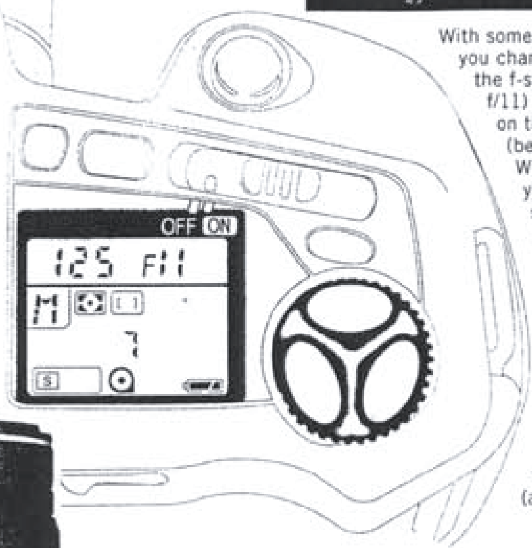
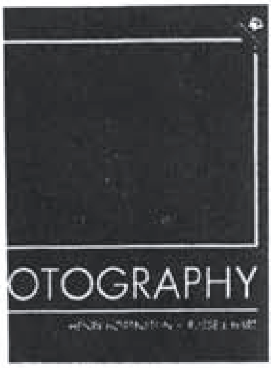
LOOKING AT LENSES



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



. IN THE NEW WORLD OF DIGITAL SLRs, E LENS IS ESSENTIAL TO PHOTOGRAPHY. HERE'S HAT YOU NEED TO KNOW ABOUT F-STOPS, PTH 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 workshop 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.

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Can a Lens Be Digital?

Because digital SLRs started life as retrofitted 35mm SLRs, they've come to rely on their film-using cousins' existing lens systems. The advantage of sharing optics was that a D-SLR entered the world with a full set of lenses. The disadvantage is that because these cameras typically have smaller-than-35mm sensors, they use a smaller portion of the image circle projected by the lens. The net effect: Lens focal length is increased with a D-SLR, by a factor of 1.5X or 1.6X.

Actually, that increase can be a boon if you're doing telephoto shooting because it gives you more reach with far-off subjects. A 300mm telephoto, for example, functions as a 450mm lens, producing a tighter shot of your subject from a given distance. But the same increase *limits* the short end of the focal-length spectrum. When a truly-wide 28mm focal length is used with a D-SLR, it produces an angle of view comparable to a near-normal 42mm in the 35mm format.

Some manufacturers have addressed this problem by making lenses specifically for digital capture. These optics offer much shorter focal lengths that still deliver serious wide-angle capability in D-SLRs; a good example is Nikon's DX Nikkors, which now include the **10.5mm f/2.8G ED AF DX Fisheye-Nikkor** and the **12-24mm f/4G ED-IF AF-S DX Zoom-Nikkor.** But even though these lenses share the same mount as existing 35mm lenses, if you put them on a 35mm SLR their smaller image circle causes vignetting.

Then there's the Olympus E-1, the only digital SLR built from the ground up with an all-new system of lenses. This unique model's makers hold that the problem with 35mm lenses goes beyond focal length. When lenses made for 35mm film are used on a digital SLR, light rays strike the latter's sensor at a more glancing angle toward its outer edges. That's no problem with a film emulsion, but because an electronic image sensor's individual light-sensing cells are like microscopic cups, they can't gather light as efficiently if it strikes them at an angle. The result is falloff, an unwanted darkening of the corners and edges of the image, and related color inaccuracies.

The new Zuiko lenses are designed so that light rays strike the sensor at a more perpendicular angle, which is why Olympus calls them "Digital Specific." The system currently ranges from the **Olympus 300mm f/2.8 Zuiko Digital Telephoto,** below (see Technology & Vision, page 47), to the new **Olympus 11-22mm f/2.8-3.5 Zuiko Digital Zoom,** above. This wide-angle zoom is actually the useful equivalent of a 22-44mm wide-angle zoom in the 35mm format. All that said, we haven't heard users of Canon and Nikon D-SLRs complain about the performance of their 35mm-based lens systems. In digital photography, image quality is in the eye of the beholder. —R.H.

…ller apertures provide more depth of field; larger apertures provide less depth of field. A simple adjustment of lens aperture thus allows great control over the appearance of a photograph.

…ting the aperture also affects how a photog… 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 Look into your camera's lens, and you will see a group of metal leaves or blades that overlap one another to …m a rounded opening (see below). This group of …ades 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 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 …h numbers next to them. With many modern, electronically controlled cameras, you adjust … aperture by pushing, sliding, and/or rotat… …rols on the camera body while referring … …bers on an adjacent LCD panel.

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

However your lens is adjusted, the size of the …erture is indicated on the lens's aperture ring, on … LCD panel, and/or in the viewfinder with a …mber called an **f-stop.** Indicated with the pre… "f/," f-stop numbers appear in the following …ndard sequence: f/1.0, f/1.4, f/2, f/2.8, f/4, f/5.6, … f/11, f/16, f/22, f/32, f/45, f/64, and so forth. …st lenses for 35mm cameras offer a range from …out f/2.8 or f/4 to f/22 or f/32.

…ameras with electronic displays on LCD panels …ite often also show in-between numbers, such … f/3.5 or f/9. Lenses with aperture rings rather … LCD displays usually have half-stop settings … "click" when set. But whether they click …ot, these lenses can be set anywhere between … stops—though the settings may not be criti… … …se. (See the chart above for the com… …uence of full and fractional f-stops.) …ver your lens, the larger the f-stop number, … 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, 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 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.

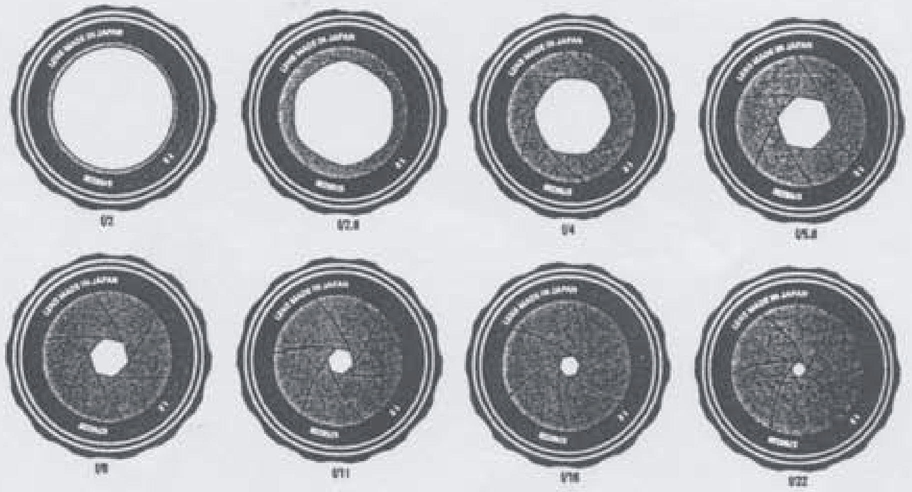
The actual, physical size of a given f-stop thus depends entirely on the focal length of the lens. With a 50mm lens, f/4 indicates an aperture with a diameter of 12.5mm (1/4 of 50mm, or about 1/2-inch wide). But with a 200mm lens, the same f-number represents an aperture of a different size, because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

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

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



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.

f/2

f/22

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.

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.

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. 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.

...mum 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.

Focus and Depth of Field

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

For most pictures, you choose a specific subject—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 above left). To make as much of the scene as sharp as possible, set as small an aperture as circumstances permit. To single out a subject, 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 above right). 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. 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 opposite, top). 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. 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

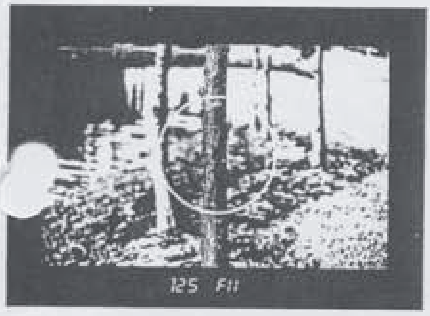
How Focal Length Affects Depth of Field The longer your lens focal length, the shallower the depth of field. Using a moderate telephoto lens (105mm) caused the background to fall out of focus (left). Using a wide-angle lens (28mm) made the background sharp (right). Note that both photographs were taken 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.

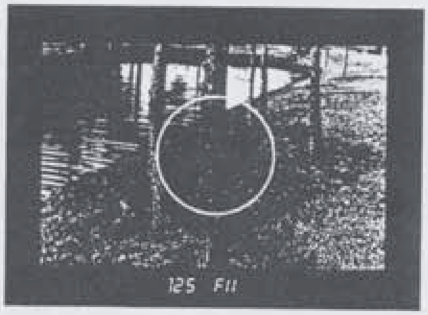
photographic tool, letting you change depth of field and adjust exposure at will. But it's really not that simple. You can't choose an f-stop without affecting other factors. First of all, the lens you're using may not have an aperture quite wide enough for your purposes. A 28-80mm zoom, for example, 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 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 up to 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 handheld 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. ■





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 (top). 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-[illegible]y using the camera's depth-of-field [illegible]w button, if your camera has one. Pressing [illegible]button stops down the lens to the f-stop you've actually set, increasing the depth of field you see in the viewfinder (bottom). But it also lets in less light, causing the viewfinder to darken and making the image more difficult to see.