Macro and Close-up Lenses

By its very nature, macro photography (and to a lesser degree close-up photography) has always caused challenges for lens manufacturers, and this is no different for digital cameras.

What has changed is the ease and precision of shooting at close distances, because the uncertainties introduced by the various optical calculations disappear with the instant feedback from a DSLR.

DSLRs are ideal for macro shooting, because the on-board processing of the image can deal with the problems of contrast, color, and even sharpness. Also, by shooting direct to a computer, you can use the larger monitor to check detail and tolerances. Moreover, with DSLRs that use a sensor smaller than 35mm film, only the center of the lens is used for imaging, and this is relatively free of many aberrations, including spherical aberration, which is worse at close distances.

The two most usual measurements in close-up imaging are magnification and reproduction ratio, and they are linked. The commonly accepted starting point for close-up photography is between 0.1× magnification (1:10 reproduction ratio, meaning the image is one-tenth life-size) and 0.15× magnification (1:7). At 1.0×, the image is life-size (1:1). Across this range, as the lens racks forward in its barrel, the light-reaching the sensor falls off increasingly, but autoexposure takes care of this.

Photomacrography, commonly known as macro, extends from 1.0× to 20× (a 1:1 reproduction ratio to about 20:1), at which point the laws of optics make it more sensible to use a microscope. Photomicrography, incidentally, means something else entirely—photography on a large scale. Photomicroscopy means photography using a microscope, for which there are a number of off-the-shelf systems for attaching a DSLR camera.

The most efficient method of magnifying an image is to extend the lens forward, away from the sensor, the way that most lenses are focused for normal photography. However, for close focusing, the lens elements need to move much further than normal, because of the relationship between the two conjugates (the distances from the principal point of the lens to the subject on one side and to the sensor on the other). When the subject is more than about ten times the focal length distant, the image conjugate stays more or less the same. Closer than this, however, and the image conjugate gets significantly larger. When the two conjugates are equal, you have 1:1 magnification and a life-size image.

This makes lens manufacture a little tricky because most lenses perform best when subjects are distant, but not so well when they are close. Aside from the mechanics of moving the glass elements inside the lens barrel, the sharpness suffers and aberrations get worse. A true macro lens is the ideal solution.
Close-up and macro lenses and accessories

Close-focusing lenses
Modern lens design makes it possible for standard lenses to focus down to close distances. The quality of the image at close focus, however, varies from make to make, and is likely to be compromised—at least in comparison to a true macro lens. The performance of a standard lens can be disappointing.

Macro lenses
These are designed to deliver their best image quality at close distances, and acceptable quality at normal distances up to infinity. Some manufacturers offer a choice of focal length between normal and long-focus; the advantage of the longer macro lenses is that you can use them at a greater working distance from the subject, which is useful, for example, with insects that might otherwise be frightened off by a close approach.

Extension rings and tubes
A standard method of increasing magnification is to increase the distance between the lens and the sensor, and the simplest way of doing this with an SLR is to fit a ring or tube between the lens and the camera body. The focal length of a lens is the distance between the sensor and the lens when it is focused at infinity. Increasing this distance by half gives a reproduction ratio of 1:2. Doubling the distance gives 1:1, and so on. Some, but not all, extension rings and tubes have linkages that connect the aperture and other lens functions to the camera.

Extension bellows
Flexible bellows moved by rack-and-pinion offer fine control over magnification, and are normally used for extreme close-ups. Because magnification is relative to the lens focal length, the shorter the lens attached, the more powerful the effect.

MACRO LENS
Nikon’s AF-S Micro Nikkor 105mm lens is a true macro lens—Nikon use the term “micro” to mean macro. It’s a true macro lens in the sense that it can capture images at a 1:1 ratio (life size).

DIFFRACTION
Another optical issue that is more relevant to macro than normal photography, is diffraction. This occurs when an opaque edge obstructs the light path, causing it to bend slightly and spread. This is what the aperture blades in the diaphragm inside a lens do, and the result is unsharpness.

Back to front lens
Most camera lenses are designed to perform well when the image conjugate is smaller than the object conjugate. At magnifications greater than 1 × (1:1) this is no longer true, and the image is better when the lens is reversed. For optical reasons, this only works well with lenses of a symmetrical design and with certain retrofocus lenses. Once reversed, the lens must then be stopped down manually.
Digital photography has made stitching together overlapping frames—to make a significantly larger image—a relatively straightforward technique.

The technique’s most common use is to create panoramas, but there are other applications. Although this is strictly speaking a software matter, it is highly relevant to lens focal length and coverage, because in effect you are creating a wider-angle view.

Also, with this kind of imaging, even though it makes heavy use of software, all of the planning needs to be done at the time of shooting—photography and stitching are separate operations. This is known as planar stitching, and the result is a normal digital image, saved usually as a TIFF or JPEG. A quite different, but very important alternative is cylindrical or spherical images, which are usually saved as QuickTime movies.

In principle, you could combine the overlapping images manually in Photoshop, but there are two obstacles. One is that as you turn the camera to one side for the adjacent frame, objects in the frame change their shape slightly—noticeably so with a wide-angle lens—so that each frame later needs a distortion adjustment. The other is that it is difficult to blend the brightness of adjacent frames when there are large, smooth areas such as a sky—again, particularly with wide-angle lenses. Stitcher software does this automatically, in two steps. The software first finds a number of corresponding points in adjacent images and warps the images so that they fit perfectly, to within one pixel. It then equalizes the images so that there is a seamless blend of brightness at the edges.

**Tiling for higher resolution**

Shooting a sequence horizontally creates a panorama, with the added advantage of making a larger image file than normal. This is, indeed, the easiest solution to creating a high-quality large image file—take any scene that you have just photographed, switch to a longer focal length, and photograph it again in sections, before assembling these into a higher-resolution version. This is known as tiling. It can also fulfill another objective, which is to increase the FOV (field of view). Smaller sensors make wide-angle lenses less effective, but you can increase the coverage by tiling.

**Panorama heads**

Numerous QuickTime tripod heads are available, designed to assist in taking images at the exact angles required to build up a QuickTime VR scene. These are essentially 360° panoramas, which in some cases also allow the viewer to look up and down (hence the second adjustment on the Manfrotto head). In order to create panoramas, each shot should be taken from exactly the same spot. QuickTime VR technology includes specialized stitching software.
A panorama sequence

Step 1 Decide on the area of the scene you want to cover, and the lens focal length you will use. Longer focal lengths need more frames to complete the same coverage as a wide-angle focal length: this gives a bigger final image file (good for a high-resolution image, but it takes up more space on the memory card and hard drive, and is more demanding of the processing) and less angular distortion.

Step 2 Mount the camera on the tripod and level the head. Use a QuickTime head, or equivalent, mounting the camera so that the nodal point of the lens is exactly over the axis of rotation. If the scene is distant and you are using a telephoto, take care to line up frames. Shooting with the camera frame vertical gives a deeper panorama.

Step 3 Make a dry run. In the simplest case, pick a short panorama, loosen the tripod’s pan head, start at the left (or right), and check the number of frames that you will need, panning to one side, allowing for an overlap of about 30% (between 15% and 40%). Judge the rotation between frames either by using the scale on the pan head (if there is one), or by eye through the viewfinder. If you have a grid focusing screen, use one of the vertical lines as a guide. Find a detail in the scene that is either centered or on the leading edge of the frame, and pan the camera so that it appears on this grid line (see below).

Step 4 Select fixed settings for the exposure and white balance. Check these out for sample frames across the sequence, paying particular attention to the highlight clipping and histogram. You may have to sacrifice some highlight or shadow detail.

Step 5 Check for movement within the scene, such as a passer-by, objects moving in a breeze, or changing light, and try to shoot when there is none. Shoot the sequence.

Step 6 Check that you have all the frames. Missing a frame in a sequence is easy when you are tiling rather than doing a simple side-to-side panorama.

Three images, shown here in red, blue, and green, were used to create this panorama of Prague.
Creating HDR Images

High dynamic range imaging, or HDRI, is a relatively new way of capturing the entire range of tones in a high-contrast scene, from shadows to highlights, which is beyond the ability of a normal sensor to capture with one shot.

For instance, a typically bright, sunlit scene containing highlights and shadows has a dynamic range in the order of 2,500:1, and while the human eye can accommodate this (though it does it by scanning the scene rapidly and building up a cumulative image), a digital sensor cannot completely manage it. This is because, while a typical 12-bit sensor shooting Raw theoretically has a dynamic range of 4,000:1, its practical range is closer to 1,000:1, mainly because of noise. If the sun appears in the shot, the dynamic range will shoot up to something in the order of 50,000:1. Another typical high dynamic range scene is an interior with a view to a sunlit exterior—a situation where the dynamic range can reach 100,000:1.

If the camera remains steady, a sequence of frames at different exposures can capture all the detail. The software exists to combine such a sequence into a single HDR file format. There are several HDR formats, but typically they are 32 bits per channel, and instead of this extra bit depth being pre-assigned to a range of values, as happens with 8-bit and 16-bit images, it is used in quite a different way. The bits are assigned to decimal points, so that any real-world tonal value can be given a precise digital value, and for that reason, this is known as floating point coding. A number of commercial programs exist for generating an HDR 32-bit floating point image file automatically from a sequence of exposures (normally shot about 2 f-stops apart). They include Photoshop, Photomatix, and easyHDR Pro.

The resulting HDR image contains all the information, but is essentially unviewable due to the limitations of the display media. Most monitors have a bit depth of 8 and can at best handle a dynamic range of about 350:1, while few papers do better than about 100:1. This requires a second step, which is to compress the data in the 32-bit image down to 8 bits per channel.

This is where HDRI becomes tricky, because there is in principle no ideal way to do this. Something has to go, and a satisfactory result depends on the way the tones were distributed in the original scene, on the range of exposures taken in order to create the HDR image, the algorithms and techniques used for compressing, and on top of all this the taste and judgement of the person doing it. The net result is deep unpredictability and many different appearances of output.

The process of assigning the original huge range of values from deep shadow to bright highlight is known as tone-mapping, for obvious reasons, but the methods vary according to the software. Photoshop offers four routes: Exposure and Gamma, Highlight Compression, Equalize Histogram, and Local Adaptation, of which only the last offers a useful "photographic" result. Photomatix, the leading dedicated HDR software, offers the choice of Tone Compressor (which features the powerful Tone Mapping control) and Details Enhancer. The former is the route for the more "artistic" HDR imagery, while the latter creates more naturalistic results.

Tone mapping an HDR image is unpredictable and often difficult to get exactly as you would like. Nevertheless, HDRI is hugely powerful and can enable photography of a kind that was previously impossible without the help of lighting, and makes high-quality, professional-looking existing-light photography perfectly viable.
Creating an HDR image

Although you can create an HDR image using Photoshop’s Merge to HDR... command under File -> Automate, the more popular route is to use Photomatix Pro, a dedicated HDR program. Photomatix Pro is available either as a standalone application or a Photoshop plug-in, providing a greater degree of control and allowing you to be a little more “artistic” with the Tone Mapping settings.

**Step 1** To create an HDR image you need to start with a number of exposures of the same scene; three is usually sufficient. What’s important is that, between them, the exposures capture the full range of tones in the scene, from the brightest highlights to the darkest shadows.

All DSLRs allow you to bracket exposures, and with the camera set to Continuous shooting, it’s easy to capture the various exposures you need.

Alternatively, Photomatix will allow you create “faux” HDR images using just one Raw capture. Although this will not create an HDR image in the strict sense of the term, you’ll be able to use the Tone Mapping settings to create HDR-like images.

**Step 2** Open Photomatix and click Generate HDR. Navigate to the exposures and click OK.

**Step 3** Once Photomatix has processed the various exposures, select Tone Mapping; this is when you’ll begin to see how your image will look. The most important settings are Light Smoothing and Micro-Smoothing. Experiment with these to determine how naturalistic you want your image to appear.

**Step 4** In this final version, Light Smoothing and Micro-Smoothing settings were deliberately chosen to create a painterly effect. The 16-bit HDR image was saved, and further color and tone work was undertaken in Photoshop before the image was sharpened slightly and saved as an 8-bit TIFF.