Chapter 2

Techniques of Biological Close-Up Photography

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Anne D. Webb received her Biology BA from Carleton College in 1966. She received her Biology MAT from Smith College in 1970 and her PhD in Botany from the University of Montana in 1977. She taught at Southern Oregon State College, Ashland, at Framingham State College, Massachusetts and at the University of Puerto Rico. Her research interests are in Plant Ecology and Population Biology, and she has taught courses in General Ecology, Environmental Biology and Field Botany. Both of the Webbs are avid nature photographers. Anne Webb received her critical training from Danny On, and she passed her knowledge on to David Webb.

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Introduction

The use of 35 mm slides in biology teaching has become almost universal. Transparencies on a wide variety of topics are available from major educational supply houses and from companies specializing in audio-visual materials, but as one develops his or her courses the need for illustrations which are not commercially available arises. Slides are also required for seminars and research talks. With a 35 mm single-lens reflex camera plus a few inexpensive attachments, it is relatively easy to take high-quality pictures for teaching and research. In addition, the basic skills of biological photography can be incorporated into advanced courses so that students can learn how to document their work and sharpen their powers of observation.

Two comprehensive reviews on biological photography have recently been written by Blaker (1976, 1977). An attractive volume by Nuridsany and Perennou (1976) and an inexpensive handbook in the Petersen's series (Owens 1975) also provide useful information on this subject. The major purpose of this article is to review the basic operating principles of single-lens reflex photography and to concentrate on the use of close-up techniques for the production of color slides. Special emphasis is placed on the use of battery-operated electronic flash units.

Instructors' Materials

Film Selection

Image quality depends on a variety of factors, and the selection of the best film for a given subject and situation is the first consideration to be made. For natural light and flash photography, we usually select Kodachrome 64. This is a warm film which produces natural colors with good saturation, and it has a fine grain. The only problem encountered with this film has been with flash photography of some red flowers where the natural color can be transformed into a surrealistic carnival red. This effect can be exciting, but it can also be annoying if you are trying to record the natural color of the subject. Ektachrome 64 is somewhat cooler than Kodachrome, and it is slightly more expensive. However, flash exposures with Ektachrome yield natural colors throughout the spectrum, and it should be considered as an alternative to Kodachrome. Kodachrome with an ASA of 64 requires more exposure than Ektachrome, which comes as ASA 200 or 400. The latter more sensitive films provide wider latitudes of exposure under low light. However, these "faster" films produce more grainy images. Agfachrome comes in two speeds at ASA 64 and 100. Both films are similar and produce warm colors with good saturation. The colors produced by Agfachrome are distinct from those produced by the Kodak films. Agfachrome is especially good for natural-light photography. However, these films have a large grain which makes them less desirable for enlargements. We have had more than the average share of problems with factory processing of Agfachrome and have discontinued use of these films.

For laboratory photography with incandescent light Ektachrome 160 is a good all-purpose film. It is excellent for copying black and white as well as color illustrations. It is also good for photographing cultures and for photomicrography with stereo or compound microscopes. Eastman 5247 color negative film is an interesting and inexpensive alternative to Ektachrome. This movie film is sold by RGB Color Labs, 816 North Highland Ave., Hollywood, CA 90038. It has an ASA of 100, but it can also be used at ASA 200 or 400. It produces fine-grain slides which come with negatives. These have good color saturation with tungsten illuminaton. This film can also be used for natural light and flash photography, but we have not had satisfactory results under these latter circumstances with 5247 film. The negatives can be used to make more slides or to make color prints. These negatives could also be used to make black and white prints with Kodak Panalure photographic paper. However, we have not tried this last procedure and cannot comment on the quality of the prints produced. A variety of other films, incuding Fujichrome, are available and should be tested against the above films.

Camera Basics

Cameras are available in all sizes and shapes. For ease of use, versatility and image quality, the 35 mm single-lens reflex camera is the instrument of choice for biological photography. (Note: 35 mm here refers to the width of film which fits the camera.) Camera prices have remained relatively constant during the past decade, and recent emphasis on compact design plus electronic innovations has made sophisticated cameras available to most biologists. It is important that any camera intended for use in close-up photography have a fully manual operational mode!

With a single-lens reflex camera focusing is performed directly through the camera's lens. Most lenses have two sets of distance markings engraved on them (Figure 2.1). For distant objects the lens is focused at infinity. As you focus on close objects, the subject-to-lens distance will be indicated in feet and meters on the lens. Most standard lenses with a focal length of 50 mm will focus from infinity to 0.5 meters (approximately 18 inches). A typical 50 mm macro lens will focus from infinity to 0.2 meters (8 inches).

After focusing on the subject the correct exposure must be determined. Film exposure is governed by the sensitivity of the film to light. This is indicated by an ASA and/or DIN number. Most cameras have an adjustable ring on top of the camera for setting the light meter to the correct ASA for the

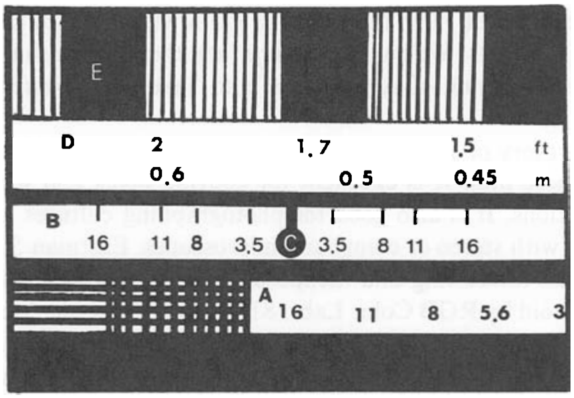


Figure 2.1. Diagram of the base of a typical lens. A, f-stop ring; B, depth of field scale; C, f-stop and focal distance indicator; D, focal distance scale in meters (m) and feet (ft); E, focusing grip. In this figure, the lens opening is set at f/16 and focal distance a little beyond 1.7 ft (.52 m). The depth of field scale indicates that with these settings anything between 1.5 and approximately 2.2 ft away will be in focus.

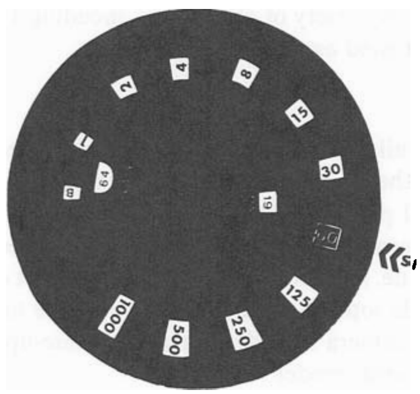


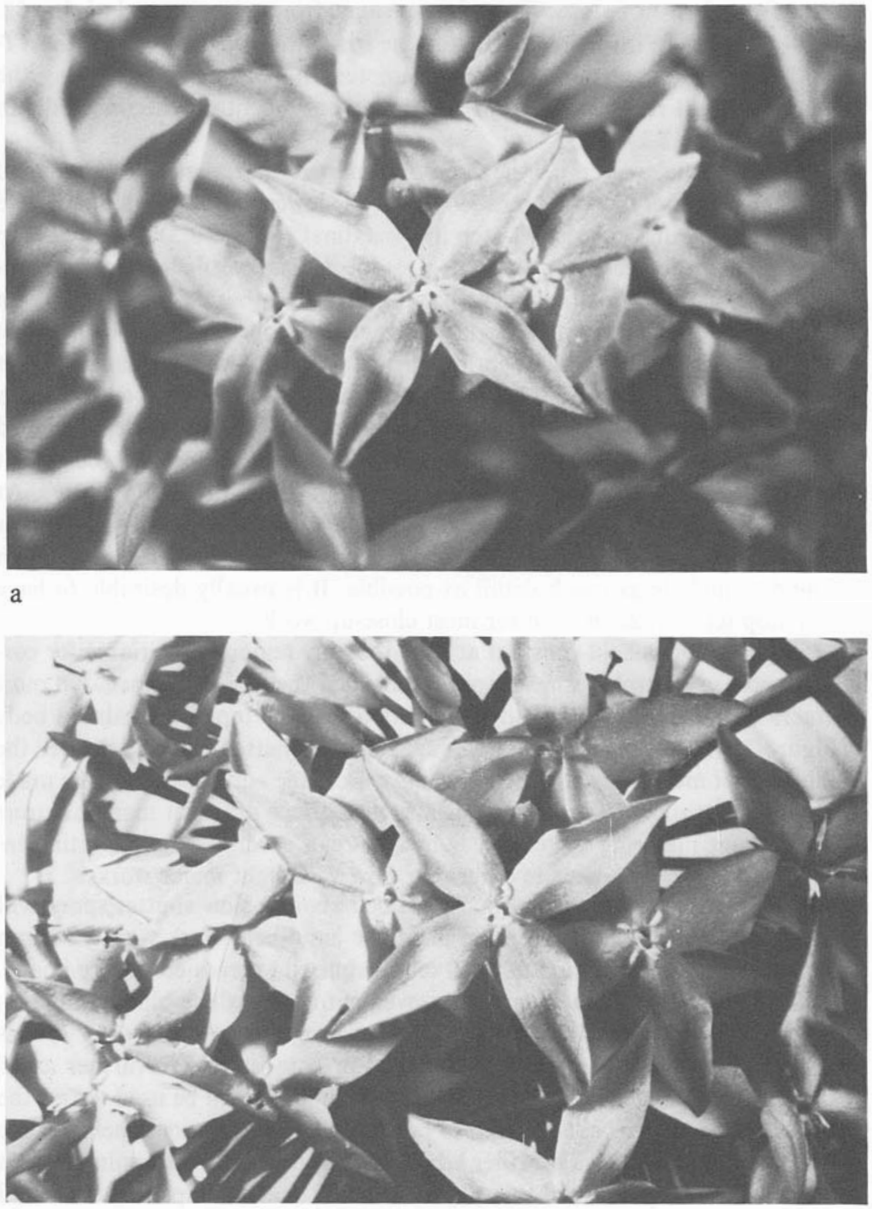
Figure 2.2. Shutter speed control with shutter speeds from 1 sec to 1/1000 sec. B (bulb) is for manually-timed exposures. The shutter speeds are indicated by black numbers arranged in a circle. The white shutter speed (1/60 sec) would be the correct one for taking flash pictures. The film sensitivity, indicated as DIN and ASA, must be set. SI, shutter speed indicator.

film in use. Some cameras have ASA and DIN numbers on the same scale (Figure 2.2). The higher the ASA or DIN number, the greater is the film's light sensitivity. For this article only film with ASA 64 (DIN 19) will be considered. With the ASA set at 64 exposure depends on the lens aperture and the shutter speed. Lens aperture is controlled by a ring dial on the lens which is connected to an iris diaphram inside the lens. The numbers on the ring are called f-numbers or f-stops. These f-stops range from approximately 1.4 to 32. (f/1.4 to f/32). With the lowest f-stop the iris is wide open. At the highest f-stop the iris is closed to its smallest diameter. In addition to regulating the amount of light reaching the film the lens iris also controls the image depth of field (Figure 2.2).

Depth of field refers to the zone of apparent sharpness in front of and behind the point of focus (Owens 1975). At the lowest f-stop the depth of field is minimal and at the largest f-stop it is maximal (Figure 2.3). At any f-stop depth of field decreases as the lens-to-subject distance decreases. The approximate depth of field is indicated on the lens. On both sides of the f-stop indicator line there are small markings for each f-stop. The distance between these brackets indicates the depth of field for the indicated lens to subject distance (Figure 2.1). At f/11, focused at 2 meters, the depth of field extends from 3 to 1.75 meters. At the same f-stop focused at 1 meter the depth of field extends from approximately 1.25 meters to 0.9 meters, and when focused at 0.3 meters the depth of field extends from 0.305 meters to 0.295 meters. At closer focusing ranges the depth of field becomes critically small. Since most biological subjects are three dimensional it is important to have sufficient depth of field to include as much detail as possible. It is usually desirable to have the f-stop set at f/22 or f/16 for most close-up work.

If the f-stop is held constant at f/22 the only remaining variable for correct exposure control is shutter speed: how long the film is exposed. On most cameras the shutter speed is adjusted with a knob on top of the camera body (Figure 2.2). To set the correct exposure turn the shutter speed knob until the built-in light meter indicates a correct exposure. Fine adjustments can be made by making small changes in the lens aperture. Since different manufacturers use different metering systems it is best to read carefully the operating instructions for your camera to determine how your light meter works.

Under the restrictive conditions outlined above a slow shutter speed will be required to properly expose the film. For hand-held work with a 50 mm lens a shutter speed of 1/125 or 1/60 sec is required to produce a sharp image. At slower speeds camera or subject movement can produce blurred images. This problem is intensified at close focusing ranges. At slow shutter speeds the camera must be supported by a tripod or copy stand. To further avoid camera vibration a cable release or a built-in timer should be used to trip the shutter. Wind screens can be used to prevent subject vibration when you are working in the field. This is rather laborious, but it is time-consuming to wait until the wind stops or until the subject decides to take a nap. One dedicated photographer constructed his tent around a rare wildflower so that he could block wind currents.



a

b

Figure 2.3. (a) Close-up of inflorescence of *Ixora* taken with 50 mm macro lens fully extended, plus +10 diopter lens at f/4. The center of the picture is in focus but the area around the center is out of focus. (b) Same as a. except that the lens was set at f/32. Note that the borders of the picture are now in focus because of the greater depth of field at this higher f-stop.

For extreme close-ups there might not be enough ambient light to expose the film at f/22 unless the shutter remains open for several seconds. At very long exposures the color rendition of the subject may not be saturated, and washed-out images can be produced. For laboratory work supplementary lighting can be obtained from small reflector lamps and from dissecting microscope illuminators. A tungsten film must be used with these lights. There are some fluorescent lights which produce accurate colors with daylight film, but we have not experimented with fluorescent illumination. With daylight film a portable electronic flash is ideal for additional lighting. Use of a flash has several advantages. The flash pulse is 1/1000 to 1/3000 sec and therefore any camera or subject movement is frozen. The light produced by the flash gives saturating, natural colors with daylight film. When the flash is used at close lens-to-subject distances at f/22 the light reflected from the subject exposes the film, but the background objects appear dark and may be completely blacked out since they do not reflect enough light to expose the film. This results in striking images of sharp contrast and detail.

Flash photography has two disadvantages. With most cameras it is impossible to use the built-in light meter to measure the strength of the flash pulse. Correct exposures for distant subjects can be estimated from the calculator on the back of most flash units. The shutter speed is relatively unimportant since most of the light will be coming from the flash. The shutter can be set at a slow speed if you wish to increase the amount of background atmosphere present in the picture. However, on most cameras the shutter speed must be set at 1/60 sec or less for synchronization between the flash and the shutter. On some cameras the flash and shutter are synchronized at 1/125 sec or less. You should check your camera to determine the maximum shutter speed for flash use. This shutter speed is usually painted a different color from the other shutter speeds (Figure 2.2). To use the calculator rotate its dial to indicate the ASA of your film. The recommended f-stop will appear opposite the lens-to-subject distance on a separate part of the calculator. Most small flashes are effective from 2–20 feet. Many units have built-in automatic sensors which regulate the duration of the flash pulse within the above distance range. To use this feature, the aperture is set at a standard f-stop indicated on the flash calculator. The amount of light reflected from the nearest subject regulates the flash pulse. This works well with distant subjects, but since the recommended f-stops on most units are around f/4 there is a serious loss of depth of field at close focusing ranges. It is best to use the manual flash mode at close range and to determine the f-stop from the calculator. Neither of these procedures is infallible, and you need to experiment with your camera to determine the best aperture settings for automatic and manual exposures. It is wise to take one picture at the recommended f-stop and one at the next higher f-stop.

Experimentation must also be conducted when the subject-to-lens distance is less than 2 feet. Flash exposures at close range can be calculated (Blaker 1976), but a simple experiment can yield enough information so that you can usually estimate the proper flash-to-subject distance for the close-up equipment in use. One of the major activities described in this chapter is the empirical determination of the best flash-to-subject distances for a variety of close-up attachments. A general practice which works for us is to hold the flash at approximately the same distance from the subject as the camera back. This reference point changes with the type of attachment used and also with the relative reflectance of the subject. In general, with dark colors like blue, purple, green and red the flash can be held at the same distance as the camera back or closer. With white, yellow or light pink objects it is best to hold the flash 5 to 10 cm farther from the subject than the camera back. As with all flash procedures it is wise to take several exposures at a variety of angles and distances to ensure that a satisfactory image is obtained.

The second problem associated with flash photography is that when the flash is oriented at a low angle to the subject a sharp shadow may be cast by any projection. These shadows may provide attractive highlights, but they can obscure details and may create distracting dark areas. Most of these problems can be avoided by aiming the flash so that it is pointed as directly as possible at the subject. With extreme close-ups it is almost impossible to avoid placing the flash at low angles to the subject. A piece of white cardboard or aluminum foil can be used as a reflector to bounce the flash light back onto the subject from the side opposite the flash. Alternatively, a second flash can be used with an electronic slave which will automatically trigger the second flash after the first flash has fired. The use of two flashes usually requires a tripod to hold the camera or the second flash. This procedure also requires recalculation of the flash-to-subject distances obtained with one flash. The reflector method also increases the amount of light reflected by the subject, and this alters the exposure. To compensate for the extra light the flash should be moved back approximately 5 cm when a reflector is used. We have not experimented with the two-flash technique and cannot comment on the adjustment of the flash-to-subject distances required with this procedure.

The flash can be directly attached to the camera by the hot-shoe on top of the view finder (Figure 2.4) or by a flash-synchronization cord which connects to an outlet on the camera body. The flash cord is plugged into the X outlet. Hot-shoe attachment is good for subjects at 3 to 20 feet. For close work the flash should be hand-held so that it can be directed at the subject. Spiratone Inc. (135–06 Northern Blvd., Flushing, N.Y. 11354) makes an attachment which allows you to place your flash on a boom attached to your camera's hot shoe. This allows you to aim your flash while you hold the camera with both hands. The hand-held technique has been called the close-up flash method

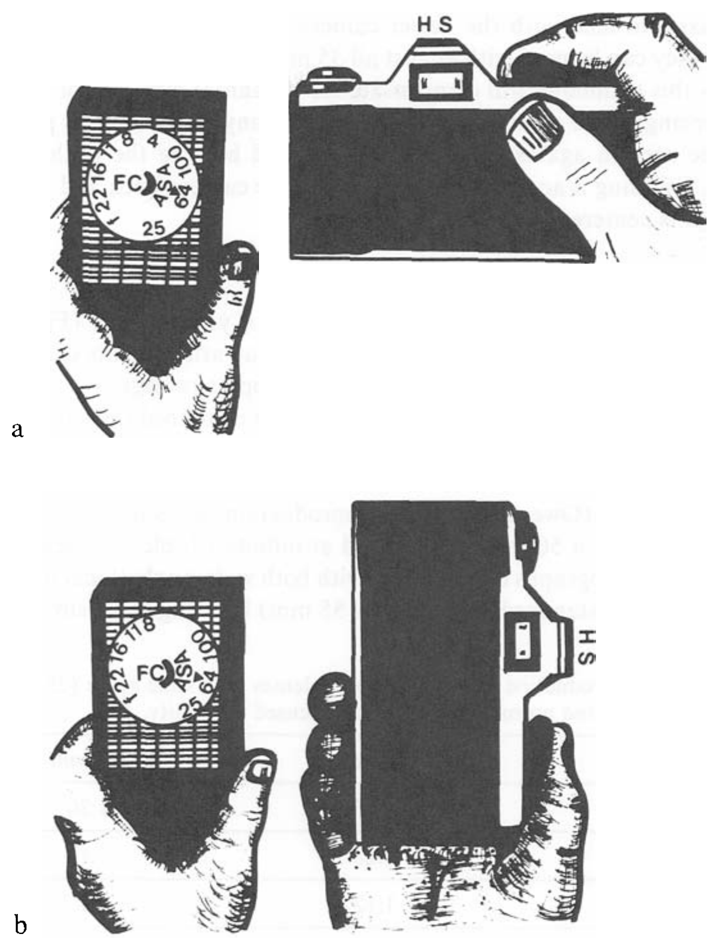


Figure 2.4. (a) Hand-held close-up flash method for horizontal or vertical pictures. (b) Hand-held close-up flash method for vertical pictures. FC, flash calculator; HS, hot shoe.

by Blaker (1977). It is fast, simple and versatile but it is also somewhat awkward. We use the hand-held technique for 99% of our own close-up work. To use this method hold the camera in your right hand. For horizontal pictures place one side of the camera against the palm of your right hand so that your index finger can depress the shutter button. Secure the camera with your thumb from behind and with your other fingers on the front of the camera (Figure 2.4a). The same grip can also be used with vertical pictures, or you can support the camera by placing the lens between your index and middle fingers while the lower edge of the camera rests between your thumb and index finger (Figure 2.4b). Your thumb can depress the shutter button. These grips are much easier to hold with the newer cameras of small dimensions, but with practice they can be used with almost all 35 mm cameras. The amount of time saved by this technique will compensate for the initial difficulty of mastering the balancing of the camera in your hand. In many instances it is possible to brace the camera against the wrist of the hand holding the flash for extra stability. Focusing is accomplished by moving the camera back and forth until the image is centered.

Close-Up Attachments

Close-up lenses which screw onto the front of your camera (Figure 2.5) are the easiest to use and most inexpensive close-up attachments of all. These can be purchased in sets or individually with diopter ratings of +1 to +20. They can be used individually or combined. When combined the strongest lens with the highest diopter rating should be placed on the camera first. A total diopter rating of +20 is the maximum which can be used without encountering aberrations (Owens 1975). The reproduction ratios for close-up lenses with a 28 mm and a 50 mm lens focused at infinity (Table 2.1) demonstrate that close-up photographs can be taken with both wide-angle (focal length less than 50 mm) and standard lenses (50 or 55 mm) by using these simple lenses (Owens 1975).

Table 2.1. Reproduction ratios for close-up lenses with wide angle (28 mm) and normal camera lenses focused at infinity.

Diopters	*28 mm*	*50 mm*
+1	1:36	1:20
+2	1:18	1:10
+3	1:12	1:6.7
+4	1:9	1:5
+5	1:7	1:4
+6	1:6	1:3.4
+7	1:5.5	1:2.9
+8	1:4.5	1:2.5
+10	1:3.5	1:2
+20	1:1.7	1:1

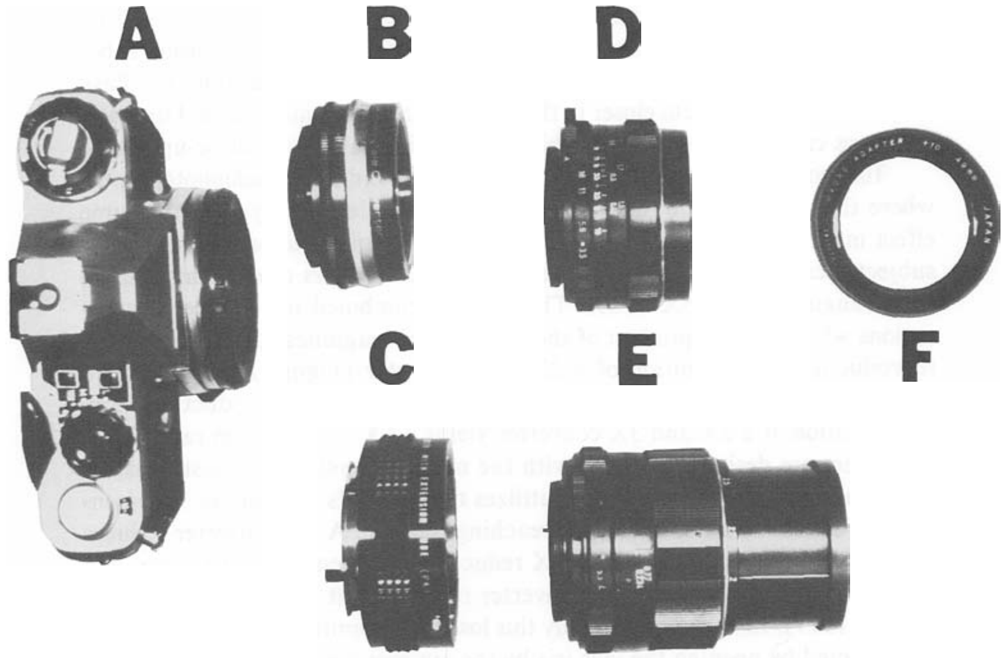


Figure 2.5. (A) Typical 35 mm camera (B) with 2X tele-converter, (C) 35 mm lens, (D) 25 mm extension tube, (E) 50 mm macro lens, and (F) +10 diopter lens.

The reproduction ratios in Table 2.1 can be increased by focusing the camera lens closer than infinity. Even greater magnifications can be achieved by combining close-up lenses with a macro lens or with extension tubes (Figure 2.5) which will be discussed later. Spherical aberrations can be produced with close-up lenses unless large f-stops are used. With close-up flash photography we have had excellent results with both the +10 and +20 diopter lenses. These lenses do not require exposure compensation since they transmit light with little loss in intensity. For close-up flash photography at f/22 the flash should be held 5–10 cm farther from the subject than the back of the camera.

Extension tubes are simply hollow cylinders which increase the distance of your camera's lens from the film plane. The resulting magnification is achieved without the addition of other lenses to your camera. The resulting image is as sharp as your camera's lens will permit. Extension tubes usually come in sets which provide 50 to 100 mm of extension. With a 50 mm lens and 50 mm of extension the reproduction ratio will be 1 : 1 (Owens 1975).

Automatic extension tubes are coupled to your camera's light meter so that exposures in natural light are made in the standard fashion. Extension tubes reduce the amount of light reaching the film. In flash photography the flash may have to be held 5 cm closer to the subject than the camera back. Dramatic close-ups can be achieved by combining extension tubes with close-up lenses.

Tele-converters are usually thought of for their use in telephotography, where they increase the focal length of the prime lens. They have the same effect in close-up photography with the advantage of not altering the lens-to-subject focal distance for the prime lens. Tele-converters come in magnifications ranging from 1.5X to 3X. They can be combined to produce magnifications which are the product of their individual magnifications. With a 1 : 1 reproduction ratio addition of a 2X tele-converter (Figure 2.5) produces a 2 : 1 reproduction ratio, and a 3X converter yields a 3 : 1 reproduction ratio. Combination of a 2X and 3X converter yields a 6X reproduction ratio. Tele-converters are designed to work with the metering systems of most cameras so that ambient light photography utilizes the camera's light meter. Tele-converters reduce the amount of light reaching the film. A 2X converter reduces the light intensity by 2 f-stops, a 3X reduces light intensity by 3 f-stops, and a combination of a 2X and 3X converter reduces light intensity by 5 f-stops (Blaker 1977). In flash photography this loss of transmitted light intensity can be corrected by opening the lens iris by the appropriate number of f-stops, or the flash-to-subject distance can be decreased. With a 2X tele-converter the flash-to-subject distance can be halved and the lens aperture can be increased by 1 f-stop (Blaker 1977). With a 3X tele-converter the flash-to-subject distance can be reduced to 1/3 normal and the aperture can be increased by 1 f-stop. There is no real loss of depth of field when the lens aperture is increased because the tele-converter actually increases the effective f-stop of the prime lens (Blaker 1977). We have experienced variability in the degree to which different tele-converters decrease the amount of light transmitted in close-up work, so it is a good idea to conduct a series of test exposures with different lens apertures and flash-to-subject distances with your equipment.

Tele-converters produce some spherical aberrations at low f-stops and may increase the amount of grain in the image. However, at the large f-stops used in flash photography we have not experienced either of these problems. Tele-converters have been unjustly given a bad reputation (Blaker 1977); for ease of use, image quality and magnification power they rank highly on our list of close-up attachments. By combining a tele-converter with a normal 50 mm lens and a +10 close-up lens remarkable close-ups can be taken.

A bellows acts like a variable extension tube. With a 50 mm lens a typical bellows will provide reproduction ratios from 1 : 1 to 4 : 1. A 5 : 1 reproduction ratio can be obtained by using a reversal ring to reverse the direction of the lens attachment to the bellows. Since the bellows does not maintain a connection between the prime lens and the camera metering system, exposure in ambient light must be determined with the lens stopped down. The proper f-stop must be manually adjusted after focusing with the aperture open. A double cable release which closes the lens iris and trips the shutter may also be used.

Because of the large extension achieved with a bellows the amount of light reaching the film will be reduced. Therefore, slow shutter speeds may be required for exposures at f/11 or f/16 where good depth of field would be achieved. A tripod or a copy stand is usually required to support the camera during bellows use. Most bellows have a focusing rail which attaches to the tripod or copy stand. The focusing rail should have a scale so that the amount of extension can be recorded. As a general rule for extension tubes and bellows, the reproduction ratio is equal to the amount of extension divided by the focal length of the lens. For example, with a 50 mm lens plus 200 mm of extension the reproduction ratio is approximately 4 : 1.

For ultraclose-up work it is important to have a prime lens with a flat focal field. Special flat-field lenses can be purchased for bellows use. A macro lens (Figure 2.5) has optical qualities similar to those of a flat-field lens. The macro lens has the added advantage of being useful for normal photography. Most normal lenses (Figure 2.5) are designed to achieve their best focus at infinity (Owens 1975), and they are not very good for high magnification photography. These latter lenses can be used to achieve 1 : 1 reproduction, but at greater magnifications lens aberrations may produce poor images. For 3X to 4X reproductions the normal lens should be reversed with a reversal ring (Owens 1975).

Most bellows can be used for copying slides by adding an attachment. This feature can be especially useful for teaching and research. We have not used a bellows and can not make experienced comments on this apparatus.

Polarizing filters have several uses in biological work. Almost all prime lenses have a set of threads at the end of the lens barrel to allow for filter attachment. In natural and artificial light photography there are usually two sources of polarized light. A clear blue sky from 90 to 180 degrees opposite the sun is one source of polarized light. The other source is reflected light from nonmetallic surfaces like glass or water (Blaker 1977). By rotating the polarizing filter one can remove most of the polarized light from the beam passing through the camera's lens. This has several desirable effects. The polarizing filter can be used to darken the sky without altering the other color values in the picture. This can be very useful in landscape work where it is difficult to expose properly for both the foreground and the sky. Distant haze will also be partially penetrated by a polarizing filter. The polarizer will suppress reflection from culture flasks and aquatic habitats. This latter quality has many obvious advantages for biological work. Most polarizing filters reduce the amount of light entering the lens by 2 f-stops, and this is the only disadvantage of these filters.

Procedures

The laboratory will consist of three exercises. Exercises II and III can be done together.

I. *Determination of Correct Flash-to-Subject Distances with a Macro Lens and Close-Up Attachments*
   A. Groups of three will work with a camera equipped with a 50 mm macro lens, 50 mm extension tube, 2X tele-converter and +10 close-up lens. The camera body will be mounted on a tripod or copy stand. The film ASA is 64, the shutter speed will be held at 1/60 sec, and the lens aperture will remain at f/22.
   B. Each member of the group will take turns exposing frames with each lens accessory. The other team members will record the camera back-to-subject distance and the flash-to-subject distance for each picture in Table 2.2. The subject color should also be recorded in Table 2.2.
   C. To start, fully extend the lens and focus on the subject by moving the entire camera up or down.
   D. After focusing, record the subject-to-camera-back distance in Table 2.2.
   E. Position the flash at ½ the camera back-to-subject distance and record this value in Table 2.2.
   F. Position the flash so that it is pointing as directly as possible at the subject. Use a cable release to trip the shutter.
   G. Repeat the above procedure holding the flash at the same distance as the camera back from the subject and at 1 ½ this distance.
   H. Add the extension tube and repeat A. to G.
   I. Remove the extension tube, add the tele-converter and repeat A. to G.
   J. Remove the tele-converter, add the +10 close-up lens and repeat A. to G.

Table 2.2. Determination of flash-to-subject distance at f/22 1/60 sec, ASA 64.

Subject Color

	Camera-to-Subject Distance (X)	*Flash-to-Subject Distances*		
		(½X)	*(X)*	*(1½X)*
Macro Lens Fully Extended				
Exposure Quality				
Macro Lens & Extension Tube				
Exposure Quality				
Macro Lens & +10 Close-Up Lens				
Exposure Quality				
Macro Lens & Extension Tube & +10 Close-Up Lens				
Exposure Quality				
Macro Lens & 2X Tele-Converter & +10 Close-Up Lens				
Exposure Quality				

K. Combine the extension tube and the +10 close-up lens and repeat A. to G.

L. Combine the 2X tele-converter and the +10 close-up lens and repeat A. to G.

II. *Use of the Two-Hand Technique to Take Close-Up Flash Pictures*

A. Each group of three will need all of the equipment required for exercise I.

B. Start by using the fully extended lens to take flash pictures of a variety of subjects. Record the camera back-to-subject distances and the flash-to-subject distances for each picture in Table 2.3. Work as a team to aim the flash and record the distances.

C. Add the tele-converter and take several pictures.

D. Remove the tele-converter, add the extension tubes and take several pictures.
E. Remove the extension tube, add the +10 close-up lens and take several pictures.
F. Combine the tele-converter with the close-up lens and take several pictures.
G. Combine the extension tube with the +10 close-up lens and take several pictures.
H. Try other lens and attachment combinations to take several pictures. Be sure to record all data in Tables 2.2 and 2.3 so that you can interpret your results.

Subject & Color	*Camera Back-to-Subject Distance (X)*	*Flash-to-Subject Distance*	*Exposure Quality*
Macro Lens Fully Extended 1			
2			
3			
4			
5			
6			
Macro Lens & Tele-Converter 1			
2			
3			
4			
5			
6			

Table 2.3. *Continued*

Subject & Color	*Camera Back-to-Subject Distance (X)*	*Flash-to-Subject Distance*	*Exposure Quality*
Macro Lens & Extension Tube			
1			
2			
3			
4			
5			
6			
Macro Lens & Close-Up Lens			
1			
2			
3			
4			
5			
6			
Macro Lens & Close-Up Lens & Tele-Converter			
1			
2			
3			
4			
5			
6			

Table 2.3. *Continued*

Subject & Color	*Camera Back-to-Subject Distance (X)*	*Flash-to-Subject Distance*	*Exposure Quality*
Macro Lens & Extension Tube			
1			
2			
3			
4			
5			
6			
Extra Combinations A)			
1			
2			
3			
B)			
1			
2			
3			
Macro Lens & Close-Up Lens & Extension Tube			
1			
2			
3			
4			
5			
6			

Table 2.3. *Continued*

Subject & Color	*Camera Back-to-Subject Distance (X)*	*Flash-to-Subject Distance*	*Exposure Quality*
Macro Lens & Extension Tube			
1			
2			
3			
4			
5			
6			

III. *Comparison of Manual and Automatic Flash Exposures*

A. Each group of three will need a camera equipped with a macro lens and a flash with automatic and manual modes.

B. Note the recommended f-stop for the automatic mode. This should be indicated on the calculator on the back of the flash.

C. Set the shutter speed at 1/60 sec.

D. Focus on a subject at 15 feet. Use automatic mode to take a picture at the suggested f-stop.

E. Take another picture on automatic at the next higher f-stop.

F. Set the flash on manual. Use the calculator to estimate the best f-stop for 15 feet, ASA 64. Set this f-stop on the lens and take one picture.

G. Take a second picture on manual at the next higher f-stop.

H. Repeat the above at 9 feet and 3 feet. Use the camera's hot shoe for pictures at 15 and 9 feet, but use the two-hand technique at 3 feet.

I. At distances closer than 3 ft. automatic mode will not work well. Focus on a subject at 1 foot. With the flash on manual take pictures at f/16, f/22 and f/32 if possible.

J. When your film is returned complete Table 2.4. Analyze your results. What happened in the automatic mode as the subject-to-camera-lens distance decreased? Which mode gives the best depth of field? How accurate is the calculator? What effect would longer shutter speeds have on the exposure? What effect did subject color have on the exposures?

Table 2.4. Manual and automatic flash exposures.

Distance	*Mode* *Automatic*	*Manual*	*Exposure Quality*
15 ft	f/	f/	
	f/	f/	
9 ft	f/	f/	
	f/	f/	
3 ft	f/	f/	
	f/	f/	
1 ft	X	f/16	
	X	f/22	
	X	f/32	

References

Blaker, A. A. Field photography beginning and advanced techniques. San Francisco: W. H. Freeman and Co.; 1976. *A comprehensive treatise on biological photography.*

———. Handbook for scientific photography. San Francisco: W. H. Freeman and Co.; 1977. *A more simplified treatment of the same material presented in the first reference.*

Nuridsany, C.; Perennou, M. Photographing nature. New York: Oxford University Press; 1976. *A less technical and popular treatment of biological photographic techniques.*

Owens, W. J. Close-up photography. Los Angeles: Petersen Publishing Co., 1975. *An easy-to-read and informative treatment of close-up photography with many biological applications.*