale from which you can estimate the depth of field. This scale is printed on the lens as paired numbers that bracket the distances of the nearest and farthest points of the depth of field. As the lens is focused and the f -stop set, the scale shows approximately what part of the picture will be in focus. (See the lenses at left.) The farthest distance marked on the lens appears as the symbol ∞ . When the infinity mark appears within the depth of field shown on the scale, all objects beyond the closest distance in focus will be sharp.

Both shutter speed and aperture affect the amount of light entering the camera. To get a correctly exposed picture (one that is neither too light nor too dark), you need a combination of shutter speed and aperture that lets in the right amount of light for a particular scene and particular film speed.

Equivalent exposures. Once you know a combination of shutter speed and aperture that will let in the right amount of light, you can change one setting as long as you change the other in the opposite way. When using full stops, each aperture setting lets in twice as much light as the next smaller opening (larger-numbered setting). Each shutter speed lets in twice as much light as the next faster speed. (See photographs at right.) You can use a larger aperture if you need a faster shutter speed, or you can use a smaller aperture if you want a slower shutter speed. The same amount of light is let in by the combination of $f/16$ aperture at a $1/8$ -second shutter speed, as by $f/11$ at $1/15$ second, and so on. This back-and-forth balance is called a reciprocal relationship.

Shutter speed and aperture also affect

sharpness, but act differently. Shutter speed affects the sharpness of moving objects; aperture affects depth of field, sharpness from near to far. Their different effects are shown in the three photographs at right. In each, the lens was focused on the same point, and shutter speed and aperture settings were balanced to admit the same total amount of light into the camera. But the equivalent exposures resulted in very different photographs.

In the first picture, a small aperture produced considerable depth of field that rendered background details sharply. However, the shutter speed needed to compensate for this tiny aperture had to be so slow that the rapidly moving flock of pigeons appears only as indistinct ghosts. As the aperture was set wider and the shutter speed faster in the middle photo, the background is less sharp, but the pigeons are visible, though still blurred. At far right, a still larger aperture and faster shutter speed sacrificed almost all background detail, but the birds are now very clear, with only a few wing tips still blurred.

A BUCKET OF LIGHT

The quantity of light that reaches film inside a camera (or the CCD chip inside a digital camera) depends on both aperture size (f-stop) and exposure time (shutter speed).

How long does it take to fill a one-gallon bucket with water flowing from a faucet? That depends on how wide the faucet is open and how long the water flows. If the wide-open faucet fills the bucket in two seconds, then the same bucket will be filled in 4 seconds from a half-open faucet. But regardless of how long it takes to fill the bucket, the bucket always holds just one gallon of water.

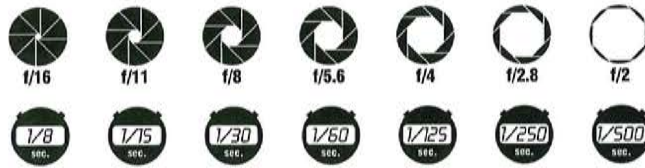
Film and CCD chips are like these one-gallon buckets. To be properly filled with light (exposed), each always requires one "gallon" of light.

If the correct exposure for a scene is 2 sec at $f/4$, you get the same total amount of exposure with twice the length of time (next slower shutter speed) and half the amount of light (next smaller aperture)—4 sec at $f/5.6$.

Compared to the top illustration, the same amount of water is delivered when half the volume of water runs for twice the length of time.



Small aperture (deep depth of field), slow shutter speed (motion blurred). In this scene, a small aperture ($f/16$) produced great depth of field; the nearest paving stones as well as the farthest trees are sharp. But to admit enough light, a slow shutter speed ($1/8$ sec) was needed; it was too slow to show moving pigeons sharply. It also meant that a tripod had to be used to hold the camera steady.



Equivalent exposures. Each combination here of f-stop and shutter speed produces the equivalent exposure (lets in the same amount of light) but produces differences in depth of field and motion.



Medium aperture (moderate depth of field), medium shutter speed (some motion sharp). A medium aperture (f/4) and shutter speed (1/125 sec) sacrifice some background detail to produce recognizable images of the birds. But the exposure is still too long to show the motion of the birds' wings sharply.

More about . . .

- Aperture, pages 24–27
- Depth of field, pages 26–27
- Shutter speed, pages 18–23



Large aperture (shallow depth of field), fast shutter speed (motion sharp). A fast shutter speed (1/500 sec) stops the motion of the pigeons so completely that the flapping wings are frozen. But the wide aperture (f/2) needed gives so little depth of field that the background is now out of focus.

Choosing a camera will be easier if you first decide what kind of pictures you want to take, then think about which basic camera design best fits your needs. If your picture taking consists of occasional snapshots of family, friends, or sightseeing views, then an inexpensive, nonadjustable, point-and-shoot camera may be satisfactory.

If you are a photography student, a serious amateur, or just someone who would like to learn more about photography, you will want an adjustable camera. For most people this is a 35mm (thirty-five millimeter describes the film size used) single-lens reflex camera. A camera may have automatic features, but at a minimum it should also give you the option of manually selecting the focusing distance and either the shutter speed or aperture, preferably both. You also want a camera that accepts

interchangeable lenses.

NOTE: Before you buy a camera and lens, be sure to read about lenses in Chapter 3. Lens selection is equally important in your choice of a camera.

Shop around to compare prices, accessories, and service. Make sure you like the way the camera fits in your hands, and that buttons and knobs are conveniently placed and easy to manipulate. With the more automatic models, see if it is convenient to override the automatic features. If you wear glasses, make sure you can see the entire image.

You may be able to find a good used camera at a considerable saving, but look over used equipment carefully. Avoid cameras with dents, scratched lenses, rattles, or gouged screw heads that could indicate a home repair job. A reputable dealer will

exchange a camera, new or used, if your first roll of film is unsatisfactory. Examine that first roll carefully for scratches, soft focus, or other signs of trouble.

The size of the film used determines the size of the camera itself and the quality of the image the camera produces. Obviously, the smaller the film format, the smaller the camera can be. High-quality images can be produced by 35mm film, which is less than 1 1/2-inches wide. But a 35mm negative, for example, has to be enlarged much more than a 4 x 5-inch negative to make the same size print. The larger the negative, the sharper, smoother, and more detailed any image will be rendered. The photographs on these and the following two pages are reproduced at the size of the film used by each camera pictured.

SINGLE-LENS REFLEX CAMERAS



A single-lens reflex (SLR) camera shows you the scene directly through the lens. The camera has a mirror and pentaprism that let you see through the taking lens to focus the scene and compose it exactly. With some cameras you can preview how much of the scene will be sharp, from foreground objects to a distant background. Most SLRs use 35mm film, like the single frame of film shown above. Some single-lens reflex cameras use larger film sizes. See the page opposite for medium-format SLR cameras that use 2 1/4-inch film.

Advantages: Since the viewing system uses the camera lens itself, it works well with all lenses from wide angle to supertelephoto; whatever the lens sees, you see—and that is what the film records. This is especially useful for close-ups. An exposure meter built into the camera measures the light passing through the lens, with the area being metered defined in the viewfinder.

Disadvantages: A single-lens reflex is heavier and larger than a rangefinder camera (see following page)

that uses the same size film. The camera is relatively complex, with more components that may need repair. Its moving mirror makes a comparatively loud clack during exposure, especially in the medium-format models; this is a drawback if you are stalking wild animals or self-conscious people. When the mirror moves up during exposure, it momentarily blacks out the viewing image, also a distraction in some situations. And the motion of the mirror and shutter may cause vibrations that make the camera more difficult to hold steady at slow shutter speeds.

Choosing a camera: 35mm single-lens reflex cameras are the most popular when a buyer moves beyond snapshot level. SLRs offer the greatest variety of interchangeable lenses, plus features such as through-the-lens metering and built-in flash.

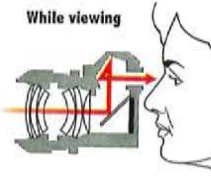
Automatic features abound: automatic exposure, focus, flash, and film winding are standard on many models. Some cameras focus as soon as you put your eye to the viewfinder and follow your eye movements to focus automatically in whatever direction you are looking. Stop for a moment to think about what features will be really useful to you before you pay extra for some special feature you might need only once in a while.

Make sure the camera allows you to manually override automatic features when you want to make exposure and focus choices yourself. For example, some cameras automatically set the film speed for you by reading the DX coding on the film cassette. That's convenient, but it's best to have a camera where you can override this feature when you want to select a film speed different from the nominal one.

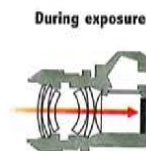
Also consider how convenient it is to select or override automatic features. Does the camera have easy-to-adjust, conveniently located knobs and dials or tiny, difficult-to-access, and even-harder-to-read menus?

The 35mm film format produces a relatively small negative, 1 x 1 1/2 inches (24 x 36mm). You can make high-quality enlargements from 35mm negatives, but you need carefully exposed and processed negatives to do so. Many types of film, both black-and-white and color, are available in 35mm.

While viewing



During exposure



A single-lens reflex camera has a viewing system that is built around a mirror. While viewing, light coming through the camera lens is reflected by this mirror up to a viewing screen, then usually travels to a five-sided pentaprism that turns the inverted image around so it appears the correct way to the eye (diagram, above left). When the shutter is released, the mirror first swings up, permitting light to reach the shutter and film at the back of the camera (diagram, above right). The image viewed through the lens is the same as the image produced on the film.

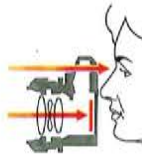
RANGEFINDER/VIEWFINDER CAMERAS

A viewfinder camera shows you the scene through a small window (the viewfinder). The viewfinder is equipped with a simple lens system that shows an almost—but not quite—exact view of what the picture will be. Many inexpensive point-and-shoot cameras have a viewfinder plus automatic focus.

A rangefinder camera has a viewfinder, plus a coupled rangefinder that lets you focus the camera manually as you view the scene. Most rangefinder and viewfinder cameras use 35mm film; a few, like the one below, right, use other film sizes.

Advantages: The camera is compact, lightweight, and fast handling. Compared to a single-lens reflex camera, it has few parts that move during an exposure, so it is quieter and less subject to vibration during operation. A high-quality rangefinder camera has a bright viewfinder image, which makes it easy to focus quickly, particularly at low light levels where other viewing systems may be dim. Wide-angle lenses are likely to be sharper than those made for reflex cameras because reflex cameras need a more complex design to provide clearance for the reflex mirror.

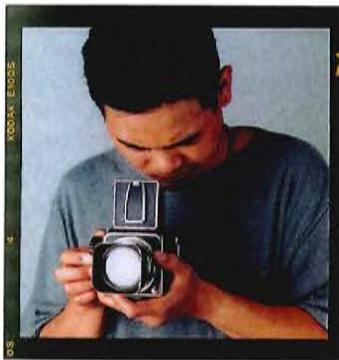
Disadvantages: Because the viewfinder is in a different position than the lens that exposes the negative, the camera suffers from an inherent defect called parallax that prevents you from seeing exactly what the lens sees. The closer the subject to the camera, the more evident the parallax. Better cameras correct to some extent for parallax. Because complete correction is impossible, a viewfinder camera is a poor choice for close-up work. Even when the edges of the picture are corrected for parallax, the alignment of objects will be different because they are seen from slightly different angles by the viewfinder and the lens that exposes the film.



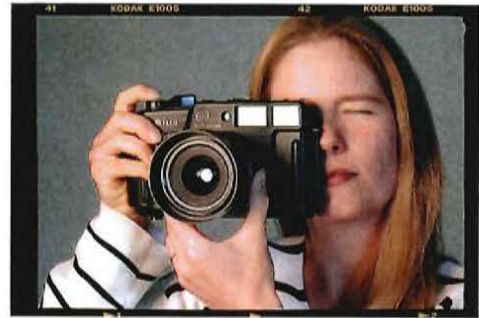
In a rangefinder or viewfinder camera, the image goes directly from the lens to the film but travels through a separate viewfinder to the eye. Because you aren't looking through the taking lens, you must accept some parallax error (see above) and depend for focus on a rangefinder, an autofocus system, or a simple distance scale.



Choosing a camera: A 35mm rangefinder camera with adjustable controls gives you more flexibility than a simple point-and-shoot model. You focus and set the exposure yourself, or with some models have the option to do so automatically. A high-quality 35mm rangefinder camera has long been a favorite of experienced photographers who want to work inconspicuously and quickly. They value the camera's dependability and its fast and precise focusing.

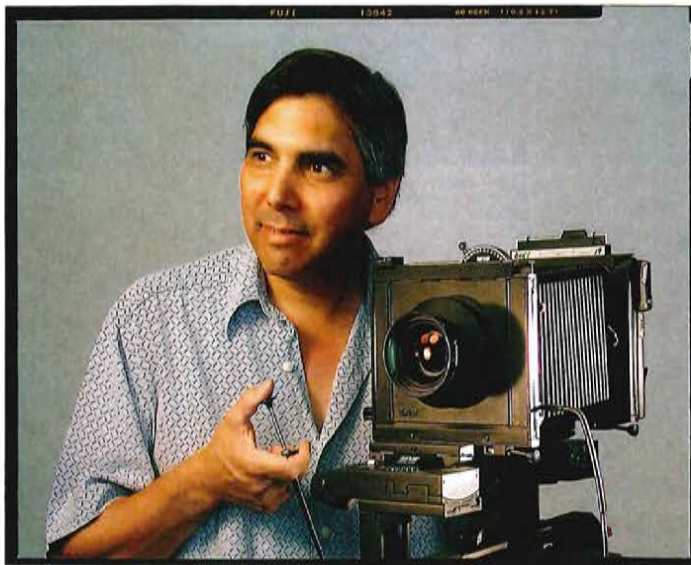


Medium-format single-lens reflex cameras are popular with photographers who want a negative larger than 35mm with the versatility of a single-lens reflex—fashion or advertising photographers, for example. Not only are lenses interchangeable, but sometimes the camera's back is too; you can expose part of a roll of black-and-white film, remove the back, and replace it with one loaded with color film or designed for digital capture. These cameras are bigger, heavier, and noisier than 35mm single-lens reflex cameras—and the price is often higher, too. Some cameras make a 6 x 6cm (2 1/4-inch square) negative, like the film frame shown above; some models have a rectangular format, such as 6 x 7cm (2 1/4 x 2 3/4 inches) or 6 x 4.5cm (2 1/4 x 1 5/8 inches).



Choosing a camera: Medium-format rangefinder cameras combine relatively large film with a compact rangefinder design. They are light weight, have a quiet shutter and a bright, easy-to-focus viewfinder. Some models have interchangeable lenses. They are popular with professionals and others who want a camera that is easy to carry in the field, but that delivers a high-quality negative larger than 35mm. The film frame above is 6 x 9cm in size.

VIEW CAMERAS



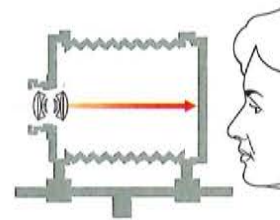
A view camera has direct, through-the-lens viewing and a large image on a viewing screen. It is the simplest and oldest basic design for a camera. A view camera is built something like an accordion, with a lens at the front, a ground-glass viewing screen at the back, and a flexible bellows in between. You focus by moving the lens or the back forward or back until you see a sharp image on the ground glass.

Heavy, bulky, and slow to operate, the view camera is still the camera of choice for architectural photography, studio work, or any use where the photographer's first goal is carefully controlled, technically superior pictures.

Advantages: The image on the ground glass is projected by the picture-taking lens, so what you see is exactly what will be on the negative; there can be no parallax error (as in a rangefinder camera, previous page) and you can preview the depth of field at the selected aperture. The ground glass is large, and you can examine it with a magnifying glass to check sharpness in all parts of the picture.

The film size is also large (4 x 5, 5 x 7, 8 x 10 inches or larger), which produces sharp detail. The camera parts are independently adjustable; you can change the position of lens and film relative to each other so that you can more precisely control focus or perspective. Each picture is exposed on a separate piece of film, so you can give negatives individual development. Digital capture backs are also available.

Disadvantages: The cameras are bulky and heavy, and almost all require using a tripod. They are slow to use. You must set up and focus first, then insert the film to make the exposure. The image projected on the ground glass is not very bright. To see it clearly you must put a focusing cloth over both your head and the back of the camera. The image you see on the viewing screen comes directly from the lens, so it is upside down, with left-side objects on the right, right-side objects on the left. You get used to this, but it is disconcerting at first.



In a view camera, the light comes directly from the subject, through the lens to a ground-glass viewing screen. The image you see comes directly from the lens, so it is upside down. As an aid in composing and aligning your subject, the ground glass may be etched with a square grid. The film frame on the left is 4 x 5 inches.



GLEN FISHBACK Edward Weston Using His 8 x 10 View Camera, Point Lobos, 1937

More about . . .

- View cameras, pages 308-327

TWIN-LENS REFLEX CAMERAS



Twin-lens reflex (TLR) cameras also deliver a negative larger than 35mm, usually 6 x 6cm (2 1/4 inches square), pictured above. With most models, lenses are not interchangeable, and few models are currently manufactured. TLRs are quiet, reliable, and generally less expensive than other types of medium-format cameras.

Finding an inexpensive used TLR is a good way to experiment with larger-format film. They are good for portraits or other fairly static photographic situations. Don't expect the speed of a rangefinder or the flexibility of a single-lens reflex.

POINT-AND-SHOOT CAMERAS



Point-and-shoot cameras, also called compact cameras, dominate the low-priced end of the market. Many use 35mm film (or an even smaller format called APS) and are usually mercilessly automatic: they read the speed of the film you put in the camera, advance it to the first frame, focus, calculate exposure, trigger a built-in flash if you need it, advance the film after each exposure, and rewind at the end of the roll. Many are nonadjustable and can only be operated automatically. Better-quality ones have a zoom lens and offer some control of focus, exposure, or flash functions. Point-and-shoot cameras are small, inexpensive, and easy to use. They often take excellent pictures, but they are easy to outgrow as soon as you become more seriously interested in photography.

More about . . .

- Digital cameras, see pages 202–205

DIGITAL CAMERAS



Digital cameras do not use film to make images; some do not even look like film-based cameras. They generate photographs by focusing a scene through a lens, like traditional cameras. But instead of exposing film, the light rays fall on a computer chip that captures a photograph by writing it onto a memory card in the camera. The resulting image, in the form of electronic 1s and 0s, can then be transferred to a computer for editing, printing, or distribution on the Internet.

Advantages: With many digital cameras, you can see what your lens sees in a small LCD monitor that is like a tiny television screen on the camera back. (The photographer above is looking into the monitor to frame his picture.) Once you've taken the picture, you can view it on the same LCD monitor, and immediately erase it if you don't like it. Or without developer or darkroom, you can print out images on photographic-quality paper using a computer and printer. Some cameras bypass computers and connect to printers directly. Others can generate an instant print on the spot. And since digital storage is reusable, you don't need to purchase film or pay for processing.

Disadvantages: Rapidly changing technology makes digital cameras obsolete relatively quickly. A camera with quality that rivals film is more expensive than traditional cameras. While film is available around the world, digital storage devices for cameras are not. When you travel, you may need to carry a computer into which you can download your pictures, or keep a costly storage device in your camera bag. Stored photographs require a computer, camera, or other device to view.

Special-purpose cameras fill a variety of needs. You can use them to take photographs underwater, make a print right away, or produce a non-standard format.

Underwater cameras, for example, allow you to take pictures beneath the sea. Some models let you dive to only a few feet below the surface, others much deeper.

Panoramic cameras take wide views of a scene. Some panoramic cameras use a fixed lens that takes in a wide view. With others, the lens swings in an arc from one side of a scene to the other, making an exposure onto film that is held in a curve.

Instant cameras produce a print within a few seconds, if not instantly. Polaroid and Fuji make instant films for their own cameras, as well as for view cameras.

Stereo cameras take two pictures at the same time through side-by-side lenses. The result, a stereograph, gives the illusion of three dimensions when seen in a stereo viewer.



JAMEY STILLINGS Sea Turtle and Boy, 1999

Underwater cameras are mostly for use underwater but also for situations where a camera is likely to get extremely wet. Some cameras are only water resistant, rather than usable underwater. In this case the photographer needed a camera that could be completely submerged to make each of the photographs that were digitally blended to make this composite. See how it was made on page 234.



TIMOTHY HEARSUM Bagdad, California

Panoramic cameras make a long, narrow photograph that can be interesting, for example, for landscapes. Some of these cameras crop out part of the normal image rectangle to make a

panoramic shape. Others use a longer-than-normal section of roll film or rotate the lens from side to side during the exposure.

More about . . .

• Instant cameras, pages 76–77, 174–175



Tripod



Monopod



Tabletop tripod



To hand hold a camera, support the camera from underneath with your left hand. The right hand presses the shutter and advances the film. Press both arms against your body, relax, breathe out, and squeeze the shutter release gently to avoid jerking the camera.



With the camera held vertically, the left or right hand can support the camera. Keep that arm against your body to steady the camera.



With a long lens or at a relatively slow shutter speed without a tripod, try to find some extra support such as a stool, chair, or other object to brace yourself against.



A tripod provides the steadiest support for a camera. It is essential for slow shutter speeds. Some tripods have a center shaft that can be removed and reversed; the tripod head and camera can then hang upside down so the camera can be brought very low to the ground. A cable release lets you trigger the shutter without jarring the camera. Leave a little slack in the cable instead of pulling it taut.

MINIMUM SHUTTER SPEEDS FOR HAND HOLDING A 35MM SLR CAMERA

Lens Focal Length	Minimum Shutter Speed
24-28mm	1/30 sec
35-50mm	1/60 sec
85-100mm	1/125 sec
135-200mm	1/250 sec
300mm	1/500 sec
600mm	1/1000 sec

Keep the camera steady during an exposure.

Even with the finest camera and lens, you won't be happy with the pictures you take if you don't keep the camera steady enough during the exposure. Too much camera motion during exposure will cause sharpness problems ranging from slight image softness to hopeless blurring.

How much camera movement is too much? That depends on several factors, including how much the image will be enlarged. Any blur is more noticeable in a big enlargement. The camera's design affects how much it moves during an exposure; SLRs are particularly prone to vibration. The slower the shutter speed, the more you have to worry about camera movement. The longer the focal length of the lens, the more movement becomes apparent. Longer lenses magnify objects on the film—and camera movement too.

If you are hand holding a camera, use a shutter speed faster than the focal length of the lens: for example, 1/60 second or faster with a 50mm lens, 1/250 second or faster with a 200mm lens, (see chart below left). Squeeze the shutter release gently and smoothly. If you can, brace your body in some way by leaning your back against a wall or your elbows on a table, fence, or other support.

Using a tripod and cable release is the best way to prevent camera movement.

The tripod should be sturdy enough for the camera; if you balance a large, heavy camera on a flimsy, lightweight tripod, your camera can end up on the floor. On the other hand, if your tripod isn't very heavy, you are more likely to make a habit of carrying and using it. When making portraits, putting the camera on a tripod lets you take your eye away from the viewfinder and establish more rapport with your subject.

Tabletop tripods are sometimes useful; their very short legs can be steadied on a table or car fender or even against a wall. A monopod, a single-leg support, gives extra stability if you have to keep moving, for example, along a football sideline.

James Nachtwey's gentle manner and voice belie the violence and heartache he has recorded. A contract photographer for *Time* magazine, Nachtwey is one of the best-known and most widely respected photojournalists. He has covered wars and civil strife in El Salvador, Nicaragua, Lebanon, Sri Lanka, Afghanistan, Chechnya, Northern Ireland, Rwanda, South Africa, the West Bank and Gaza, Bosnia, and Kosovo.

Nachtwey taught himself photography, then began his career with four years on a newspaper. Black Star, a photo agency, helped him get assignments and publish pictures when he started freelancing. In 1986, he joined Magnum, the respected photo cooperative.

When arriving in a war zone, Nachtwey says, he first establishes a logistical base. This includes transport, communication (often involving an interpreter), and a place to stay. Lodging might be a hotel, a room with a local family, the floor of an abandoned bombed-out building, or a sleeping bag or blanket on the ground. If possible, he contacts a local newspaper or one of the international wire services to orient himself to the ongoing situation.

When photographing in tumultuous situations, Nachtwey uses patience and common sense. "Many photographers rush their images," says Robert Stevens, Nachtwey's editor at *Time*. "They arrive, see a subject in front of them, and start shooting. They often think they have recorded what is important in a few moments, but they haven't. It's important to take time and wait. Jim waits and waits until the time is right."

Many photographers forget about the background, Stevens explains, and end up with images where the background distracts from the most important part of the photo. Using a 35mm Canon single-lens reflex camera and a 17-35mm zoom lens, Nachtwey frames his photos in a deliberate but fast way, by shifting his body up or down, right or left to get elements the way he wants them. He ships his undeveloped color slide film or Tri-X black-and-white film directly to *Time*, so he rarely sees his pictures before they appear in the magazine.

Nachtwey works on the front lines, but he avoids reckless behavior. "I try to be aware of the changing dynamics of whatever situation I am in," he says. "I make split-second decisions, based on a combination of intuition and experience, calculated to enable me to do an effective job and survive. In the riskiest situations, I usually work alone, but sometimes with another, trusted colleague."

Emotional strength can be as critical as technique or tactics. How does he continue photographing while witnessing horror? "If you go with a camera to places where people are experiencing a great tragedy, you have a responsibility," he told one interviewer. "The value of the work is to make an appeal to the rest of the world, to create an impetus for change through public opinion. Public opinion is created through awareness. My job is to make people aware."

"I used to call myself a war photographer," he says. "Now I consider myself an antiwar photographer."



JAMES NACHTWEY Bardara, Somalia, 1992

"Nachtwey's photographs are always clean and striking compositions. . . . because he is honest and clear in his stance," writes historian Luc Sante. The photographer sees images such as this one of a woman preparing to bury her dead child, "as a visualization of the kind of hell on earth that can be created by human beings for human beings."



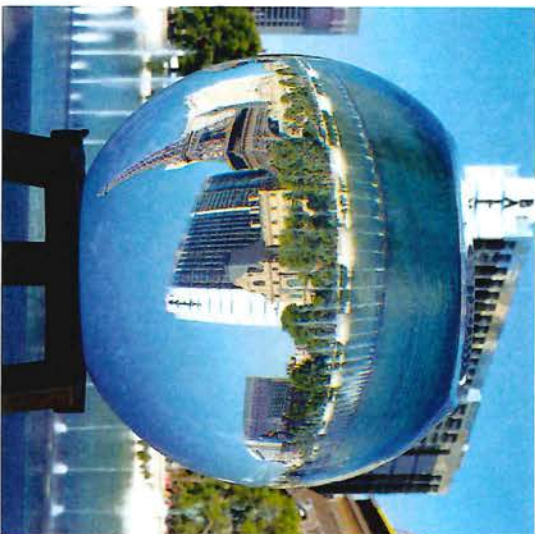
DAVID TURNLEY Nachtwey Under Fire

Photojournalist James Nachtwey takes the front line during a gun battle in South Africa. According to writer David Friend, fellow journalists say Nachtwey borders on being invincible under fire, almost as if shielded by a force field.

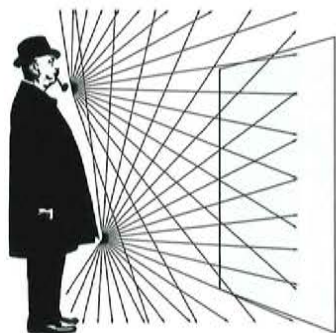


JAMES NACHTWEY Nicaragua, 1982

Nachtwey covers conflicts as they take place but also shows their impact on people's lives. For a Nicaraguan child, an abandoned tank provides a playground.



JULIE AHAND
Water Lenses, 2003
The simple lens
formed by a water-
filled fishbowl inverts
an image exactly the
way your camera's
more complex lens
does. Ahand uses the
device to comment on
water use in America's
arid southwest.



Light must be controlled if our eyes or our cameras are to form images of objects. You can't simply place a square of sensitized film in front of a subject and wait for an image to appear on the film. The light reflecting from the subject would hit the film in a random jumble, resulting not in a picture but in a uniform exposure over the entire surface of the film. Light acts both like rays and like waves. For simplicity's sake, this drawing shows it as rays—only a few coming from just two points on the man. But their random distribution over the film makes it clear that they are not going to produce a useful image. What is needed is some sort of light-control device in front of the film that will select and aim the rays, placing the rays from each part of the image where they belong, resulting in a clear picture.

A simple pinhole will form an image, but a lens forms a sharper one.

Lens focal length is probably the most important difference between lenses. The longer the focal length, the larger a subject will appear.

A viewer will almost always look first at the sharpest part of a photograph, the part on which you have manually focused or the camera has automatically focused.

How sharp an image appears is also affected by the depth of field, the area from near to far that is acceptably sharp in a photograph.

Perspective, the apparent size and shape of objects and the impression of depth, is affected not just by the lens you use but by where you position the lens.

You have options in selecting a lens. Here is help understanding them and then getting the most from your lens and camera.

From Pinhole to Lens 40

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Getting the Most from Your Camera and Lens.....65

All photographic lenses do the same basic job: they collect light emanating from a scene in front of the camera and project it as an image onto a piece of film (or onto a digital recording chip), at the back of the camera. This chapter explains how you can use lens focus (which adjusts the sharpest part of an image), lens focal length (which controls the magnification of a scene), lens aperture, and subject distance to make the kinds of pictures you want. Lenses for both film and digital cameras follow the same principles of optics.

Light acts in some ways like rays and in some ways like waves. Each point in any scene emanates waves or reflects rays in all directions. Although all the light reflected from a point or an object cannot produce an image, a selection of it can.

When reflected light reaches a barrier with a small pinhole in it, like that in the drawings on the far right, all but a few rays from each point are deflected by the barrier. Those few rays that do get through, traveling in straight lines from the subject, can make an image when they reach a flat surface, like the film at the back of a camera. The image is rotated upside down. Everything that was at the top of the subject appears at the bottom of the image on the film and everything at the bottom appears at the top. Similarly, left becomes right and right becomes left.

The trouble with a pinhole camera is its tiny opening. It admits so little light that very long exposures are needed to register an image on film. If the hole is enlarged, the exposure becomes shorter, but the image becomes much less sharp, like the center photograph at right.

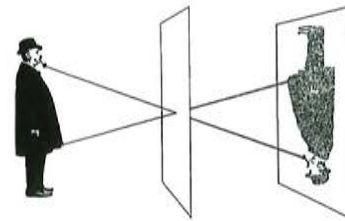
A pinhole, small as it is, actually admits a cluster of light rays. Coming at slightly different angles, these rays continue through the hole in slightly different directions. They fan out, so that when they hit the film the rays from a point on the subject make a tiny, blurry circle instead of forming a point again. As the size of the hole is increased, a larger cluster of light rays gets through to the film and makes a wider blurry circle. These circles overlap, so the wider each circle becomes, the less clear the picture will be.

A lens creates a sharp image with a relatively short exposure. To get sharp pictures, the image of a tiny point should also be a tiny point. But there is no way to achieve that with a pinhole camera. Even a very small opening, which admits little light and requires long exposure times, will not make a very sharp image. To admit more light and to make a sharper picture than even the smallest pinhole, a different method of image formation is needed. That is what a lens provides.

Photograph made with small pinhole



To make this picture, the lens of a camera was replaced with a thin metal disk pierced by a tiny pinhole, equivalent in size to an aperture of $f/182$. Only a few rays of light from each point on the

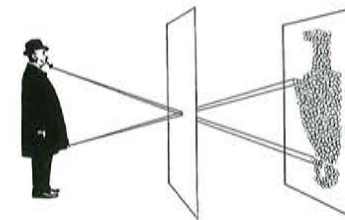


subject got through the tiny opening, producing a soft but acceptably clear photograph. Because of the small size of the pinhole, the exposure had to be 6 sec long.

Photograph made with larger pinhole



When the size of the pinhole was increased to $f/65$, the result was an exposure of only $1/5$ sec, but an extremely out-of-focus image. The larger hole let through more rays from each point on the

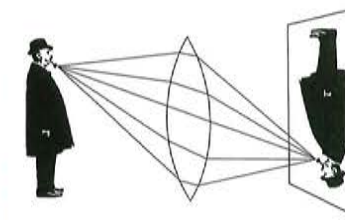


subject. These rays spread widely before reaching the film, making large circles that overlapped one another creating a very unclear image.

Photograph made with lens

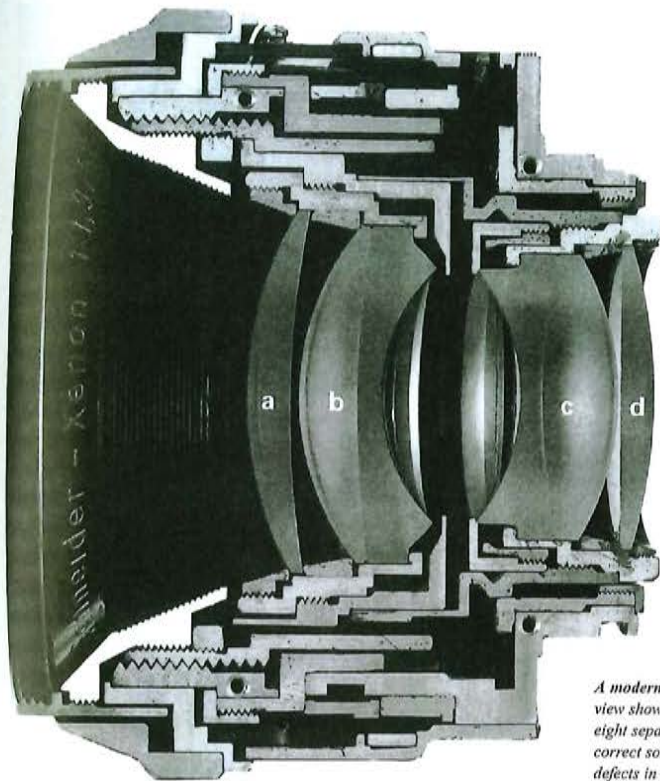


This time, using a simple convex lens with an $f/16$ aperture, the scene appeared sharper than the one taken with the smaller pinhole, and the exposure time was much shorter, only $1/100$ sec.

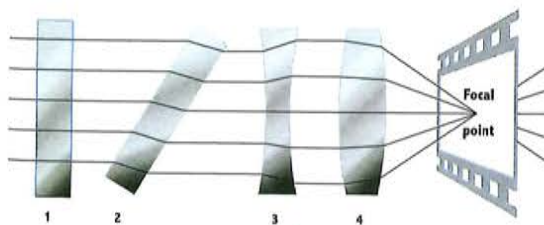


The lens opening was much bigger than the pinhole, letting in far more light, but it focused the rays from each point on the subject precisely so that they were sharp on the film.

More about . . .
• Pinhole photography, pages 296-297



A modern compound lens, as this cutaway view shows, is usually made up of six or eight separate lenses. Each lens is added to correct some of the aberrations or focusing defects in the others. This lens has six elements in four groups. An element is a simple lens with two curved sides or one curved and one flat side. A group may be a single element, like (a) or (d), or it may be two or more elements cemented together, like (b) and (c).



How refraction works is shown in this diagram of rays of light passing through four glass blocks. The rays, entering from the left, strike the first block head on (1) and therefore pass straight through. The next block (2) has been placed at an angle, so that the rays are bent, but as they exit the lens they are bent back to resume their former direction on the other side. The concave surfaces of the third block (3) spread the rays apart, but the last block (4)—a convex lens like the basic light-gathering lenses used in cameras—draws the rays back together so that they cross each other at the point of focus.

Most modern photographic lenses are based on the convex lens. Thicker in the middle than at the edges, a convex lens collects a large number of light rays from any single point on an object in front of the lens and refracts, or bends, them toward each other so that they converge at a corresponding single point (diagram, left) behind the lens. Each point in the scene (object point) corresponds to a point behind the lens (image point). Inside a camera, a strip of film is stretched flat across the film plane. All the points in a corresponding object plane in the scene will focus as points on the film, so the picture will be sharp for everything in that plane.

How does a lens refract (bend) light to form an image? When light rays pass from one transparent medium, such as air, into a different transparent medium, such as water or glass, the rays refract, or bend. Look at the shape of a spoon half submerged in a glass of water and you will see a common example of refraction: rays of light reflected by the spoon are bent by the water and glass so that part of the spoon appears displaced.

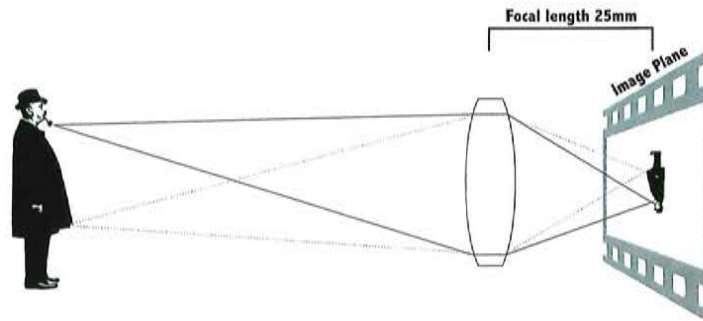
For refraction to take place, light must strike the new medium at an angle. If light rays are perpendicular to the surface when they enter and leave the medium (diagram left, 1), the rays will pass straight through. But if they enter or leave at an oblique angle (2), the rays will be bent to a predictable degree. The farther from the perpendicular they strike, the more they will be bent.

When light strikes a transparent medium with a curved surface, such as a lens, the rays will be bent at a number of angles depending on the angle at which each ray enters and leaves the lens surface. They will be spread apart by concave surfaces (3) and directed toward each other by convex surfaces (4). Rays coming from a single point on an object and passing through a convex lens (the simplest form of camera lens) will cross each other—and be focused—at the image point.

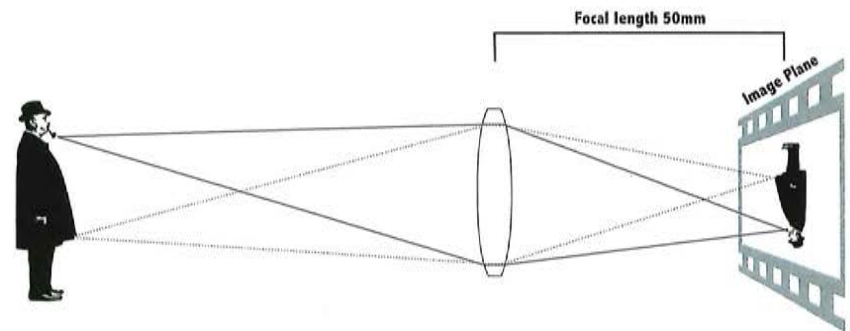
The most important way lenses differ is in their focal length. Since most cameras can be used with interchangeable lenses, you can choose which lens to buy or use. A lens is often described in terms of its focal length (a 50mm lens, a 12-inch lens) or its relative focal length (normal, long, or short). Technically, focal length is the distance between the lens's rear nodal point and the focal plane when the lens is focused at infinity. Theoretically, infinity is a distance immeasurably far away, beyond the edge of the universe. In photographic terms, infinity is any distance from which light enters the lens in parallel rays. Lens designers call the image point where those rays come together the focal point.

Focal length controls magnification, the size of the image formed by the lens. The longer the lens, the greater the size of objects in the image (see diagrams, right).

Focal length also controls angle of view, the amount of the scene shown on a given size of film (see photographs opposite). A long-focal-length lens forms a larger image of an object than a short lens. As a result, on a given size of film, the long lens includes less of the scene in which the object appears. If you make a circle with your thumb and forefinger and hold it close to your eye, you will see most of the scene in front of you—the equivalent of a short lens. If you move your hand farther from your eye—the equivalent of a longer lens—the circle will be filled by a smaller part of the scene. You will have decreased the angle of view seen through your fingers. In the same way, the longer the focal length, the smaller the angle of view seen by the lens.



A lens of short focal length bends light sharply. The rays of light focus close behind the lens and form a small image of the subject.



A lens of longer focal length bends light rays less than a short lens does. The longer the focal length, the less the rays are bent, the farther behind the lens the image is focused, and the more the image is magnified. The size of the image increases in

proportion to the focal length. If the subject remains at the same distance from the lens, the image formed by a 50mm lens will be twice as big as that from a 25mm lens.

More about . . .
 • Focal length and film size, page 44



17mm



28mm



50mm



85mm



135mm



300mm

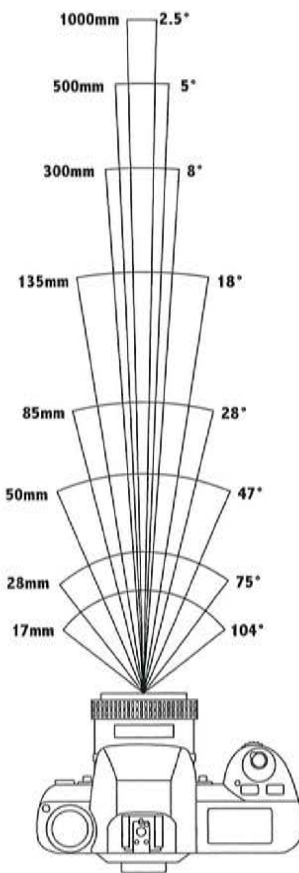


500mm



1000mm

The effect of increasing focal length while keeping the same lens-to-subject distance is an increase in magnification and a decrease in angle of view. Since the photographer did not change position, the sizes of objects within the scene remained the same in relation to each other. The diagram below shows the angle of view of some of the lenses that can be used with a 35mm camera.



A normal-focal-length lens, also called a standard-focal-length lens, approximates the impression human vision gives. One of the greatest of modern photographers, Henri Cartier-Bresson, who described the camera as "an extension of my eye," often used a normal lens. His picture opposite includes as much of the scene as you would probably be paying attention to if you were there, the angle of view seems natural, and the relative size of near and far objects seems normal.

A lens that is a normal focal length for one camera can be a long focal length for another camera. Film size determines what will be a normal focal length. The larger the size of the film format, the longer the

focal length of a normal lens for that format; it corresponds roughly to the measurement of a diagonal line across the film frame (see below).

A camera using 35mm film takes a 50mm lens as a normal focal length (50mm is about two inches). For a camera taking 6 x 7cm pictures on 120 film, a normal focal length is about 80mm. For a camera using 4 x 5-inch film, a 150mm lens is normal. The digital capture chips in many cameras are smaller than a 35mm frame, so their normal lenses are shorter than 50mm. Usage varies somewhat: for example, lenses from about 40mm to 58mm can be referred to as normal focal lengths for a 35mm camera.

A lens of normal focal length has certain advantages over lenses of longer or shorter focal length. Most normal lenses are faster; that is, they open to a wider maximum aperture, so can be used with faster shutter speeds or in dimmer light than lenses that do not open as wide. They often are less expensive, more compact, and lighter in weight.

Choice of focal length is a matter of personal preference. Some photographers habitually use a shorter focal length because they want a wide angle of view most of the time; others prefer a longer focal length that narrows the angle of view to the central objects in a scene. If you have a 35mm camera, a 50mm lens is a good focal length to start with.

A lens of a given focal length may be considered normal, short, or long, depending on the size of the film you are using. If the focal length of a lens is about the same as the diagonal measurement of the film (broken line), the lens is considered "normal." It collects light rays from an angle of view of about 50°.

The photograph on the right was taken with a 4 x 5 view camera using a 150mm lens. The diagonal measurement of 4 x 5-inch film is about 150mm, so a 150mm lens is considered a normal focal length for that size film.

But 150mm is much longer than the diagonal of 35mm film. A 150mm lens is considered a long-focal-length lens for a 35mm camera (see bottom photo, right).



View of 150mm lens on a 4 x 5-inch view camera



PETER VANDERWARKER Custom House Tower and Central Artery, Boston, 1989



View of 150mm lens on a 35mm camera



More about . . .

- Focal length and angle of view for 35mm camera lenses, page 43
- Focal length and film sizes, page 64



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HENRI CARTIER-BRESSON Place de l'Europe, Paris, 1932

Using a normal-focal-length lens is a way for the photographer to let the subject speak. Wide and long lenses make a stronger statement about the technical decisions a photographer must make, such as about perspective or depth of field.

Although Cartier-Bresson resisted discussing technique, it is known that he frequently used a normal (50mm) lens on his Leica camera. In this case, the size relationships in the frame—clues that give us our sense of perspective—are not unusual. We are drawn to what the photographer wants us to notice, the poetry of an instant snatched from the fabric of time itself. Cartier-Bresson called this a "decisive moment."

A long-focal-length lens provides greater image magnification and a narrower angle of view than a normal lens. For a 35mm camera, a popular and useful long focal length is 105mm. For a camera using 120 film for 6 x 7cm negatives, a popular comparable focal length is 150mm. For a 4 x 5 view camera, it is about 300mm.

Long lenses are excellent when you cannot or do not want to get close to the subject. In the photograph opposite, the photographer seems to be in the middle of the action even though he is not. Long lenses make it possible to photograph birds and animals from a distance. Medium-long lenses are excellent for portraiture; most people become self-conscious when a camera is too close to them so their expressions are often artificial. A long lens used at a moderate distance also avoids the kind of distortion that occurs when shorter lenses used close to a subject exaggerate the size of whatever is nearest the camera—in a portrait, usually the nose (see below).

Long lenses often produce better portraits. A moderately long lens (such as an 85mm or 105mm lens on a 35mm camera) used at least 6 ft from the subject (near right) makes a better portrait than a shorter lens used close to the subject (far right). Compare the size of nose and chin in the two pictures of the same subject. Photographing a person at too close a lens-to-subject distance makes features nearest the camera appear too large and gives an unnatural-looking dimension to the head.

There are subtle qualities that can be exploited when you use a long lens.

Because a long lens has less depth of field, objects in the foreground or background can be photographed out of focus so that the sharply focused subject stands out clearly. (See opposite page.) Also, a long lens can be used to create an unusual perspective in which objects seem to be closer together than they really are (see page 63).

Long lenses have some disadvantages, and the longer the lens the more noticeable the disadvantages become. Compared to lenses of normal focal length, they usually are heavier, bulkier, and more expensive, especially telephotos with wide apertures. Because they have relatively shallow depth of field, they must be focused accurately. They are difficult to use for hand-held shots since they magnify lens movements as well as subject size. The shutter speed for a medium-long lens, such as a 105mm lens on a 35mm camera, should be at least 1/125 second if the camera is hand held.

For a 200mm lens, you will need at least 1/250 sec. Otherwise, camera movement may cause blurring. A tripod or other support is your best protection against blurry photos caused by camera movement.

Photographers commonly call any long lens a telephoto, or tele, although not all long lenses are actually of telephoto design. A true telephoto has an effective focal length that is greater than the actual distance from lens to film plane. This design makes the lens shorter and easier to handle. A tele-extender or teleconverter contains an optical element that increases the effective focal length of any lens. It attaches between the lens and the camera body and magnifies the image from the lens onto the film. With these devices, the effective length of the lens increases, but less light reaches the film. A converter that doubles the lens focal length, for example, loses two f-stops of light.



Long lens, moderate distance



Short lens, up close

More about . . .

- Depth of field, pages 56-59
- Focal length and angle of view for 35mm camera lenses, page 43
- Focal length and film sizes, pages 44, 64
- Lens length and shutter speed, page 35



LOU JONES Women Swimming, 1998

Athletes at sporting events, like these swimmers, can be at a considerable distance. Photographers often rely on long lenses—like the 600mm telephoto used here—to come in tight on the action. Jones set his lens to the next-to-widest aperture so he could use a very high shutter speed. The shallow depth of field resulting from that wide aperture blurs out the background and calls attention to the sharply-focused swimmer in the foreground.

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A short-focal-length lens increases the angle of view and shows more of a scene than a normal lens used from the same position. A short lens (commonly called a wide-angle lens) is useful when you are physically prevented (as by the walls of a room) from moving back as much as would be necessary with a normal lens.

For a 35mm camera, a commonly used short focal length is 28mm. A comparable lens for a 6 x 7 cm camera is 55mm. For a 4 x 5 view camera, it is 90mm.

Wide-angle lenses have considerable depth of field. A 24mm lens focused on an object 7 feet away and stopped down to f/8 will show everything from 4 feet to infinity in sharp focus. Photographers who work in fast-moving situations often use a

moderately wide lens, such as a 35mm lens on a 35mm camera, as their normal lens. They don't have to pause to refocus for every shot, because with this type of lens so much of a scene is sharp. At the same time it does not display too much distortion.

Pictures taken with a wide-angle lens can show both real and apparent distortions. Genuine aberrations of the lens itself such as curvilinear distortion are inherent in extremely curved or wide elements made of thick pieces of glass, which are often used in wide-angle lenses. While most aberrations can be corrected in a lens of a moderate angle of view and speed, the wider or faster the lens, the more difficult and/or expensive that correction becomes.

SLR cameras need a special kind of wide lens

called a retrofocus, to leave room behind the lens for the reflex mirror to move. It is more difficult to correct aberrations in this kind of lens; wide-angle lenses for cameras without mirrors—rangefinders and view camera—often perform better.

A wide-angle lens can also show an apparent distortion of perspective, but this is actually caused by the position of the photographer, not by the lens. An object that is close to a lens (or your eye) appears larger than an object of the same size that is farther away. Since a wide-angle lens is often used very close to an object, it is easy to get this kind of exaggerated size relationship (below and right). The cure is to learn to see what the camera sees and either minimize the distortion, or use it intentionally (pages 51 bottom and 63 right).



KARL BADEN
Amelia, 1995

A wide lens lets you work in close quarters, like this child's bedroom. The unusual perspective, caused by a very short distance from lens to feet, creates a vision that is both amusing and a bit disorienting.

More about . . .

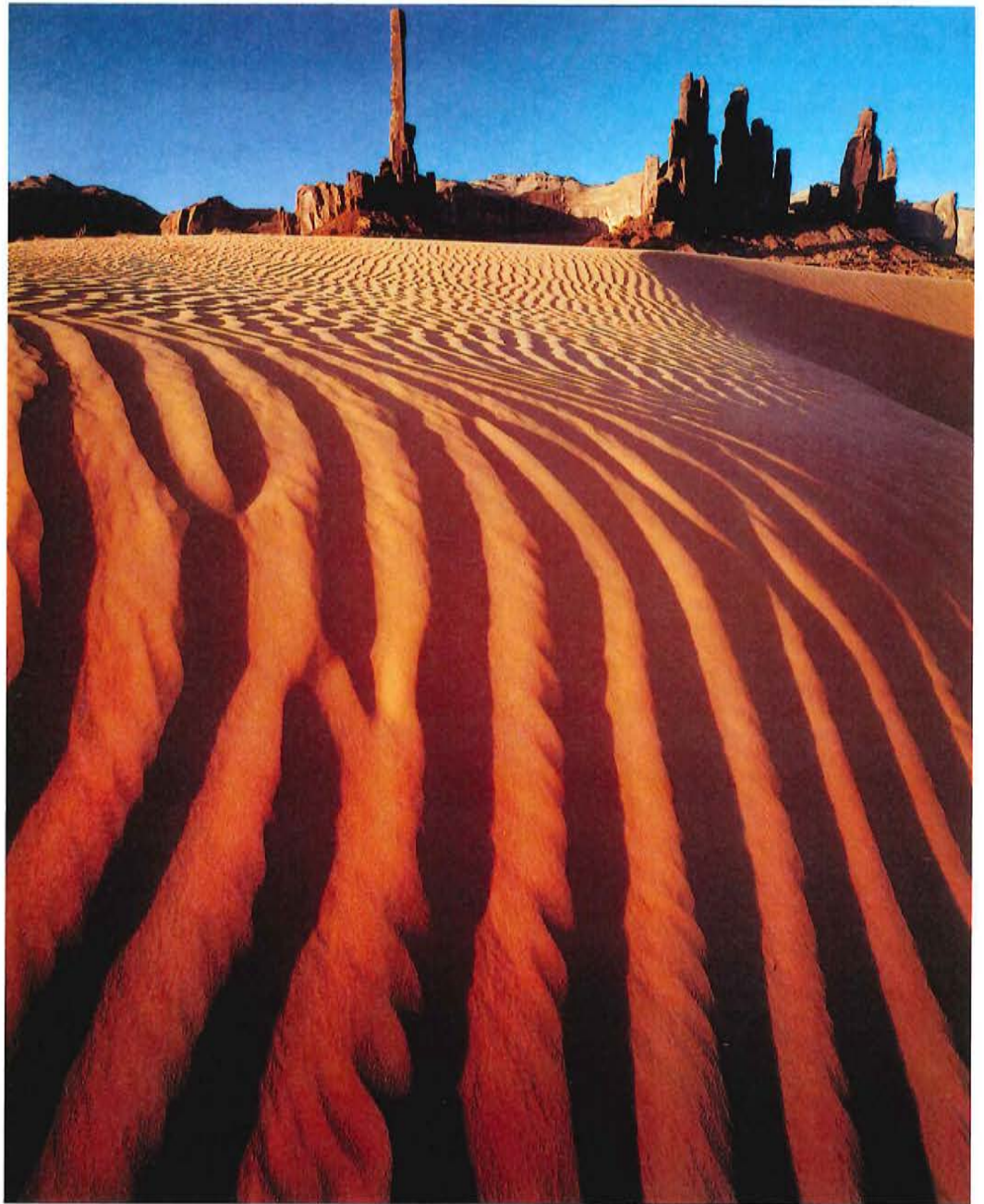
- Focal length and angle of view for 35mm camera lenses, page 43
- Perspective, pages 62-63

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—rangefinders
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DAVID MUENCH
Sand Dunes, Monument Valley,
Arizona, 1985

*With a 75mm lens on his
4 x 5 view camera (a wide-
angle lens for that format),
David Muench positioned
his camera relatively close
to the furrows of sand in the
foreground. The result was
to increase the apparent
size of the furrows nearest
the camera and to create an
impression of great distance
from foreground to
background.*



Zoom lenses are popular because they combine a range of focal lengths into one lens. Using a 28–105mm zoom, for example, is like having a 28mm, 50mm, 85mm, and 105mm lens instantly available, plus any focal length in between. The lens elements inside a zoom can be moved in relation to one another; this changes the focal length and therefore the size of the image.

It is convenient to be able to frame an image merely by zooming to another focal length, rather than by changing your lens or position. Some photographers carry only two lenses: a 24–80mm zoom and a longer 80–200mm zoom. A zoom lens is particularly useful for making color slides, since cropping the image later is not easy.

A zoom has some disadvantages. Compared to fixed-focal-length lenses, zooms are somewhat more expensive, bulkier, heavier, and they can be optically inferior. However, one zoom lens will replace two or more fixed-focal-length lenses.

The best prices and fewest drawbacks are found with a modest zooming range, from 35mm to 105mm, for example. The greater the range, the more evident the disadvantages become.

Some zoom lenses are best used where light is ample because they have a relatively small maximum aperture. Zooms that keep the same maximum aperture at all focal lengths are complex designs and therefore relatively expensive; most reduce the size of the maximum aperture as their focal length increases. For example, a 28–105mm zoom may open to $f/4$ when it is set to 28mm, but only to $f/5.6$ at 105mm focal length. **TIP:** With a zoom, be especially careful to make sure your shutter speed is fast enough to avoid blur caused by camera movement. With the lens at 28mm, you can use a minimum shutter speed of $1/30$ second, but when you zoom out to 100mm, you will need at least $1/125$ second unless you have the camera on a tripod.

Used outdoors during the day, most zoom lenses work fine. However, to shoot indoors with available light you may want a zoom that stays at a minimum of $f/2.8$ over its entire range.



A zoom lens gives you a choice of different focal lengths. Here, the photographer used the widest focal length for the picture on the left, then took the center picture, below, at a focal length near normal. The third photograph, bottom, used the longest focal-length of the lens. All three photographs were made while standing in the same position.



More about . . .

- Shutter speed and camera movement, page 35

DORRITH DOHERTY
Ant Farm, 1990

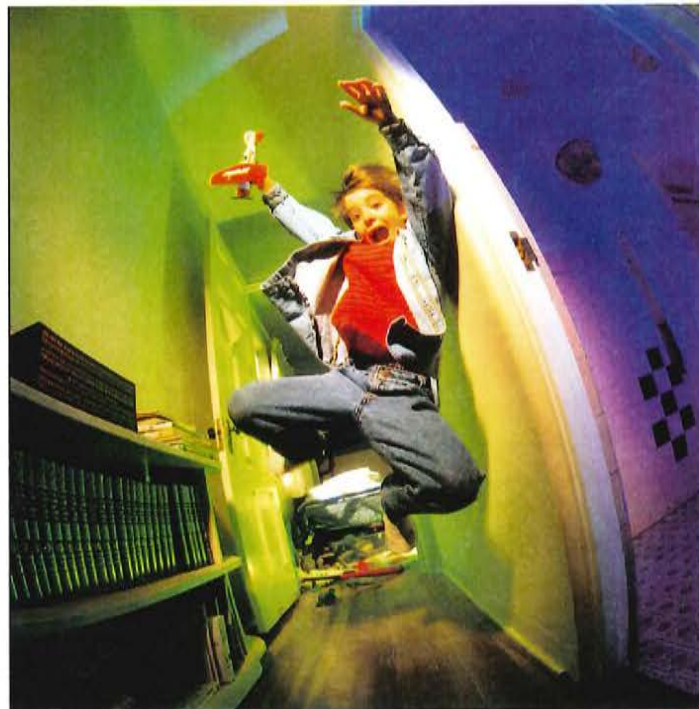
A macro lens is useful for photographing very close to a subject without having to use other accessories such as extension tubes. When you photograph close to a subject, depth of field is very shallow—only a narrow distance from near to far will be sharp.

Asked why there are no visible ants, the photographer says, "since these are not viable colonies (they can't send you a queen), the ants spent a lot of time making an ant cemetery, which you can see in the lower left of the picture."



CHIP SIMONS
Too Much Sugar, 1995

A fisheye lens distorted space to illustrate an article on hyperactive youth. The photograph shows a fisheye lens's typical characteristics: very deep depth of field, pronounced differences in size between objects very close to the camera and those in the background, and barrel distortion curving straight lines in the image. Simons chose the lens for its radical rendering and then enhanced the viewer's vertigo by putting gels over the studio strobe lights for saturated, surreal colors.



More about . . .

- Macro lenses and close-up photography, pages 290–293
- Perspective control, pages 322–323

A macro lens is useful for extremely close shots, such as that of the ant farm, left, top. The lens allows you to focus at a very close range and is corrected for aberrations that occur at close focusing distances. The lens is occasionally called, somewhat inaccurately, a micro lens. Some zoom lenses come with a macro feature. They focus closer than a non-macro zoom but not as close as a fixed-focal-length macro lens.

For the widest of wide-angle views, consider the fisheye lens. A fisheye has a very wide angle of view—some even greater than 180°—and exaggerates to an extreme degree differences in size between objects that are near to the camera and those that are farther away. Inherent in its design is barrel distortion, an optical aberration that bends straight lines into curves at the edges of an image. Fisheye lenses also produce great depth of field. Objects within inches of the lens and those in the far distance will be sharp. It is not a lens for every—or even many—situations, but it can produce startling and effective views (bottom left).

Aberrations are deliberately introduced in a soft-focus lens, also called a portrait lens. The goal is to produce an image that will diffuse and soften details such as facial wrinkles.

A perspective-control lens brings some view-camera adjustments to other types of cameras. The lens shifts up, down, or sideways to prevent parallel lines, such as the sides of a building, from tilting towards each other if the camera is tilted.

A catadioptric or mirror lens is similar in design to a reflecting telescope. It incorporates curved mirrors as well as glass elements within the lens. The result is a lens with a very long focal length but modest size, one much smaller and lighter than a lens of equivalent focal length that uses only glass elements. A unique effect caused by the front mirror is that out-of-focus highlights take on a donut shape. A "cat" lens has a fixed aperture, usually rather small— $f/8$ or $f/11$ is typical.

With manual focus, you select the part of the scene you want to be the sharpest. What is the most important part of the scene to be sharp? What do you want to emphasize? What do you expect viewers to look at first? If you are photographing a person, focus on the eye. If the person is at an angle and you are up close, both eyes may not be sharp in the photograph. Depending on the scene, it may be more important to have the near eye or the far eye sharp.

The nearer you are, the more important it is to focus critically. If you are 2 feet away, focus is critical, because depth of field will be shallow, with only a narrow area from near to far appearing sharp. If you focus on something 200 feet away, everything at that distance and beyond will be sharp.

Focus manually like you would tune a guitar. Go a little past the point you think is correct, then come back. If you adjust the focus until the image looks sharp, then adjust it a little more until the subject looks unsharp, then go back to sharp, you'll know exactly when your subject is at its sharpest.



Sharp focus attracts the eye. When you are photographing, it is natural to focus your eyes—and the camera—on the most important area of a scene.

Follow focus is a technique that lets you keep a subject that is moving toward you well focused. If a runner is coming toward you, you have to adjust the focus at about the same rate that the runner's distance is changing.

One way to learn how to follow focus is to practice focusing on people moving toward and away from you. Then practice on faster things, such as the license plates of moving cars. You don't need this skill if still lifes are your only subject, but it is vital if you want to photograph football games, auto races, dancers, or anything else that moves fast.

NOTE: Don't forget that shutter speed and aperture also play an important role in making objects appear sharp in the final picture. If your shutter speed isn't fast enough, a moving object will appear blurred in a photograph, no matter how sharply focused it was. This applies to autofocus as well. If your aperture isn't small enough, you may have focused on an important area, but an equally important nearby area may be out of focus. See, for example, the photographs on pages 26–27.



Sharp focus is a signal to pay attention to a particular part of an image, especially if other parts are not sharp.

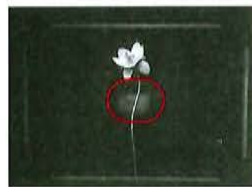
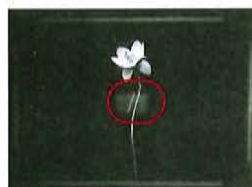
VIEWFINDER SCREENS FOR MANUAL FOCUS



Single-lens reflex and view cameras use ground-glass viewing screens. Light coming through the lens hits a pane of glass that is etched, or ground, to be translucent. This ground glass creates a surface on which a viewer, looking at it from the other side, can see an image and focus it. As you rotate your lens barrel to focus, the ground-glass screen shows clearly when a scene is sharp and in focus (left, above) and when it is not (left).



Reflex cameras may also include a micropism, a circle that appears dotted until it is focused, and sometimes a split-image focusing aid that appears offset until the image is focused.



Rangefinder cameras have split-image focusing, which operates by superimposing two images of the same subject on the focusing screen (left). One image passes through a viewfinder and one is reflected by a rotating prism connected to the lens. The two images appear exactly superimposed (left, below) only when the lens focuses sharply on the subject. The red circles on the images here call attention to the focusing aid. They would not appear in the viewfinder.

NOTE: If you have vision problems you might find manual focusing difficult at times. Some cameras come with a viewfinder adjustment that allows you to dial in a correction (called a diopter) like prescription glasses. Other cameras offer an accessory called a diopter lens, available in several strengths, that screws directly onto the eyepiece to do the same. Your optometrist can tell you the appropriate correction to buy.

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ELLIOTT ERWITT New York, 1946

With everything in the photo soft except the dog and feet, which are on the same plane of focus, the photographer leaves no doubt about where he wants the viewer's eye to go. The human brain looks for sharpness in a scene or in a photograph. By controlling focus, photographers also can control where people look when an image is viewed.

More about . . .

- Depth of field, pages 56–61

Automatic focus (AF) does the focusing for you. In the simplest designs, you push the shutter-release button and the lens brings the image into focus. The camera adjusts the lens to focus sharply on whatever object is at the center of the viewfinder or within the focusing brackets. This type of autofocus works well in situations where the main subject is—and stays—in the middle of the picture. The camera may display a confirmation light when it has focused, but the presence of a light does not assure that the picture will be sharp overall.

If your subject is not in the center, you can use autofocus lock to make it sharp. Frame the subject within the focusing brackets or simply point the camera straight at it. To temporarily lock in the focus, press the shutter release halfway down. Keeping the shutter button partially pressed, reframe the scene, then press the shutter release all the way down (see photos, right).

Wide-area focus systems provide more options. Some viewfinders display several focusing brackets. By rotating a dial or thumbwheel on the camera back, you select a bracket that covers the subject you want to be sharp. When you press the shutter, the camera focuses on the selected area—allowing you to maintain your framing without having to center, lock, and reframe each picture. This allows you to shoot fast-moving subjects that are not in the center of the frame (see photo, opposite page, below right).

Some wide-area autofocus systems use light reflected off your eye to identify your subject by the direction you are looking, and therefore what area of the picture to bring into sharp focus. Other systems automatically select the nearest subject in the picture and focus there.

Once you lock onto a subject, some cameras predict where the subject is likely to be next, keeping the subject in focus even if it moves across the frame. These tracking systems can lock onto a subject,

adjusting the focus as the subject moves closer to, or farther from, the camera. These systems work especially well if the subject, like a race car, is traveling at a constant speed toward or away from the camera.

Some cameras have two autofocus systems. Active autofocus sends out a beam of infrared waves. The camera uses the part of the beam that bounces back to measure the distance to the subject. Passive autofocus looks instead at the image inside the camera, using the principle that contrast on the focal plane is greatest when the subject is sharpest.

Both are used because neither one works in every situation. The infrared beam in active autofocus, for example, will bounce back from the glass in a window instead of from a subject on the other side of the glass. Passive autofocus may miss the focus if a subject has very low contrast, is in very dim light, or consists of a repetitive pattern like window blinds or plaid. Cameras that employ both systems are more likely to find maximum sharpness under most conditions.

An autofocus system can be fooled. If you are photographing a soccer game focusing on the goalie, for example, and the referee moves in front of your camera, autofocus may track the referee and not the player. The camera does not know what you are trying to photograph, so unwanted subjects can cause the lens to focus incorrectly.

Your camera may let you select among its several focus modes. Manual focus is frequently supplemented by two other options—single-shot autofocus, sometimes called focus priority, and continuous focus. With a modern camera, if you want the machine to make quick and accurate decisions for you, you must understand its methods.

Read your camera's instructions so you know how its autofocus mechanism operates and when you would be better off focusing manually.

CENTER-WEIGHTED AUTOFOCUS LOCK



Shutter-release button

Subject off center, out of focus. Autofocus cameras often focus on the center of a scene. This can make an off-center main subject out of focus if it is at a different distance from whatever is at the center. Above, brackets at the center indicate the focused area.



Halfway down, autofocus activated

Focus on the main subject. In autofocus mode, first focus by placing the autofocus brackets on the main subject; with many cameras, you press the shutter button part way. Keep partial pressure on the release to lock focus.



All the way down, shutter released

Hold focus and reframe. Next, reframe your picture while keeping partial pressure on the shutter release. Push the shutter button all the way down to make the exposure. You can get the same results—a sharply focused main subject—simply by focusing the camera manually if your camera allows that.



JAMES GLOVER II Batter Up—Bat Out, 1999

Center-weighted autofocus can be fooled in a situation like this one, where it might have focused on the fence in the background instead of the batter. You can use autofocus lock (see opposite page) to lock focus on the batter and then reframe the picture.



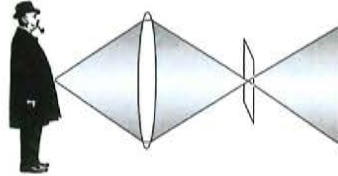
Wide-area autofocus allows you to stay framed on the situation while using a dial or other camera control to select the part of the image you want to be in focus, in this case, the batter. You could have selected the left-hand segment of the focusing brackets to focus on the person in the left-hand part of the frame. Some systems offer even more precise control.

What exactly is sharpness, and how much can it be controlled? In theory, a lens can only focus on one single distance at a time (the plane of critical focus) and objects at all other distances will be less sharp. But, in most cases, part of the scene will be acceptably sharp both in front of and behind the most sharply focused plane. Objects will gradually become more and more out of focus the farther they are from the most sharply focused area.

Depth of field is the part of a scene that appears acceptably sharp in a photograph. Depth of field can be shallow, with only a narrow band across the scene appearing to be sharp (photo, opposite), or it can be deep, with everything sharp from near to far (photo, right). To a large extent, you can control how much of it will be sharp. There are no definite endings to the depth of field; objects gradually change from sharp to soft the farther they are from the focused distance.

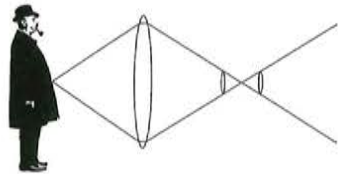
Circles of confusion affect the depth of field. Light from a single point on the subject reaches the lens in the shape of a cone. Behind the lens, that same light converges, again in the shape of a cone, to a

corresponding image point. If your film is located at the tip of that cone of light, that image point will be exactly in focus (see diagram, below).



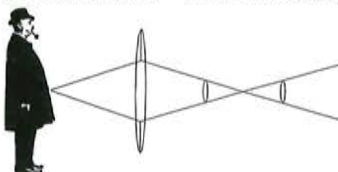
If the film is not at the tip of the cone and instead slices through the cone in front of or behind the focus point it will record a circle instead of a point (diagram, below).

it's a circle instead of a point. This size is called a circle of confusion. Any points in the subject's image that make a circle this size or smaller will appear to be in focus. Any points within this range are inside the depth of field.



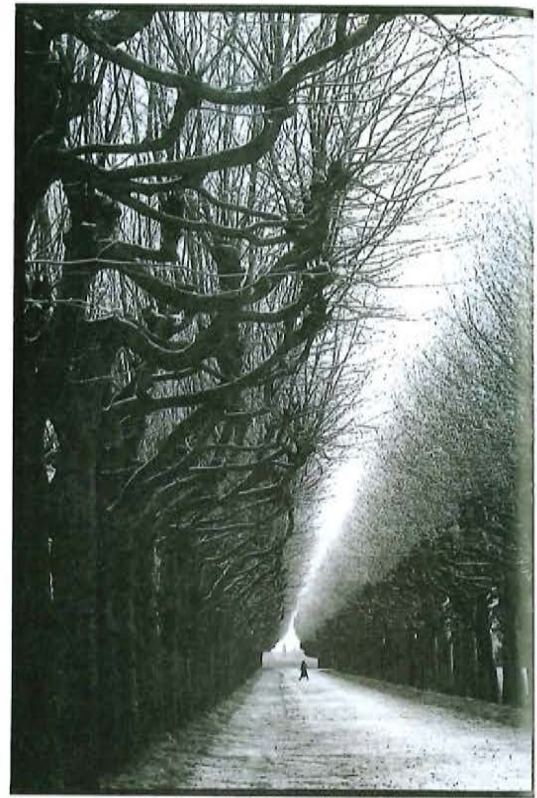
Reducing the size of the lens aperture makes the base of each cone of light smaller and its angle narrower (diagram, below). The film can then slice a circle of confusion farther from the focus

point. So even though a smaller aperture doesn't change the actual location of the plane of focus, it widens the range of points that appear to be in focus, thus increasing the depth of field.



In general, the more a print is enlarged, the less sharp it appears because the enlargement has increased the size of each circle, making more of them larger than the circle of confusion and

visible as circles, not points. But sharpness is also affected by viewing distance: a mural-size print viewed at a distance of 20 feet may appear sharp; the same print viewed up close may not.



MARTINE FRANCK Meudon Observatory, 1991

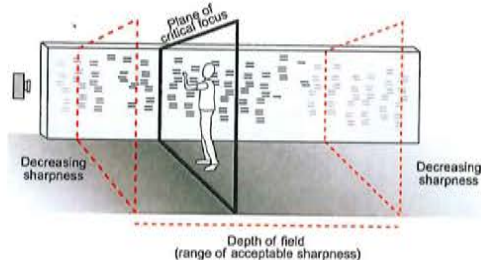
Depth of field, the area in a scene in which objects appear sharp, can be deep or shallow. In the photograph above, everything is sharp from the nearest tree to beyond the figure in the background. The smaller the aperture, the greater the depth of field.

More about . . .

- Controlling depth of field, pages 58-61



MICHA BAR-AM Yad Vashem Holocaust Memorial, Jerusalem, 1981



A lens focuses on the plane of critical focus, in this case, a column of names at the memorial in Jerusalem that commemorates the six millions Jews killed in World War II. Imagine the distance on which your lens is focused as a pane of glass parallel to the camera, stretched across the scene in front of you. Everything at this distance (the plane of critical focus) will be sharp in the photograph. That's why the face on the right is in focus too; it is the same distance from the camera as the text on the left that is in focus. In front of and in back of the plane lies the depth of field, the area that appears acceptably sharp.

The farther that objects are from the plane of critical focus, either toward the camera or away

from it, the less sharp they will be. When objects are far enough from the plane of critical focus, they lie outside the depth of field and will appear noticeably out of focus. At normal focusing distances, the depth of field extends about one-third in front of the plane of critical focus, two-thirds behind it. When focusing very close to a subject, the depth of field is more evenly divided, about half in front and half behind the plane of critical focus.

The search for missing relatives continues to this day. Hand and Name is the literal meaning of Yad Vashem; yad also means memorial. Journalist Bar-Am has been photographing Israel since its independence in 1948.

Evaluating and controlling the depth of field is more important in some situations than in others. If you are relatively far from the subject, the depth of field (the distance between the nearest and farthest points in a scene that appear sharp in a photograph) will be greater than if you are up close. If you are using a short-focal-length lens, you will have more depth of field than with a long lens. If the important parts of the scene are more or less on the same plane left to right, they are all likely to appear sharp as long as you have focused on one of them.

But when you photograph a scene up close, with a long lens, or with important parts of the subject both near and far, you may want to increase the depth of field so that parts of the scene in front of and behind the point on which you focused will also be sharp.

Sometimes, though, you will want to blur a distracting background that draws attention from the main subject. You can accomplish this by decreasing the depth of field.

You can use the aperture to control depth of field. To increase the depth of field so that more of a scene in front of and behind your subject is sharp, setting the lens to a smaller aperture is almost always the first choice. Select $f/16$ or $f/22$, for example, instead of $f/2.8$ or $f/4$. This is the case even though you have to use a correspondingly slower shutter speed to maintain the same exposure. A slow shutter speed can be a problem if you are photographing moving objects or shooting in low light.

To decrease the depth of field and make less of the scene in front of and behind the subject sharp, use a wider aperture, like $f/2.8$ or $f/4$.

There are other ways to control depth of field. You can increase the depth of field by changing to a shorter focal length lens or stepping back from the subject, although both of those choices will change the picture in other ways as well (see opposite).

To decrease the depth of field and make less of the scene in front of and behind your subject sharp, you can use a longer lens or move closer to the subject. These alternatives will also change the composition of the picture (see opposite).

Why does a lens of longer focal length produce less depth of field than a shorter lens used at the same f-stop? The answer relates to the diameter of the aperture opening. The relative aperture (the same f-stop setting for lenses of different focal lengths) is a larger opening on a longer lens than it is on a shorter lens (see below).

LENS FOCAL LENGTHS, APERTURES, AND LIGHT

The two lenses below, both set at $f/4$, let in the same amount of light, even though the actual opening in the 100mm lens (left) is physically smaller than the opening in the longer 200mm lens (right).

The longer the focal length, the less light that reaches the film (or CCD chip on a digital camera), therefore a long lens will form a dimmer image than a short lens unless more light is admitted by the aperture.

The sizes of the aperture openings are determined so that at a given f-stop number the same amount of light reaches the film, no matter what the focal length of the lens. The f-stop number, also called the relative aperture, equals the focal length of the lens divided by the aperture diameter.

$$f\text{-stop} = \frac{\text{lens focal length}}{\text{aperture diameter}}$$

If the focal length of the lens is 100mm, you need a lens opening of 25mm to produce an $f/4$ aperture.



$$\frac{100\text{mm lens}}{25\text{mm lens opening}} = \frac{100}{25} = f/4$$



If the focal length of the lens is 200mm, you need a lens opening of 50mm to produce an $f/4$ aperture.



$$\frac{200\text{mm lens}}{50\text{mm lens opening}} = \frac{200}{50} = f/4$$



More about . . .

- Ways to control depth of field, pages 60–61

SHARPNESS & DEPTH OF FIELD

The smaller the aperture, the greater the depth of field. Here the photographer focused on the front clock. Near right: with a wide aperture, $f/2$, the depth of field is relatively shallow; other clocks that are farther away are out of focus.

Far right: using the same focal length and staying at the same distance, only the aperture was changed—to a much smaller one, $f/16$. Much more of the scene is now sharp. Changing the aperture is the best way to change the depth of field because it does not affect other aspects of the photograph.

LESS DEPTH OF FIELD



Wider aperture



MORE DEPTH OF FIELD



Smaller aperture



The shorter the focal length of the lens, the greater the depth of field. Near right: with a 180mm lens, only the first subject is sharp.

Far right: with a 50mm lens at the same distance, set to the same aperture, and focused on the same point as the previous shot, the person in the background is sharper. Notice that changing the focal length changes the angle of view (the amount of the scene shown) and changes the magnification of everything in the scene. The kind of picture has changed as well as the sharpness of it.



Longer focal length



Shorter focal length



The greater the distance from the subject, the greater the depth of field. Near right: with the lens focused on the subject in front about 3 ft away, only a narrow band from near to far in the scene is sharp.

Far right: using the same focal length and aperture, but stepping back to 10 ft from the front subject and re-focusing on her made much more of the scene sharp. Stepping back has an effect similar to changing to a shorter focal length lens: more of the scene is shown, and more of the scene is sharp.



Closer to subject



Farther from subject

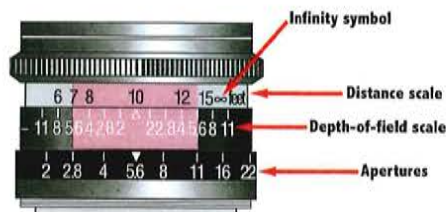


Two more techniques let you control depth of field, zone focusing (this page) and focusing on the hyperfocal distance (opposite). For these you need a lens with a depth-of-field scale. A fixed-focal-length lens is more likely to have such a scale; a zoom lens may not. Ordinarily, you will need a camera that can be focused manually, although a few autofocus cameras let you adjust the camera appropriately.

Zone focusing lets you set the depth of field in advance of shooting. It is useful when you want to shoot rapidly without refocusing, and can predict approximately where, if not exactly when, action will take place (for example when photographing strangers on the street). It lets you be relatively inconspicuous by not having to spend time focusing with your camera to your eye.

To zone focus, use a lens's depth-of-field scale to find the f-stop settings that will

give you adequate depth of field (see lens diagram, below). Everything photographed within the near and far limits of that depth of field will be acceptably sharp. The precise distance at which something happens is not important because the whole area will be sharp. Generally, zone focus works best with normal- or short-focal-length lenses. A long-focal-length lens may have too little depth of field to make the technique practical.



Zone focusing uses a lens's depth-of-field scale so you can be ready to shoot without focusing before every shot. Suppose the nearest focus point you want sharp is 7 ft away, and the farthest is 13 ft away. Turn the focusing ring until those distances on the distance scale fall opposite a matched pair of f-stops on the depth-of-field scale. If you set your lens aperture to that f-stop, objects between the two distances will be in focus.

Here, the two distances fall opposite a pair of f/5.6 marks. With this lens set to f/5.6 or a smaller aperture, such as f/8 or f/11, everything between 7 ft and 13 ft will remain sharp. You will not need to refocus as long as the action stays between those distances.

HELEN LEVITT New York, c. 1942

If you think that focusing your camera could distract your subject, you can zone focus. Before you begin to photograph, use your lens's distance scale to prefocus, then adjust the depth-of-field scale to find the area that will be sharp in front of and behind the focus point. It is often faster to zone focus in advance of action than it is to try to focus on a particular subject during a peak moment.

Helen Levitt made many photographs of children playing on New York City streets. Ben Maddow wrote of her work, "She sees, trails, hunts, and seizes hold of those dances that ordinary people do on their own turf."

More about . . .

• Controlling depth of field, pages 58–59

Focusing on the hyperfocal distance will give you maximum depth of field for the lens you're using, with objects as sharp as possible from the foreground to the far distance. When a scene extends into the distance, you may find that you focus visually on the part of the scene that is quite far away. In photographic terms, you have

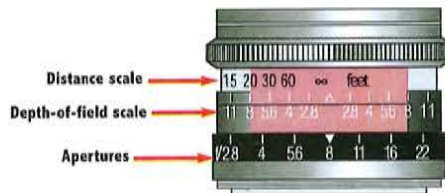
probably focused on infinity, which is as far as the eye can see and as close as the lens usefully gets to the film. (Infinity is marked ∞ on the lens distance scale.)

But for maximum depth of field in a scene that extends to a far distance, don't focus on infinity. Instead turn the focusing ring so that the infinity mark falls just within the depth of

field for the f-stop you are using (see lenses, below). You are now focused on the hyperfocal distance, a distance that is closer to the lens than infinity. Everything far will still be sharp, but more of the foreground will also be in focus. The hyperfocal distance, different for every aperture, gives you the most possible depth of field every time.



JOHN PFAHL Niagara Falls, Niagara River, New York, 1991



For maximum depth of field in a scene that extends to the far distance (infinity in photographic terms, ∞ on the lens distance scale), do not focus on the infinity symbol. With the lens to the left, if the aperture is $f/8$ and the lens is focused on infinity, everything from 20 ft to infinity will be sharp.

Instead, as has been done with the lens to the right, set the distance scale so that the infinity mark lines up opposite your chosen f-stop on the depth-of-field scale ($f/8$ in this example). Now, with the lens still set to $f/8$, everything from 10 ft to infinity will be sharp.



More about . . .
controlling depth of
field, pages 58–59

The camera image can seem surprisingly different from reality, so it is vital to see things the way the camera sees them. A long lens used far from a subject gives a so-called telephoto effect. In the photo opposite left, for example, the people and traffic seem impossibly compressed. A short lens used close to a subject produces what is known as wide-angle distortion. Opposite right, it enlarges part of the human form to unnatural proportions. These photographs seem to show distortions in perspective.

Perspective is the way the brain judges depth in a two-dimensional representation. Depth is determined mostly by comparing the sizes of objects, so it

seems to increase if foreground objects appear larger than background ones.

Perspective is affected by the lens-to-subject distance, not by lens focal length. Moving your camera closer to a subject will make objects in the foreground larger relative to those in the background.

Below, the pictures in the top row were taken from the same distance with lenses of different focal lengths. The shortest lens produced the widest view; the longest lens gave the narrowest view, simply an enlargement of the scene. The relative sizes of the eggs in the foreground and the bird remain constant because all three pictures were taken from the same distance.

The pictures in the bottom row were taken with the same lens from different distances.

The closer the lens came, the bigger the foreground objects (the eggs and nest) appear relative to the background one (the cage).

In one sense the focal length of a lens does affect the perspective. A short lens can focus closer to an object than a long lens, and it doesn't eliminate most of the scene from view when you move in close. Consequently, a short lens can produce wide-angle distortion because it is easy to use it up close. A long lens can produce a telephoto effect because you are more likely to shoot from relatively far away. But the lens isn't creating the effect; the distance from the subject is doing so.

FOCAL LENGTH CHANGES, CAMERA POSITION STAYS THE SAME

Short-focal-length lens, far from subject



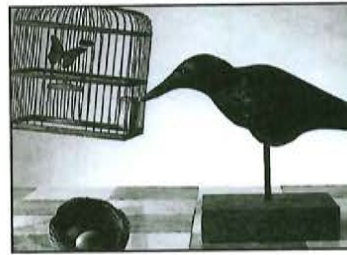
Lenses of different focal lengths change the size of all the objects, not the size of one compared to another. Each photo above was shot from the same

Medium-focal-length lens, far from subject



position but with a longer focal length lens each time. Eggs, bird, and cage all increased in size the same amount.

Long-focal-length lens, far from subject



FOCAL LENGTH STAYS THE SAME, CAMERA POSITION CHANGES

Short-focal-length lens, far from subject



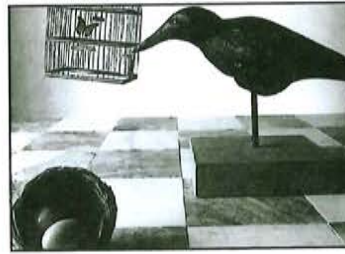
Changes in a lens's distance from a scene change the relative size of near and far objects. As the lens came closer, foreground objects enlarged more than

Short-focal-length lens, medium distance



background ones to give three different perspectives. The nest is smaller than the cage in the first picture, bigger than the cage in the last picture.

Short-focal-length lens, close to subject





ANDREAS FEININGER Midtown Fifth Avenue at Lunch Hour, New York, 1950



A short-focal-length lens used up close (above) increases the apparent size of the part of the subject that is closest to the camera, producing what is called wide-angle distortion. Like telephoto effect (left), this is caused by the distance from the lens to the subject, not by the lens itself.

Exaggerating perspective, the impression of compressed or expanded space in a photograph, is one way to add impact to an image or to communicate an idea visually.

A long-focal-length lens used far from a subject produces what is known as telephoto effect. It seems to compress the objects in a scene into a crowded mass. Andreas Feininger made many photographs of New York that conveyed its beehive crowding and intense activity. The super-long lens he used for these pictures was so long that he had to add a two-legged extension to his tripod to support the lens.

Start with a normal lens or a zoom lens with a moderate-focal-length range if you are getting a camera with interchangeable lenses. Don't buy more lenses until you feel a strong need to take the different kinds of pictures that other focal lengths can provide.

Get your lenses one at a time and think ahead to the assortment you may someday need. Begin by buying lenses in increments of more or less two times the focal length; for example, a good combination for a 35mm camera is a 50mm normal lens for general use, a 28mm wide-angle lens for close-in work, and a 105mm long lens for portraits and for magnifying more distant subjects. Be wary of ultra-wide-angle (24mm or below) and extra-long (above 200mm) lenses. They may be a lot more expensive than the others and are so specialized that their usefulness is limited.

Also, when buying a zoom lens, beware of the ones that reduce the aperture as you increase their focal length. Many are relatively cheap but don't let in enough light to shoot indoors without flash or without a tripod when they are extended to their longer focal lengths.

Don't spend money on extra-fast lenses unless you have unusual requirements. Buying a lens with a couple of extra f-stops may cost you an extra couple of hundred dollars. With today's high-speed films (and sensitive computer chips for digital cameras), a lens that can open to f/2.8 is adequate in all but the dimmest light. With this lens, you can take pictures indoors without flash.

NOTE: Lenses made by reputable manufacturers can be assumed to be reasonably good. And yet two lenses of the same focal length, perhaps even made by the same company, may vary widely in price. This price difference usually reflects a difference in the speed of the lens. The faster and more expensive lens will have a wider maximum aperture and admit more light. It can be used over a wider range of lighting conditions than the slower lens, but otherwise may perform no better. It may, in fact, perform less well at its widest aperture because of increased optical aberrations.

Consider a secondhand lens. Many reputable dealers take used lenses in trade, and they may be bargains. But look for signs of hard use, such as a dented barrel, scratched lens surface, or a slight rattling that may indicate loose parts, and be sure to check the diaphragm to see that it opens smoothly to each f-stop over the entire range of settings.

Test your lens. The only sure way is to take pictures with it on your own camera at various f-stops, so insist on a trial period or a return guarantee. If you plan to buy several lenses eventually, a good investment is a standardized test chart that can give an accurate reading of a lens's sharpness.

A lens shade is a very desirable accessory to attach to the front of the lens to prevent flare. Buy one that is matched to the focal length of the lens; too wide a shade is inefficient, too narrow a shade will vignette or cut into the image area. This problem is most likely to occur with wide-angle lenses of 28mm focal length and below.

Maximum aperture. The lens's widest opening or speed. Appears here as the ratio 1:1.8. The maximum aperture is f/1.8, the last part of the ratio.

Manufacturer

Focal length. The shorter the focal length, the wider the view of a scene. The longer the focal length, the narrower the view and the more the subject is magnified.



On the lens barrel (below) are controls such as a ring that focuses the lens. Cameras and lenses vary in design, so check the features of yours. For example, some cameras have push-button controls on the camera body instead of an aperture control ring on the lens.

Engraved around the front of the lens (above) are its focal length, maximum aperture, and other information. Some lenses also indicate the filter size. A 50mm lens, for example, may require a 49mm filter, expressed on the lens rim as Ø 49mm.

Focusing ring rotates to bring different parts of the scene into focus.

Distance marker indicates the distance at which the lens is focused.

Depth-of-field scale shows how much of the scene will be sharp at a given aperture. Not all modern lenses have this feature.



Aperture-control ring rotates to let you select the f-stop (size of the lens opening).

TYPICAL FOCAL LENGTHS FOR CAMERAS USING VARIOUS SIZES OF FILM

Focal lengths are usually stated in millimeters, sometimes with older lenses in inches or centimeters. There are approximately 25mm to an inch.

Film size	35mm	6 x 4.5cm (2 1/4 x 1 5/8 in) or 6 x 6cm (2 1/4 x 2 1/4 in)	6 x 7cm (2 1/4 x 2 3/4 in) or 6 x 9cm (2 1/4 x 3 1/4 in)	4 x 5 in
Short focal length	35mm or shorter	55mm or shorter	65mm or shorter	90mm or shorter
Normal focal length	50mm	75mm, 80mm	80mm, 90mm	150mm (6 in)
Long focal length	85mm or longer	120mm or longer	150mm or longer	210mm (8 1/2 in) or longer

Manufacturer

Lenses

Aperture

Focal length

Shutter speed

ISO

White balance

Flash

Viewfinder

Mirror lock-up

Self-timer

Remote control

Lens cap

Lens hood

Lens filter

Lens cap

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PROTECTING AND CLEANING YOUR CAMERA AND LENS



Cleaning inside the camera. If you are cleaning the lens or changing film, also check inside the camera for dust that can settle on the film and cause specks on the final image. Blow or gently dust along the film path, particularly along the winding mechanisms, tilting the camera so the dust falls out and isn't pushed farther into the camera. With a single-lens reflex, be careful not to damage the shutter curtain in the body of the camera or the film pressure plate on its back. The shutter curtain is particularly delicate; don't touch it at all unless absolutely necessary.



Cleaning the lens. First, blow or brush any visible dust off the lens surface (above). Holding the lens upside down helps the dust fall off the surface instead of just circulating on it. Be especially careful with granular dirt, like sand, which can scratch the lens surface badly. To clean grease or water spots from the lens, use a clean piece of camera lens tissue or a specially coated cloth into a loose ball and moisten it with a drop or two of lens cleaner solution. Don't put drops of solution directly on the lens; they can seep along the edges of the lens to the inside. Wipe the lens gently with a circular motion (below). Finish with a gentle, circular wipe using a dry lens tissue.

NOTE: Don't use any products designed for cleaning eyeglasses.



Protect from dust and dirt. The best way to keep equipment clean is not to get it dirty in the first place. Cases and bags protect cameras and lenses from bangs and scratches as well as keep them clean. Sand is a particular menace; clean your equipment well after using it on the beach. **NOTE:** A UV or skylight filter on the lens can help protect it. If you scratch a protective filter, it is much less expensive to replace than a lens. When you take a lens off a camera, protect both front and back lens surfaces either by placing the lens in a separate lens container or by capping both ends.

Protect from moisture. Most modern cameras are packed with electronic components that can corrode and malfunction if exposed to excessive humidity or moisture, especially salt water. On a boat or at the beach, keep equipment inside a case when it is not in use. If you use it where salt spray will get on it, wrap it in a plastic bag so just the lens pokes out. Digital cameras are particularly sensitive to high humidity.

Protect from temperature extremes. Excessive heat is the worst enemy. It can cause parts to warp, lubricating oil inside the camera to flow into places it should not be, and film to deteriorate. Avoid storage in places where heat builds up: in the sun, inside an auto trunk or glove compartment on a hot summer day, or near a radiator in winter.

Excessive cold is less likely to cause damage but can make batteries sluggish and lubricants stiff. If you photograph outdoors on a very cold day, keep your camera warm inside your coat until you are ready to use it, then return it afterwards. Moisture can condense on a camera, just as it does on eyeglasses. Any metal or glass that has gotten cold outdoors will get damp when it comes indoors and meets warm, humid air. Keep a cold camera wrapped up and lens caps capped long enough to reach room temperature.

Protect during storage. If you won't be using the camera for a while, release the shutter, make sure the meter is off, and store in a clean, dry place. If humidity is high, ventilation should be good to prevent a buildup of moisture on electronic components. Wind and release the shutter once in a while; it can become balky if not used for long periods of time. For long-term storage, remove batteries to prevent possible damage from corrosion.

Check the battery strength regularly (see manufacturer's instructions). Batteries provide the power for a camera's metering system, readout data, automatic functions, and sometimes the shutter. Lithium batteries last longer, but check the manufacturer's directions, since not all models accept them.

Use professional care for all but basic maintenance. Never lubricate any part of the camera yourself or disassemble anything for which the manufacturer's manual does not give instructions. Cameras are easier to take apart than they are to reassemble.

Cameras and lenses are rugged, considering what precision instruments they are.

Common-sense care and a little simple maintenance will help keep them running smoothly and performing well.

A clean lens performs better than a dirty one. Dust, grease, and drops of moisture all scatter the light that passes through a lens and soften the sharpness and contrast of the image. **NOTE:** Although a lens should be kept clean, too frequent or too energetic cleaning can produce a maze of fine scratches or rub away part of the lens coating. Manufacturers coat lens surfaces with a very thin layer of a metallic fluoride that helps reduce reflections and subsequent flare. The coatings are extremely thin, as little as 0.0001mm, and relatively delicate. Treat them with care when cleaning the lens.

Stopping down the lens aperture often improves the image by eliminating rays from the edges of the lens where certain aberrations increase. Even a well-designed lens will have some aberrations that were impossible to overcome in design. This is especially so if it is a zoom, extremely wide-angle, or telephoto lens, or if it has a very wide maximum aperture or is used very close to the subject.

There is a limit to the improvement that comes with stopping down. As light rays pass across a sharp, opaque edge, like the edge of the diaphragm opening, the rays scatter slightly. As the lens is stopped down and the aperture becomes smaller, this scattering, called diffraction, reduces sharpness and contrast over the entire image. Even though depth of field increases, sharpness decreases. Most lenses are sharpest at an aperture closed down one or two f-stops from the widest. This is enough to minimize aberrations but not enough to cause noticeable diffraction. In general, you should close down the aperture far enough for the depth of field you need, but no farther.

More about . . .

- Preventing or solving camera and lens problems, pages 400-402