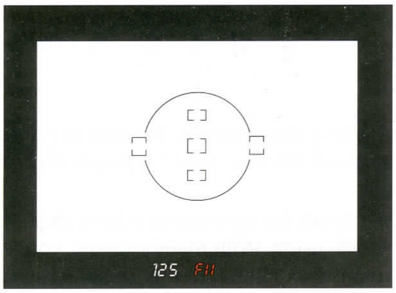
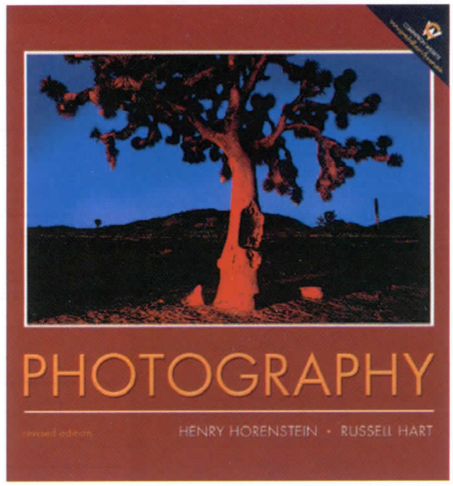




With some SLRs, you change the f-stop (here, f/11) with a ring on the lens (right). With others, you rotate a small wheel on the camera body (center). Depending on your model, the f-stop is displayed on an external panel (center) and/or in the viewfinder (above).

LOOKING AT LENSES

EVEN IN THE NEW WORLD OF DIGITAL SLRS, THE LENS IS ESSENTIAL TO PHOTOGRAPHY. HERE'S WHAT YOU NEED TO KNOW ABOUT F-STOPS, DEPTH OF FIELD, AND HOW FOCUS AND FOCAL LENGTH AFFECT THEM.

Whether you're shooting with a digital SLR or with film, you need a lens to form and focus an image of the subject on the camera's sensor or the film's emulsion. Either way, the same optical fundamentals apply: You have to know your f-stops and focal lengths and how depth of field is influenced by both. The following tutorial on lenses is taken from Photography *(Prentice-Hall) by Henry Horenstein and Russell Hart (above left). Newly revised, this fully illustrated college textbook covers both traditional and digital approaches to photographic image-making.*

Your camera's lens does more than gather scattered light rays from the subject and focus them into a recognizable image on film. A mechanism inside the lens, called the **diaphragm,** lets you vary the amount of light that enters the camera to create the image by changing the size of an opening, called the **lens aperture,** in the center of the diaphragm.

If you think of the lens as a pipe that carries light, the diaphragm functions like a valve. This valve can be opened up as large as possible—to what is usually called a "wide aperture"—so that it lets in a lot of light. It also can be closed down to a small opening—to a "small aperture"—so that it lets light through in a trickle. Or it can be set to apertures in between these two extremes. Keep in mind that the diaphragm and lens aperture don't actually start and stop the flow of light to the film. This task is handled separately by the shutter.

Controlling the flow of light to the film is crucial to getting the proper exposure—making sure your photograph is neither too light nor too dark. If you're taking a picture in dim light, you usually need to set a wide lens aperture to make sure enough light gets through to the film. If the light is bright, on the other hand, you will generally need to set a small lens aperture in order to prevent too much light from reaching the film.

Varying the size of the lens aperture does other important things. Chief among these is controlling depth of field: the area in front of and behind your subject that looks sharp in the final photograph. Smaller apertures provide more depth of field; larger apertures provide less depth of field. A simple adjustment of lens aperture

constant-aperture zoom Zoom lens in which the maximum aperture remains the same no matter what focal length is set.

depth of field Zone from the front to the back of a scene within which elements will be rendered with acceptable sharpness.

depth-of-field preview Switch, button, or other device on a camera that allows you to view the subject's depth of field at selected lens apertures.

depth-of-field scale Markings on some lens barrels that allow you to determine the depth of field at a particular f-stop and focused distance.

diaphragm Mechanism inside a lens that forms an opening the size of which can be adjusted to control the amount of light that enters the camera and strikes the film.

fast lens Lens that has a relatively wide maximum aperture, which when set allows more light to enter the camera than with a "slower" lens.

f-stop Numerical value that indicates the relative size of a lens aperture, and how much light it allows to enter the camera and strike the film.

hyperfocal distance Focused distance at which a lens of given focal length provides the most possible depth of field at a given aperture.

lens aperture Adjustable opening formed by the lens diaphragm.

maximum aperture Size of the widest aperture possible for a given lens, expressed as an f-stop, as in "an f/2 lens."

slow lens Lens that has a relatively small maximum aperture, which when set allows less light to enter the camera than with a "faster" lens.

stop down To set a smaller lens aperture (f-stop) in order to reduce the amount of light striking the film.

stops Expression of a quantity of light. A "stop" is twice as much light as the next smallest stop, and half as much light as the next largest stop.

variable-aperture zoom Zoom lens in which the maximum aperture gets smaller as you increase the focal-length setting.

wide open Term used to describe a lens set to its maximum (largest) aperture, which admits as much light as it possibly can.

zone focusing Focusing technique in which the photographer calculates the f-stop and focus settings needed to optimize sharpness from the front to the back of the subject.

F-Stops Most cameras offer one of two ways to set the f-stop. Some models have lenses with built-in aperture rings that are calibrated in "full" f-stops and sometimes with click positions at half-stop settings as well. You simply line up the f-stop you want with an index mark on the lens. Other models have a small finger- or thumb-controlled wheel and/or pushbuttons on the camera body. You turn the wheel or push the button and the chosen f-stop is displayed numerically in the viewfinder and/or on an external LCD panel. In the second type, you'll see numbers that designate settings in between full stops; some models are calibrated in thirds of stops, others in half stops. The designated numbers may not represent exact thirds or halves, but setting them nonetheless causes third- or half-stop changes in exposure. Here are the sequences for each type of system.

Whole Stop	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/4.0	f/4.0 f/4.7	f/4.0 f/4.5 f/5.0
f/5.6	f/5.6 f/6.7	f/5.6 f/6.3 f/7.1
f/8.0	f/8.0 f/9.5	f/8.0 f/9.0 f/10
f/11	f/11 f/13.5	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/25.3 f/28

thus allows great control over the appearance of a photograph.

Adjusting the aperture also affects how a photographer adjusts the shutter speed—the length of time during which light reaches the film. In practice, the lens aperture and shutter speed are adjusted in tandem to ensure that the film gets the correct amount of light. But considerable variation in this combination is usually possible. If you set a small lens aperture, for example, you will need to use a slower (longer) shutter speed to let enough light through the lens. If you set a large lens aperture, you will need to use a faster (shorter) shutter speed to quickly cut off the light pouring through the lens.

Setting the Lens Aperture

If you look into your camera's lens, you will see a group of metal leaves or blades that overlap one another to form a rounded opening (see diagram below). This group of blades is the diaphragm; adjusting the size of its opening is called setting the aperture. The size of the aperture does not affect how much the lens "sees." It simply makes the image darker or brighter.

There are several ways to set the aperture of a lens, depending on the camera system you're using. With many systems, you adjust the aperture's size by rotating a calibrated ring on the lens barrel. This ring has a number of "click" positions with numbers next to them. With many modern, electronically controlled cameras, you adjust the lens aperture by pushing, sliding, and/or rotating controls on the camera body while referring to numbers on an adjacent LCD panel.

Set to its largest opening, the aperture is as wide as the lens elements (the shaped pieces of glass or plastic that make up a lens) themselves. Using this setting is sometimes called shooting **wide open;** setting a larger aperture is called "opening up" your lens. But the aperture can be changed from that setting to a very small aperture, or to any setting in between. When you set a smaller aperture, you **stop down** the lens.

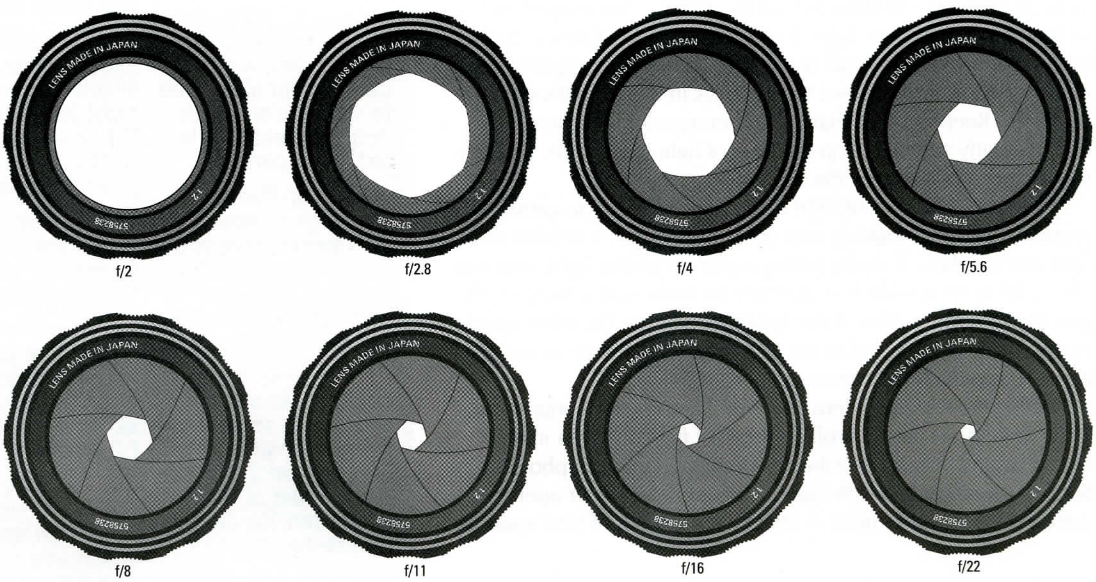
However your lens is adjusted, the size of the aperture is indicated on the lens's aperture ring, on an LCD panel, and/or in the viewfinder with a number called an **f-stop.** Indicated with the prefix "f/," f-stop numbers appear in the following standard sequence: f/1.0, f/1.4, f/2, f/2.8, f/4, f/5.6, f/8, f/11, f/16, f/22, f/32, f/45, f/64, and so forth. Most lenses for 35mm cameras offer a range from about f/2.8 or f/4 to f/22 or f/32, but this varies from lens to lens.

Cameras with electronic displays on LCD panels quite often also show in-between numbers, such as f/3.5 or f/9. Lenses with aperture rings rather than LCD displays usually have half-stop settings that "click" when set. But whether they click or not, these lenses can be set anywhere between full stops—though the settings may not be critically precise. (See the chart above for the complete sequence of full and fractional f-stops.)

Whatever your lens, the larger the f-stop number, the smaller the opening. In fact, the sequence of whole f-stop numbers actually represents an exact doubling or halving of the amount of light entering the camera. The aperture f/2 is twice as large as f/2.8, so it lets in twice as much light. The aperture f/11 lets in half as much light as f/8.

Because of this universal measurement, photographers nearly always express quantities of light in **stops.** An aperture of f/8 is said to let in one stop less light than an aperture of f/5.6. An

The lens aperture is a rounded opening formed by an adjustable set of metal blades inside the lens. You change the size of this opening to control both exposure (the amount of light entering the camera and striking the film) and depth of field (the depth of the zone of sharpness in your photograph). Different-sized openings are called f-stops. F-stops with lower numbers, such as f/2 and f/2.8, admit a relatively large amount of light into the camera and produce very little depth of field. F-stops with higher numbers, such as f/16 and f/22, admit a relatively small amount of light into the camera and produce much more depth of field. The range of f-stops pictured here—from f/2 to f/22—is typical of some lenses, but many lenses offer a wider or narrower range of choices.



aperture of f/2 is said to let in two stops more light than an aperture of f/4; f/2.8 lets in one stop more light than does f/4.

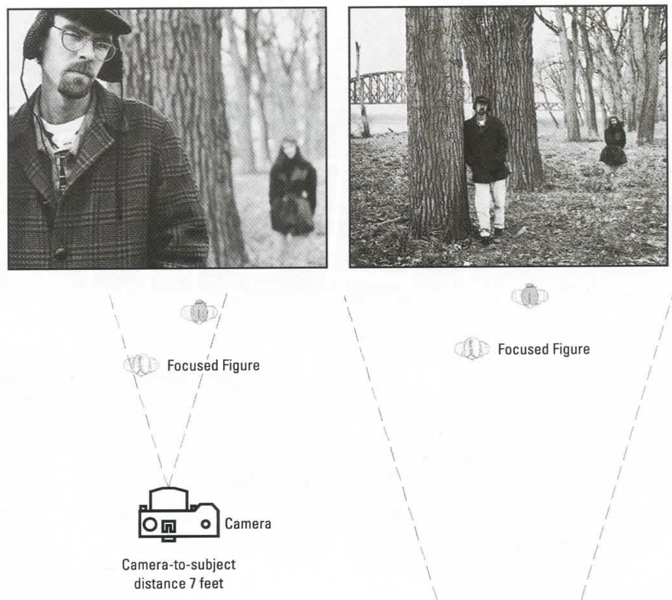
It's important to remember that an f-stop isn't the actual physical measurement of the size of the aperture but rather a number expressing how much light "fits" through the hole. The f-stop is derived by comparing a specific aperture's diameter to the focal length of the lens: If you set the lens to f/4, for example, the ratio between the aperture diameter and the focal length is 1:4. In other words, the size of the aperture diameter is 1/4 the size of the focal length. If you set the lens to f/8, likewise, the aperture diameter is 1/8 the size of the focal length.

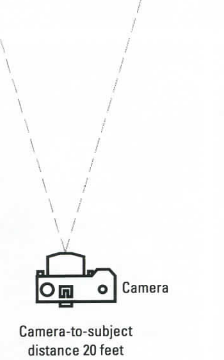
The actual, physical size of a given f-stop thus depends entirely on the focal length of the lens. With a 50mm lens, f/4 indicates an aperture with a diameter of 12.5mm (1/4 of 50mm, or about 1/2 inch wide). But with a 200mm lens, the same f-number represents an aperture of very different size, because the lens's focal length is much longer. For a 200mm lens, f/4 represents an aperture diameter of 50mm (two inches wide)—again, 1/4 the focal length.

This means that a given f-stop admits exactly the same amount of light into the camera regardless of the lens's focal length. An aperture of f/8 on a 24mm wide-angle lens causes the same amount of light to strike the film as does f/8 on a 600mm super telephoto lens, even though the physical dimensions of the aperture are different. An aperture of f/8 on a 35mm SLR lens provides the same exposure as does f/8 on a medium-format or view camera lens.

Aside from focal length, the main way lenses are described is by their **maximum aperture:** the size of the widest aperture they allow. Two lenses can have the same focal length (or in the case of a zoom lens, the same focal length setting) but have different maximum apertures.

A lens with a wide maximum aperture is called a **fast lens.** A lens with a smaller maximum aperture is called a **slow lens.** The "faster" the lens, the easier it is to photograph in low light or with faster shutter speeds or with slower films. A 50mm normal lens, for example, may have a maximum aperture of f/2 or f/1.4. A 50mm f/1.4 lens is said to be faster than a 50mm f/2 lens; a 300mm f/2.8 lens is faster than a 300mm f/4 lens; and so forth.





How Distance Affects Depth of Field The closer you are to your subject, the shallower the depth of field. At seven feet away from the subject, the background is unsharp (left). But at a distance of 20 feet, the depth of field increases, making both foreground and background sharp (right). Both pictures were taken with the same focal-length lens at the same f-stop setting. Note that it's usually best to change f-stop to control depth of field, since changing distance also changes composition.

Conversely, a 28mm f/2.8 lens is said to be slower than a 28mm f/2 lens, and a 200mm f/4 lens is slower than a 200mm f/2.8 lens.

Maximum aperture gets a bit more complicated with zoom lenses. The maximum apertures on some zooms are variable. But even at their widest aperture, these zooms are usually slower than constant-aperture zooms of the same focal-length range. For example, a 28-70mm f/3.5-4.5 zoom is slower than a 28-70mm f/2.8 zoom (see box on opposite page).

BOB HOWER (6)

How Lens Aperture Affects Depth of Field The wider the lens aperture, the shallower the depth of field. To make the main subject stand out sharply, set a wide f-stop (here, f/2) to throw the background out of focus (left). To make the overall scene as sharp as possible, set a smaller f-stop (here, f/22) to make both foreground and background appear sharp (right). Note that in both shots, the photographer focused on the front figure.

Focus and Depth of Field

There are several important means by which a photographer controls the "look" of a photograph. Perhaps the most obvious of these is how you compose the photograph. But two interrelated photographic properties, focus and depth of field, are also very important.

For most pictures, you choose a specific object—for example, a face in a portrait or a tree in a landscape—on which to focus. With many photographs, you then set the lens aperture to achieve the maximum sharpness. For other photographs, however, you may prefer to set the lens so that only the main subject is sharp, with everything in front of and behind it unsharp.

The front-to-back zone within which objects appear to be sharp is called **depth of field.** When little else but the main subject appears sharp, there is "shallow" depth of field. When the scene is sharp from front to back, there is "good" or "great" depth of field.

Note that depth of field is usually described as extending between two particular distances—say, from five to 15 feet. However, there is no specific point at which elements of a scene stop being sharp. Instead, there's a gradual tapering off in sharpness away from the point at which you've focused. When you focus on one point—one specific part of the subject—all points in a plane to the right, the left, above, and below that point are also in focus. The farther an object is from this plane, the less sharply it will be rendered. This reduced sharpness becomes visually unacceptable at a certain distance from the plane, and thus falls out of the image's depth of field.

Three factors work together to affect depth of field:

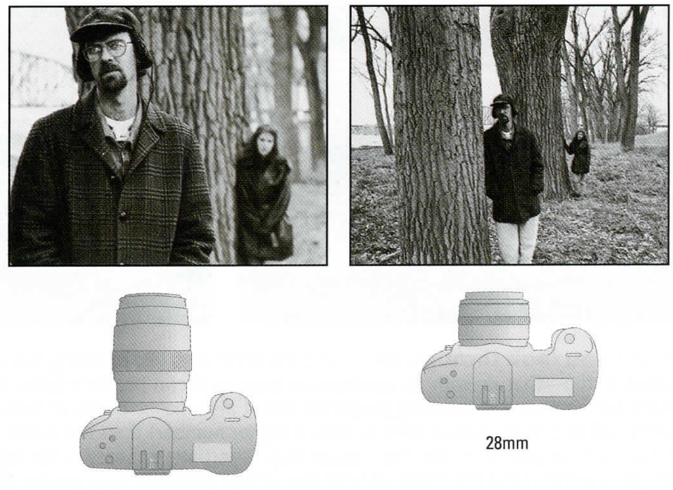
- **Lens aperture (f-stop)**
- **Distance from camera to subject**
- **Lens focal length**

Of these three factors, the one used most often to control depth of field is the lens aperture. The smaller the aperture, the greater the depth of field; thus, a subject will have greater depth of field at f/22 than at f/2 (see illustration on opposite page). If your aim is to make as much of the scene as sharp as possible, set as small an aperture as circumstances permit. If you want to single out a subject—by making the rest of the scene unsharp—set as wide an aperture as you can.

Another way to control depth of field is by changing your distance from the subject (see illustration on opposite page). To increase depth of field, back away; to reduce it, move closer. A subject shows greater depth of field when 15 feet away than when five feet away, all other factors being equal. Changing your distance from the main subject has the additional effect of changing your composition. Yet if you switch to a different lens or zoom focal-length setting to compensate for the change in distance—to maintain your composition—you offset any change in depth of field. (If you back away, you can compensate by cropping more tightly in printing and thus preserve the gain in depth of field.) This happens because focal length also affects depth of field.

From a given distance, at a given aperture, the longer the lens focal length, the shallower the depth of field; the shorter the focal length, the greater the depth of field (see illustration above right). Just keep in mind that the depth of field you get at a given f-stop varies with distance. A smallish aperture of f/11 will produce substantial depth of field with a 35-70mm zoom set to 35mm (from six to 20 feet with the lens focused at nine feet), but relatively shallow depth of field when the zoom is set to 70mm (from eight to 11 feet with the lens focused at nine feet).

As with adjustments to shooting distance, though, changing focal length to control depth of field is difficult because you'll rarely get the composition you want. This also changes the size at which the main subject is recorded on film, as well as the portion of the whole scene the lens captures. And it's true regardless of the film format: When used at the same aperture and distance, a 90mm wide-angle for 4x5 has the same depth of field as a 90mm telephoto for 35mm.



How Focal Length Affects Depth of Field The longer your lens focal length, the shallower the depth of field. Using a moderate telephoto lens (105mm) caused the background to fall out of focus (left). Using a wide-angle lens (28mm) made the background sharp (right). Note that both photographs were taken from the same distance with the same f-stop. As with changing distance, changing focal length also changes composition, so it's usually best to change the f-stop to control depth of field.

In general, it's best to use the f-stop to control depth of field and shoot from your preferred distance, with your preferred focal length.

It might seem as if the lens aperture is the ultimate photographic tool, letting you change depth of field and adjust exposure at will. But it's really not that simple. You can't choose an f-stop without affecting other factors. First of all, the lens you're using may not have an aperture quite wide enough for your purposes. A 28-80mm zoom, for example, might offer a maximum aperture of only f/3.5 or f/4 at its 35mm setting, while a 35mm single-focal-length wide-angle typically offers f/2.8 or f/2—wider apertures that can make things in front of or behind the main subject fall out of focus more dramatically. Wide apertures (and slightly long lenses, such as 85mm) are often used for portraiture, for example, because they soften background detail more thoroughly, making it less likely to distract from the main subject. The same is true with wildlife subjects, though much longer lenses are typically used.

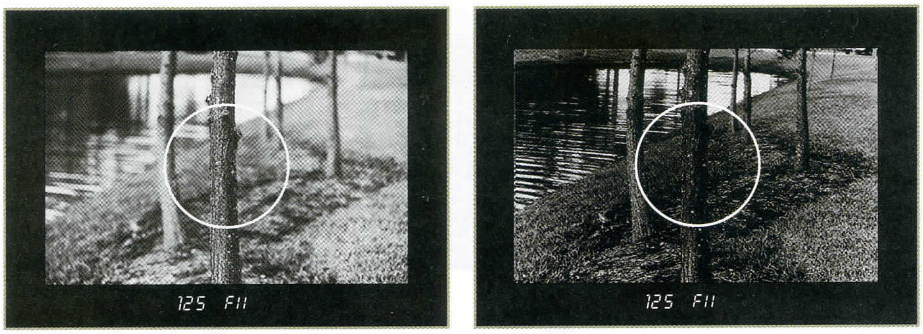
Yet even if the lens you're using has a wide maximum aperture, circumstances, such as the subject's light level, the film's speed, and the highest shutter speed available on your camera, may

Zoom Lenses and Lens Aperture Zoom lenses are a great creative convenience, allowing you to both quickly match focal length to subject without time-consuming lens changes and save the weight and bulk of several single-focal-length lenses. But those advantages come at a price. Zooms are generally slower—that is, they have smaller maximum apertures—than single-focal-length lenses within their range.

Because with an SLR you view the image through the lens itself, a zoom's smaller maximum aperture makes the camera's viewfinder image darker. This can make manual focusing difficult; it may even throw off some autofocusing systems. More significant, when you're shooting by low existing light—light that requires as wide an f-stop as possible—a smaller maximum aperture can force you to set shutter speeds too slow to safely handhold steadily. You end up having to choose between correct exposure and a sharp image, since you can't have both. You also may have to choose a faster film than you would normally prefer, so you can set a faster shutter speed.

Set to its maximum aperture of f/4, for example, a 35-80mm zoom at 35mm would require a shutter speed two stops slower, in a given light level, than a 35mm single-focal-length lens set to a maximum aperture of f/2 (fairly typical for such a lens). The single-focal-length lens would give you the ability to shoot at 1/60 at f/2, whereas with the 35-80mm zoom in the same light you'd be forced to set 1/15 at f/4 to obtain equivalent exposure. And that could make the difference between sharp and unsharp results if you are handholding the camera or if your subject is in motion.

This problem is most serious with a **variable-aperture zoom,** which actually changes its effective aperture as you change the focal length. A typical 70-210mm zoom may start out, at 70mm, with a relatively small maximum aperture of f/4, then by the time it's zoomed to 210mm, it is operating at a still smaller f/5.6. (That would be called a 70-210mm f/4-5.6 zoom lens.) So if you can afford it, you're probably better off with a **constant-aperture zoom.** These are bulkier and more expensive, but they are almost always faster than variable-aperture zooms—and just as important, the aperture you've set remains constant throughout their focal-length range. These lenses allow you to shoot safely in lower light levels and also make it easier to use slower, finer-grained films in such conditions.



When you look through an SLR's viewfinder, you're seeing the subject through the lens's widest f-stop—that is, with its aperture as large as it can be. This helps keep the viewfinder image bright for framing and focusing purposes, but it also makes depth of field appear shallow (left). If you've set an f-stop smaller (that is, with a higher number) than the lens's maximum aperture, depth of field will be greater in the final image than it actually appears in the viewfinder. However, you can get a sense of the real depth of field that will be produced by a smaller f-stop by using the camera's depth-of-field preview button, if your camera has one. Pressing the button stops down the lens to the f-stop you've actually set, increasing the depth of field you see in the viewfinder (right). But it also lets in less light, causing the viewfinder to darken and making the image more difficult to see.

combine to prevent you from using wide apertures altogether. Say you're photographing in bright sun with an ISO 100 film; even a shutter speed of 1/2,000, the fastest available on many 35mm SLRs, would cause overexposure of the film if you set an aperture of f/2.

Newer camera models offering shutter speeds of 1/4,000, 1/8,000, or even 1/12,000 allow you to use a wider aperture. You can also switch to a slower film. Placing a neutral density filter on the lens to cut the amount of light is another option for reducing the light reaching the film, allowing you to set wide apertures.

Likewise, setting a small lens aperture to achieve greater depth of field may be easier said than done. Because small apertures admit less light into the camera, you must set a slower shutter speed to obtain the correct exposure—and that shutter speed may be too slow either to freeze subject motion or to prevent blur due to camera shake (especially with hand-held shooting). In such cases, you may need to use a tripod (or otherwise brace the camera); switch to a faster film; add flash (or other supplemental lighting); or simply wait until your subject is more brightly lit. When extensive depth of field is important, as it is in much landscape photography, many photographers use a tripod all the time so they can set the slow shutter speeds that small apertures generally require.

Zone Focusing and Hyperfocal Distance

Experienced photographers sometimes use their understanding of f-stop and depth of field for special focusing techniques, such as **zone focusing,** the creation of a zone of acceptable focus before photographing. Zone focusing allows you to make the most effective use of the depth of field provided by a given lens aperture, focal length, and focused distance. It's based on the principle that at most shooting distances, depth of field extends twice as far behind the point of focus as in front of it. The technique can be used with any lens, but it is most practical with wide-angles because of their inherently greater depth of field. It can also be used in two distinctly different ways, for nonmoving subjects and for active subjects.

Here's how to focus if your subject isn't moving. Imagine that you are photographing a friend standing in front of a house. The friend is seven feet away, a distance you can establish simply by focusing on him or her and reading the number off the foot scale on the focusing ring. Let's say you'd also like to include the front of the house in sharp focus in the picture. By focusing on the house and checking your focusing scale, you determine that it is 30 feet away from the camera. To make both the friend and the house sharp, you will need to set the lens's focusing ring to a distance roughly a third of the way behind your friend toward the front of the house. In this case, it would be a setting of about 14 feet. Now look at the lens's depth-of-field scale to see what f-stop will encompass both distances. If the lines representing f/16 fall at 7 and 30 feet when the focusing ring is set at about 14 feet, set your aperture to f/16, and everything between 7 and 30 feet will be rendered sharply, including your friend and the house.

This application of zone focusing is particularly useful for landscape photographs with extreme near-far relationships. With a wide-angle lens used at a small aperture, you can make the scene sharp from just a few feet away to infinity. The focused distance at which such maximum depth of field occurs is called the **hyperfocal distance.** It can be determined by setting your lens's focusing ring at infinity, then reading the distance that is indicated above the nearest mark on the depth-of-field scale that corresponds to the aperture you are using. You then set the focus to that indicated distance. Note that with longer lenses, however, the aperture required by this technique may be impractically small.

With active subjects, zone focusing can save you the need to refocus every time the subject moves, but the technique is somewhat different than with static subjects. For example, if your subject is a child at play and you're fairly certain the child will remain within a certain distance range, you can set your focusing ring to a distance one-third of the way between the closest and farthest parts of this range, then stop down your lens to an f-stop that will ensure both are in focus. In most circumstances, you need generous light and a reasonably fast film to make zone focusing work well with active subjects.

Note that if your camera is an auto-focusing model, you can still use zone focusing as long as your lens has a depth-of-field scale. Simply switch the lens to manual focus after you've checked your distances, then proceed as described above. ■

The Viewfinder and Depth of Field Your SLR's viewfinder can be very misleading when it comes to depth of field. Even though you may have set a small aperture (say, f/11) on your lens, the camera doesn't actually set this aperture until you press the shutter button to take the picture. SLRs keep the lens aperture wide open until the instant before you take your picture to allow as much light as possible into the viewfinder. This provides the brightest possible image for framing and focusing. But it also means that the depth of field you see when viewing your subject will not be the depth of field you get in the final picture (except when you've set the lens to its widest aperture).

Many SLRs therefore offer a control called a **depth-of-field preview,** a switch, button, or other device that lets you view your subject through the lens at the f-stop you've actually set. Using it causes the viewfinder image to darken, because the aperture closes down and lets in less light; the smaller the aperture you set, the darker the image will be. (See illustration at top.) This darkening can make it difficult to judge depth of field visually.

Another way to determine depth of field is by using a lens's depth-of-field scale, if your lens has one, or by focusing to maximize depth of field. And always keep in mind that if you set the aperture to any f-stop smaller than the lens's maximum aperture, the final photograph will have more depth of field than you actually see in the viewfinder.