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Photo, above: Bart Mulder. *The "flowery" frost patterns on a window pane. The effect of the linear pattern is accentuated by the gentle variations in color, shifting between a somewhat reddish, direct sunlight and the indirect blue light from the sky.*

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CLOSE-UP

SMALL SUBJECTS ON A LARGE SCALE

For many reasons it is difficult to define what close-up photography is in only a few words. The above headline is only one of several choices; there is no all-embracing definition. This is due to two main reasons . First, the terminology, unfortunately, is faulty in several respects and it does not cover the theme adequately. Second, the limits at which close-up photography begins and ends are decided by varying values and circumstances, or (and this is less confusing) the limits are simply assumed to be understood as flexible and open.

So it is unnecessary, perhaps, to enlarge upon the actual definition of close-up photography. The above explanation is given so that the terms, equipment, and technical problems in close-up photography will be considerably easier to understand if the overall background is grasped as a whole.

Furthermore, the headline has been deliberately given a double-meaning. At first glance, the words imply what is generally understood as close-up photography, i.e., the object (or subject) is reproduced on a large scale. Semantically, it should also be defined that, in spite of the smallness of the subjects, the world of close-up photography is indefinably rich, eloquently expressive and quite unique.

Orientation in Space

The world we live in has no known, definable limits. Most people can grasp the significance of the infinite: it disappears into the outer void of the universe; it indicates the limitless expanse of the *macrocosm.* But at the other extreme there is, relatively speaking, a remarkably similar situation. Most people have heard of bacteria; some have seen them. The same remarks apply to molecules and atoms, but no one has seen the *microcosm,* either directly or indirectly with the aid of equipment. In this respect our konwledge is based on indirect proof, studied reactions, theories and suppositions.

We humans can only see and comprehend a limited part of this limitless world — the part between the extremes. Apart from what we have learned, empirically or by study, of the space and phenomena around us, we orient ourselves primarily by the use of our five senses. Of these the most important (at least in the theme under discussion) is the sense of sight; a function which has many close parallels in photography.

Close Limit of the Eye

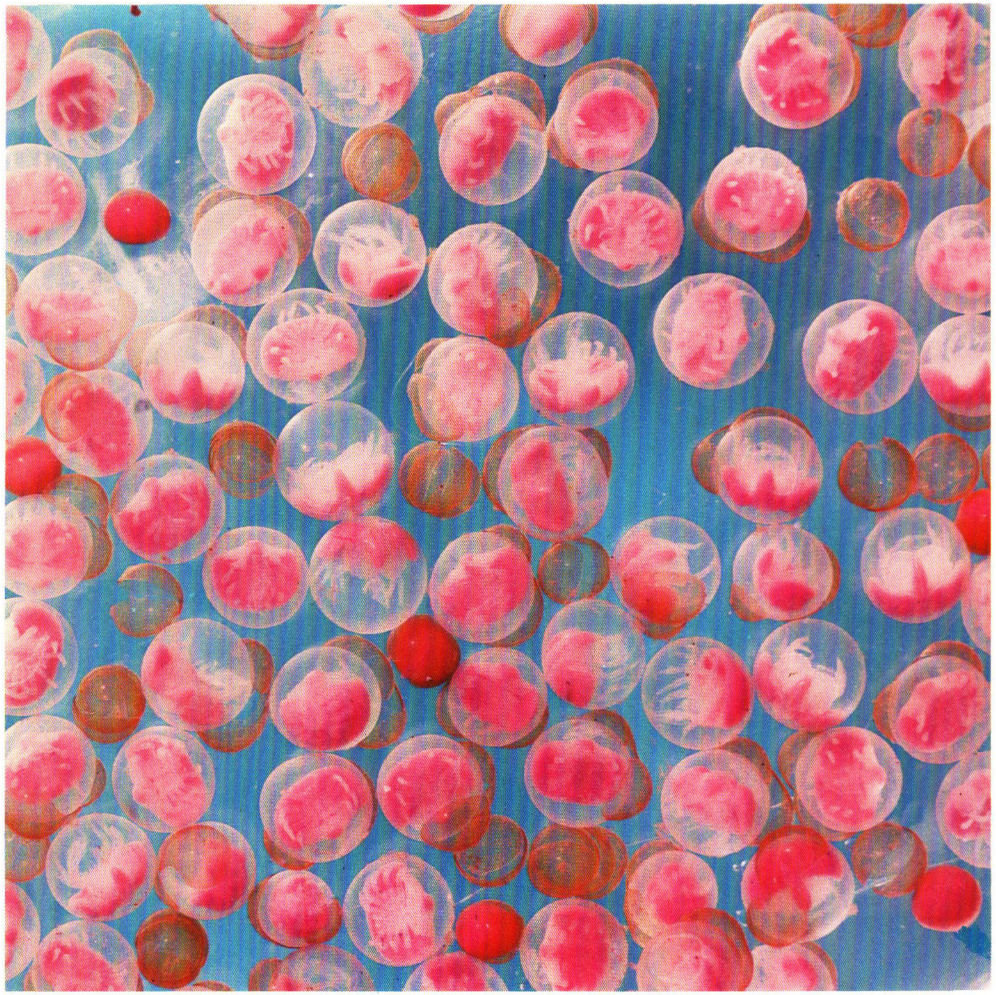
Both the human eye and the camera lens are restricted in their functions, and are full of shortcomings in several respects. The limited capacity for clear reproduction is one of them; another involves the wavelengths of the light rays which can be broken down into a usable image/picture. As is known, light is merely an extremely limited part of all electro-magnetic radiation encountered in nature.

The *distant limit* for clear reproduction is, presumably, of no importance in this connection. But that is not so. Among other factors, the distant limit is closely related to an important basic concept in optics, viz., focal length. There is no definite distant limit for clear reproduction, either for simple lenses and compound systems (such as camera lenses, for example) or for the normal eye; from a distance of a few feet (depending on the range of the focal length) to an unlimited great distance (usually expressed by the infinity sign ∞), a sharp picture is obtained at the focal-point plane. The greater the distance, to that extent the smaller the picture becomes. Even large objects are reproduced as small areas, and they become successively smaller the further away they are from the lens. This brings us to an important rule, the accuracy of which can be demonstrated quite simply: *With the same focal length the size of the picture obtained is inversely proportional to the distance* from the object. This relationship in size between the picture of an object and its actual size is called the *picture scale.* In other words, the picture scale becomes smaller as the lens-to-object distance is increased. The following is an example: if a picture 1″ high is obtained of an object 20″ high, then the picture scale is $\frac{1}{20}$; in other words 1:20.

The *close limit* defines the shortest possible distance for sharp reproduction. The optical system of the eye cannot alter its *image distance,* which is the distance between the central point of the crystalline lens (more correctly called the optical main plane) and the picture plane (the retina). Instead, the adjustment of the dioptrics of the eye for close distance is brought about to a limited extent by *accommodation* (a change in the convexity of the anterior surface of the lens); in other words, the power to break down the lights is increased through a corresponding reduction in the focal length — all this, of course, takes place only to a limited extent. And this ability declines with advancing age.

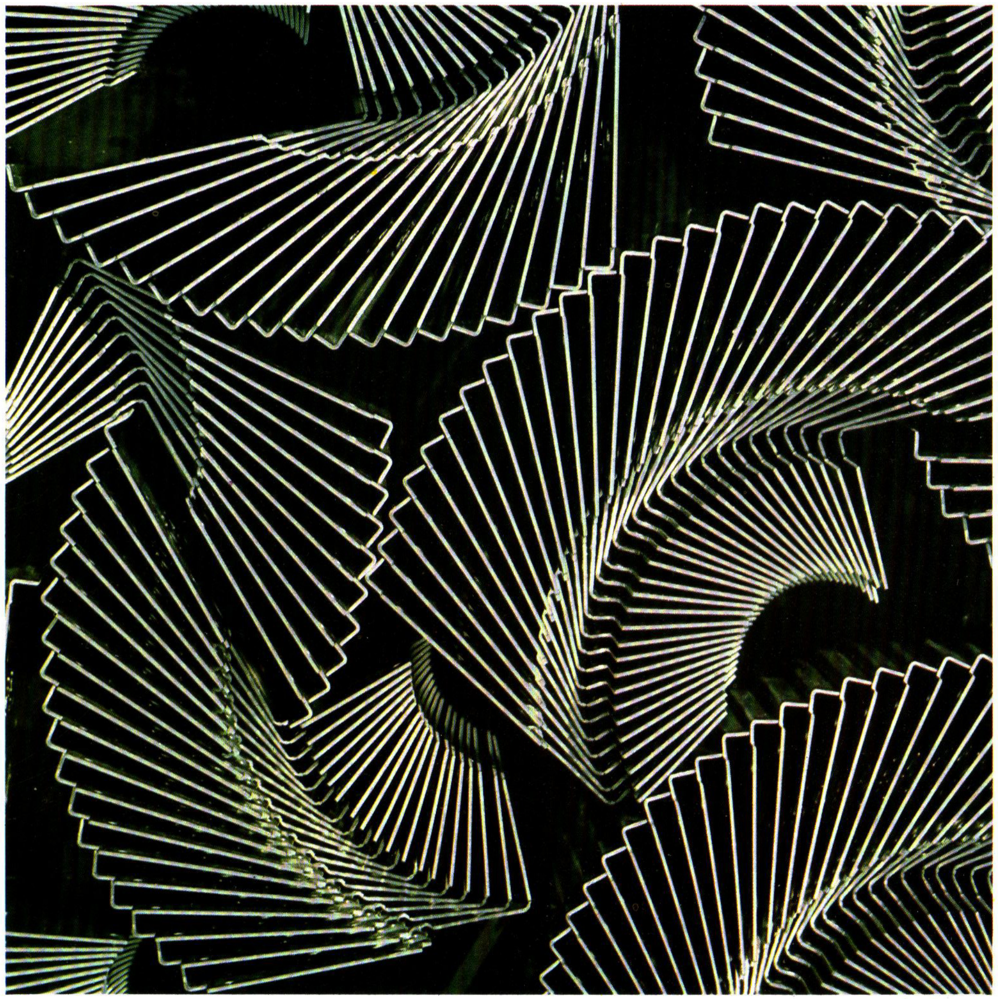
A demonstration of the close limit can be made in a simple way. Look intently at a well lighted object with contrasting details (the page in front of you, for example), and bring the page slowly towards the eyes. Gradually a distance is reached when the printed letters begin to look blurred; that distance is the close limit for your eyes. A child of 10 with normal vision has a close limit of about 4″, but by the age of 40 the close limit has reached about 10″. The latter distance is usually regarded as the close limit when using the eyes for desk or bench work, in calculating, and so on.

The camera lens also has a defined close limit but when adapting it to work at closer distances the adjustment is made by altering the image distance, i.e., the camera lens system is drawn forwards (and away from the film plane) to-



Cover photo: Ulf Sjöstedt. *Dandelions against the sun at a low level; fine details are also brought out clearly by the lighting from behind. Hasselblad 500C, Distagon 50 mm, Extension tubes 55 and 21.*

Photo, above: T. Iwago. *Small, transparent subjects can be recorded well if the light is allowed to disperse through them, and especially if the color harmonizes effectively with that of the subject. Shown here: spawn of the horseshoe crab. Hasselblad 500C, Planar 80 mm, Extension tube 55.*

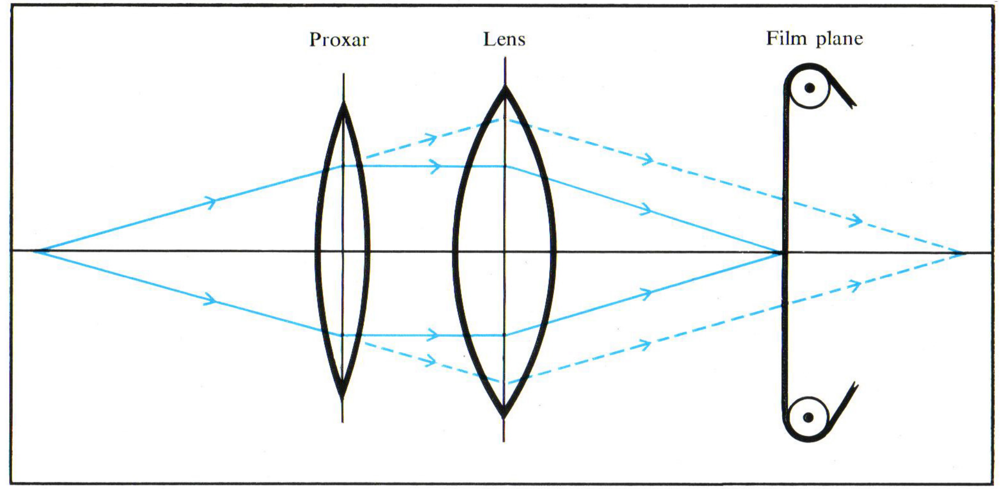


Photo, above: Bo Andersson. *Close-ups often present a picture puzzle of sorts. Shown here: the internal sides of the Hasselblad 500EL.*
Opposite page: *A schematic view of the function of the Proxar supplementary lens. The "refracting power" of the camera lens alone is insufficient to bend the rays from the object close up onto the film; instead, the image is created behind the film plane (dotted lines). The Proxar is a type of supplementary lens which helps to move the image forwards; see solid lines.*

wards the object. As a rule the close limit for a normal lens (standard camera lens) is about 3 ft., and under that distance it is not possible to get a sharp picture on the film without special aids.

The close limit can be shortened, both for the eye and the camera lens, by the use of different equipment. The use of this equipment in camera work, and its technique, is the theme of this booklet: Close-Up photography.

The rules and methods used in this branch of photography will be easier to understand if the optical principles involved are first reviewed.



ELEMENTARY OPTICS

When a beam of light passes through a simple lens or a compound lens (several lens elements) at the periphery to the central point, its direction is changed (this is called *refraction). Positive (or converging) lenses collect light; negative (or diverging) lenses scatter light.*
Light from a distant object reaching the lens can be considered as a section of parallel rays. A classic example of this is the sun and a magnifying glass (a simple, converging lens); the point at which the sun's rays meet is the *focal point*. The distance between the lens and that point is the *focal range*. This fact was already known in ancient times.
At about the same time (Aristotle and Claudius Ptolemaeus), the first tentative observations of optical reproduction were made, but it was only in the 16th Century that this subject began to receive closer study.
Gradually the behavior and formulas of lenses began to be understood and established; these first principles are still valid today as they provide a simple connection between the focal length (F), object distance (u), image distance (v), object size (O) and the image size (I); see Page 17. By the use of this data incorporated

in this simple formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{F}$ the main

formulas used in several branches of photography, including close-up photography, are made understandable, and other important formulas stem from this one (see list of formulas).

The primary goal of close-up photography is a large picture scale or scale of reproduction (M). The possibilities of achieving this result are based directly upon the formulas. A few, but important examples here should help to clarify this matter.

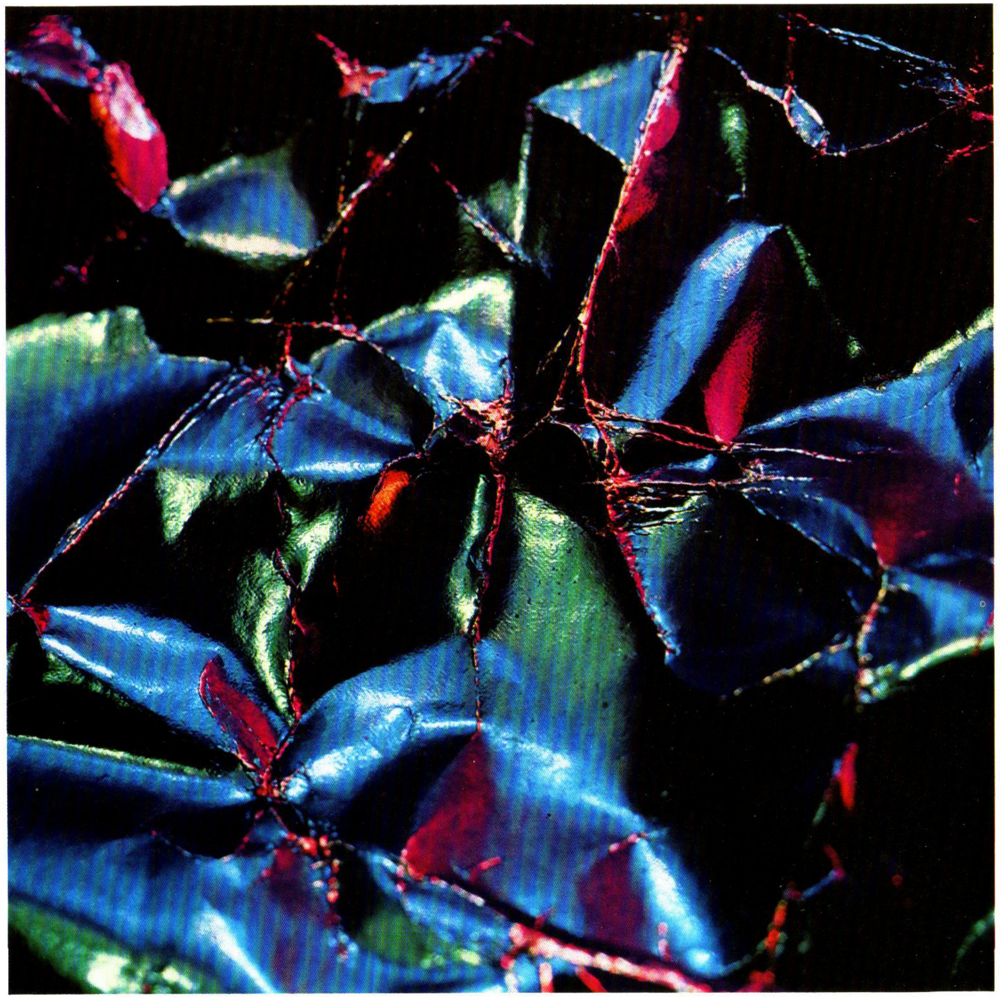
Rule 1
If the focal length (F) of the lens used is not altered, the picture scale (M) is increased if the object distance (u) is reduced; consequently the image distance (v) must be increased.

Rule 2
The focal length can also be reduced, but if the image distance is to remain the same, then the object distance must also be reduced.

Rule 3
Finally, if it is desired to keep the object distance unchanged, the picture scale can be increased by increasing both the focal length and the image distance.
All three of these rules are applied in close-up photography, but usually only the first two.

Dioptrics — Close-up Lenses

When applying Rule 2, it is assumed that there is an optical system for producing images (that is, the camera lens) in the equipment. But we want to reduce its focal length for work at closer distances in order to increase the picture scale.
As the camera lens is unable to refract the light rays (i.e., focus sharply) exactly upon the film plane where the picture is to be recorded when the object distance is reduced, we must use a



Photo, above: Francis Y. Duval. *Pictures practically abstract in effect, but by no means uninteresting, can easily be obtained from objects around us by deliberately taking advantage of the special effects offered in close-up work, a little imagination and rather simple technical aids. Shown here: colored foil, crumpled, with colored light falling from different angles. The result can be easily judged before exposure through the ground glass screen and finder, which excludes extraneous light effectively.*

close-up lens of the positive, converging type (such as a *Proxar lens)* which, in combination with the camera lens, now produces a shorter focal length and at the same time moves the image obtained forwards to the film plane (see Page 5).

When it is necessary to calculate the picture scale, the shortest distance from the object to the lens, etc., the combined focal length of the combined set of lenses must be ascertained. This can be obtained most conveniently if the combined power of all the lenses used is expressed in *diopters* (in other words, one *cannot* simply add or subtract the various focal lengths).

The *Dioptric Unit* (d) for a converging lens is obtained if the number 100 is divided by its focal length, expressed in centimeters. For example: The focal length 200 cm gives: d = 100:200 = 1/2; and the focal length 50 cm gives: d = 100:50 = 2. In other words, the dioptri, unit is a measurement of the power of the lens system, and it is increased when the focal length is reduced.

Irrespective of whether two lenses or more are combined (such as the camera lens), the resulting power is identical with the (algebraic) sum of the dioptric units of the components. Even if a diffusing lens is added to the components, the same formula can be used, but the specific dioptric unit of that particular lens is preceded by a minus sign.

This can best be clarified by a practical example. The standard lens of the Hasselblad camera (Zeiss Planar) has a focal length of 80 mm = 8 cm; its dioptric unit is therefore 100:8 = 12.5. This lens can be combined, for close-up photography, with any of the Proxar lenses, or all three, which have the respective focal lengths: 0.5, 1 and 2 m (F = 0,5, and so on), and their respective powers are 2, 1 and 0.5 diopters. We can thus obtain the following combinations: 14.5, 13.5 and 13 diopters respectively if only one Proxar lens is used, and 14.0 to 16.0 diopters with two or three lenses. The new focal lengths are obtained if 100 is divided by the resulting dioptric units, i.e., 100:14.5, and so on. The rounded-off values, in millimeters, will thus be 69, 74, 77, and 71—63 mm, and these figures can be employed in the calculations, including the lens formulas, for finding out, say, the distance of the object from the lens or the picture scale in the alternative choices.

Camera Extension

The distance between the optical main plane of the lens and the picture plane is called the *image distance*. If the object distance is long, the former distance is equivalent to the focal length (cf. parallel rays).

A large picture scale can, however, also be had by Rule 1; this is, by reducing the object distance. Inasmuch as the focal length (and thereby the refraction) remains unchanged, the image will fall behind the film if the image distance is not increased. To counteract this, it is necessary to move the lens away from the film; in other words, by using a so-called *camera extension,* usually called *distance setting.* That is why all the lens elements are mounted in an inner, threaded section which moves forward when the ring for distance setting is turned while the outer, rear section of the lens mount remains fixed in relation to the rest of the camera. However, in close-up photography, this facility must be restricted for several reasons.

It should be mentioned here that the total of the object distance (u) and the image distance (v), that is, the total length of the system, is the distance from object to picture; it is also called the *photographic distance,* as given on the lenses, and in tables. That is why, for measuring purposes, a mark for the film plane is shown on the Hasselblad magazines.

The *close limit* is equivalent to the minimum distance that can be set. This distance varies with different lenses; as a rule, the shorter the focal length, the shorter the close limit, which is allied with the fact that the extension of the lens for a determined distance must be made greater for an increased focal length (see Rule 3, and as indicated by the formulas). The close limit for a standard lens is usually about 3 ft. (approx. 1 meter).

The *maximum extension* of a lens must therefore be the difference between the image distance at the normal close limit setting and the focal length. The exact calculation of this is comparatively complicated. However, in short-range extensions a simplification may be permitted for practical purposes. This is to use the lens formula and, as a first step, to write down the focal length (which is already known) instead of the image distance (v) wanted.

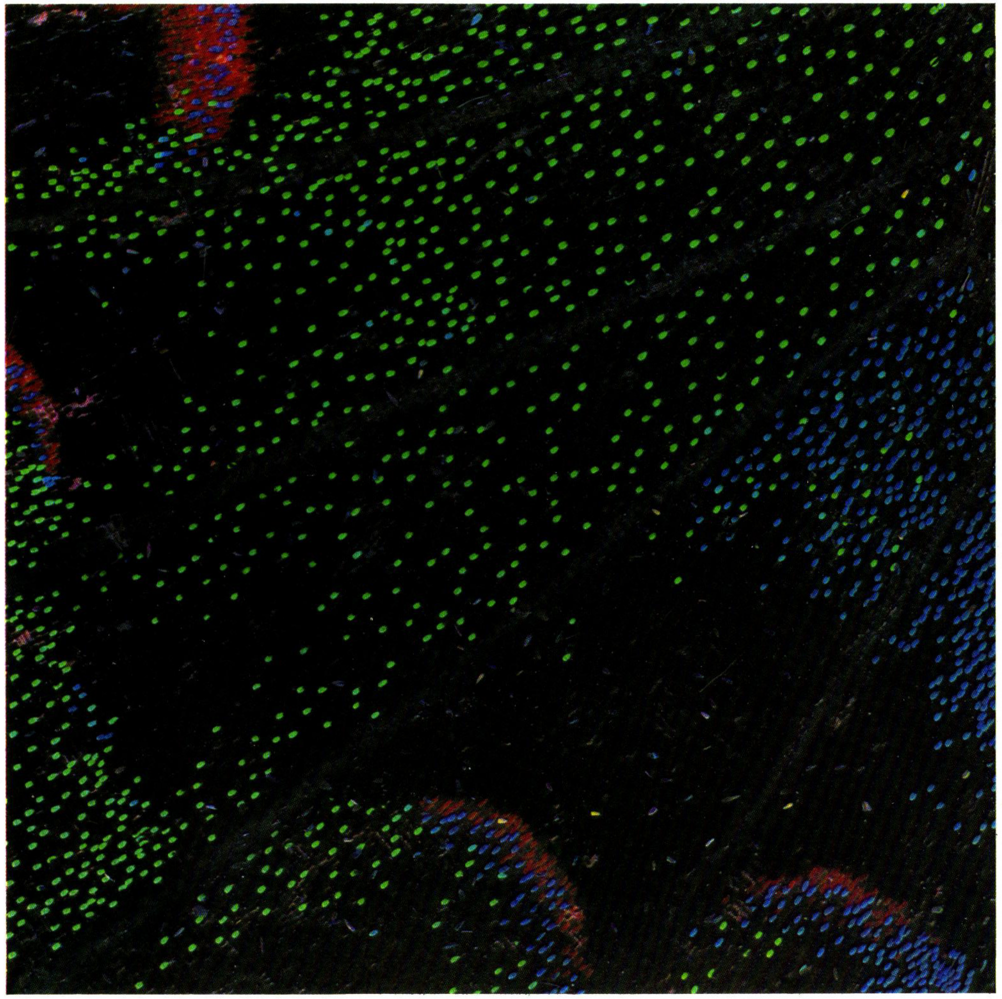
Example: The focal length of the standard Hasselblad lens is 80 mm and the normal close limit is 3 feet (0.9 m); that is: u+v. If all the measurements are in millimeters, we thus get

$$\frac{1}{900-80} + \frac{1}{v} = \frac{1}{80} \text{ from which } v = 88.7 \text{ mm.}$$

In other words, the extension is almost 9 mm (88.7—80).

The *picture scale* in the normal close limit can also be easily calculated. It stems directly from the association between the image distance (v) and the object distance (u), and in this case the formula is $\frac{88,7}{820} \approx \frac{1}{10}$ and may be written 1:10 (rounded off).

Extension accessories considerably increase the scope in making extensions. These accessories are placed between the lens and the camera, and they are either *fixed extensions (extension tubes)* or *variable extensions (bellows extension).* If the latter extension is already as great as the focal length and results in a so-called *double extension,* the picture scale has been increased to 1:1; which, in the case of the 80 mm Planar lens, would require an extension of 80 mm.



Photo, above: Ole Pedersen. *The transparent wing of the butterfly is covered by scales in layers, similar to a tiled roof. These scales contain the pigments which give the butterfly its brilliant coloration. The scales are extremely small, but by using the bellows extension, extension tubes 55 and 21, Planar 80 mm, and ringlight they become clearly visible.*
Opposite page: *The degree of enlargement can be easily reckoned if a cm-scale is placed at the object plane (see also text on Page 11).*

WHAT IS A CLOSE-UP?

It has already been mentioned in the introduction that no exact definition exists, and the same remark generally applies to the above heading.
But as we have now familiarized ourselves with the background and the problems, we can roughly define the limits before discussing equipment, techniques and methods.
The *upper limit* can be given with reasonable exactitude, at least as far as the photographic equipment is concerned. This coincides with the close limit of the standard lens, inasmuch as the picture scale cannot be increased further without special equipment. In the Hasselblad system, and with the Planar 80 mm, the upper limit would thus mean a picture scale of approximately 1:10 at a distance of 1 meter (say, 39″).

The *lower limit* cannot be given as easily for several reasons; one of them being that both the object distance and the picture scale obtained depend upon the equipment used. Theoretically, it is possible to obtain a high degree of magnification by the use of supplementary lenses with large diopters, long extensions and short focal lengths. But with successively larger picture scales, a number of inconveniences arise, so the practical use of this method should or ought to end at the ratio 3:1. If carried in excess of this, the loss in optical quality and the excessive exposure time needed will result in work of unacceptable quality. The special lenses of the Zeiss Luminar series, which do not have a shutter, however, allow for a maximum picture scale of 63:1. In other words, the lower limit of close-up photography is somewhere between 3 x and 63 x.

Photomicrography is, however, as a rule more suitable when magnification reaches the 20—25 x range. In this work, the optical equipment of a microscope is used instead of the camera lens, and the accessories for this combination are available in the Hasselblad system of accessories.

The optical limits in close-up photography have now been approximately given. Actually, nothing further need be said on this point, but as frequent reference is made to a sub-division it is necessary to elucidate further.

Macrophotography, (or "macro" pictures), is considered to cover the range 1—25 x, i.e., the picture scale from 1:1 to 25:1. Apart from the awkward restriction to the ratios, the phrase is inconvenient and misleading for this type of work.

In speaking of macrophotography, the starting point of 1:1 (with the use of an extension) is, of course, of mathematical interest, as the total distance from object to picture is then the least. But whether one works with powerful supplementary lenses, long extensions or a combination of them, one works with the same method on both sides of this starting point so the phrase is of no practical significance.

The term arose, naturally, to indicate that the image obtained is larger than life size (from the Greek *makros* = large). The opposite of this would be "micro" pictures, i.e., extremely small picture scale and, as a matter of fact, the miniature pictures popular at the beginning of the 20th Century, on paper knives, etc., were known as micro(scopic) pictures. But when the position of mankind between the macrocosm and the microcosm is considered, both terms are seen to be faulty. Even if the term "macro" picture is acceptable, the associate term "macrophotography" is even more misleading. That term should actually be used to define the photographing of macro-objects, in the same way that photomicrography covers the photographic documentation of the microworld. If one wishes to make a distinction in close-up photography (and this is more of theoretical than practical interest), then the demarcation ought to be made at the 1:1

Above, left: *The main components in the Hasselblad system: camera body at center: around it the interchangeable lens, viewfinder, film magazine and winding knob.*

Above, right: *The three Proxar lenses which can be used singly or in different combinations.*

point; but in that case, and to avoid misunderstanding, pictures larger than 1:1 should be called, say, *extreme close-ups.* This term also coincides quite well with the methods used in close-up photograhpy, i.e., the object is positioned extremely close to the lens system.

Picture Scale

It has already been mentioned, on Page 7, how the picture scale can be calculated. But this point should be clarified. Here, the picture size means the part of the image which falls on the film plane. But the question may be raised as to why an enlargement from the film image (i.e., the negative) may not be used for calculating.

Several reasons can be given against using this method. It should be remembered that the intention of the close-up technique, among other purposes, is to record and differentiate between the minute details which would otherwise be diffused or lost in a small picture scale. For example, if a negative in the scale of 1:10 is enlarged 10 x in the darkroom, the resulting print would of course be life size, or 1:1. But such a picture will not give all the detailed information of the object as a good negative taken at 1:1, and would a 1:10 negative enlarged twenty times reveal more information than the 1:1 negative just mentioned? The answer, of course, is certainly not! Details of the object can only be recorded on the film (the recording medium) during the time of exposure and by the lens (the optical system) alone. In any subsequent enlargement from the negative, which is no longer a part of the recording process, we cannot add new details to the object photographed (occasionally, the expression "lifeless enlarging" is used in this connection). On the other hand, the informative details latent in the primary image on the negative can often be brought out and revealed to the naked eye even by moderate enlarging.

The Charm of Close-up

There are many reasons why good close-ups always arouse interest. Of these, the most important is probably because the details which would otherwise be missed, or which cannot be seen by the naked eye, are caught in the negative and made visible. Attention becomes *concentrated,* as irrelevant, nearby details are blocked off, and everyday objects reveal new aspects of which we were previously unaware Furthermore, close-up photography gives us a new perspective (Latin, perspicere = to see through), and this adds to the charm of close-ups. The visual impression is somewhat altered, as the actual size of the object in relation to its surrounding space is not the same as that which normally meets the eye. But this is really no loss as the unusual perspective whets the imagination; the naked eye is unable to make a comparison without the aid of close-ups as it cannot produce a clear image at a close distance (cf. Page 2).

Above, left: *There are two extension tubes 55 and 21, which can also be combined. The figures refer to the extension length, in mm.*

Above, right: *The lens, S-Planar f. 5.6/135 mm, which is unexcelled in its class, is only for use with the bellows extension.*

SUITABLE EQUIPMENT

From the foregoing, it can be seen that a great deal is required from the photographic system to capture the many aspects possible in close-up photography, and to give the best possible results in the simplest way. The Hasselblad camera, with its wide range of accessories, fulfills all these requirements.

The Hasselblad System

The *camera body* is the core of the system. It is equipped with a mirror reflex finder which shows on a ground glass screen exactly how the picture will appear. Exchangeable viewing accessories allow the ground glass image to be examined on a magnified scale and at all photographic angles. Furthermore, it is easy to decide the picture scale for a lens system simply by placing a ruler (graduated in centimeters) at the object plane, parallel with the edge of the image. If, for example, 2 cm of the ruler is shown in the image, then the picture scale must be 5.4:2; in other words, 2.7:1, as the side of the ground glass screen measures 5.4 cm.

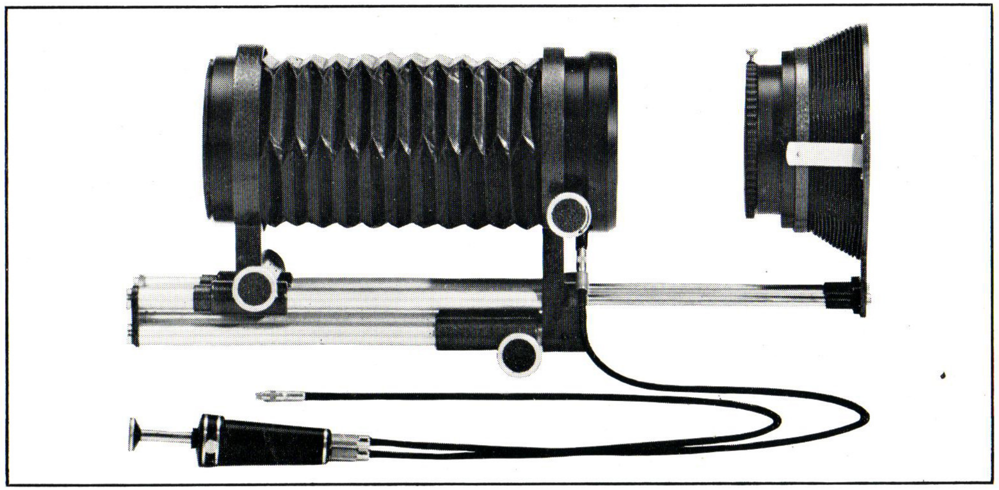
The *lens,* the qualities of which primarily decide the quality of the picture (cf. Page 10), is made by Zeiss, and it is of the highest class. As these lenses can be changed quickly because of the bayonet fitting, the most suitable focal length can always be chosen. The possibilities are increased still further by accessories such as Proxar lenses, extension tubes, bellows extension and special lenses (Luminars).

The *film magazine* is exchangeable. These magazines can be loaded with the types of film considered most suitable; for example, repro film to record extreme fidelity in details, fine-grain film of average sensitivity for the usual jobs, and color film of different types (negative and reversal). Thanks to cut film cassettes, cut film with special emulsions can also be used. Because the magazines are quickly interchangeable, it only takes a moment to make sure of getting an occasional color shot in between when shooting with black-white film (or vice versa).

METHODS

The basic procedures have been thoroughly described (see Pages 5—7). Here are a few additional details, plus a number of useful tips.

Supplementary lenses are a simple, low-cost aid to use in close-up work. Thanks to the mirror reflex finder, the image on the ground glass screen is completely without parallax. Picture scales, picture areas, and other details of interest are provided in the tables in this booklet. However, the use of Proxar lenses alone cannot produce a picture scale of unlimited size. If all three Proxar lenses are combined with the Planar 80 mm, the focal length becomes 63 mm and the maximum image distance at the 3 feet (0.9 meter) setting will be approximately 88 mm; this will give a picture scale of 1:2.5. A larger picture scale can be obtained by using more Proxar lenses of every power, or if con-



Above, right: *The Hasselblad bellows extension with lens shade attached and double cable release.*

Opposite page, above: *The under set of gear racks in the bellows extension permits the entire camera assembly to be moved upon the stationary frame.*

Below: *In this diagram, the lenses are represented by the slanting lines and the extensions by the horizontal cm-scale. The cm-scale here corresponds with that of the bellows only when the lens is set at ∞. In addition to the extension permitted by the bellows, the extension of the lens itself can be used; these extensions are shown on the diagram by the dotted lines continuing to the right of the solid extension lines for the respective lenses.*

The example shown by a red line on the diagram is for a lens with a focal length of 120 mm and an extension of 12 cm. From the extension on the cm-scale, follow the vertical line down to f=120 mm and then the horizontal line to the right; this gives the picture scale 1:1. Increase in exposure time is 4 times, or 2 steps. Depth of field of the lens at aperture 11 is about 2 mm.

verging lenses of higher dioptric numbers are attached to the filter adapter ring, Series 63. But as the quality of the picture is lessened and the mechanical arrangement somewhat unsteady, this idea is not to be recommended. (On the other hand, Proxar lenses can be combined with the accesories below).

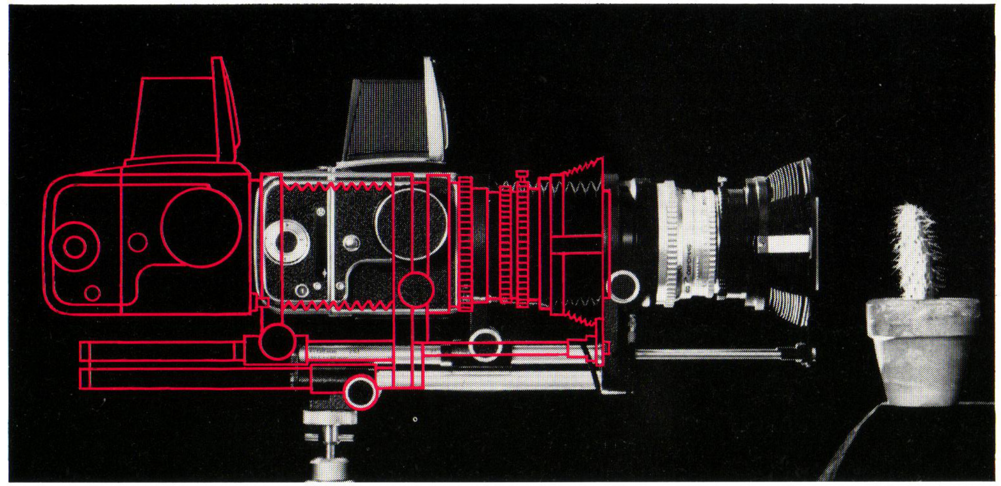
Extension Accessories

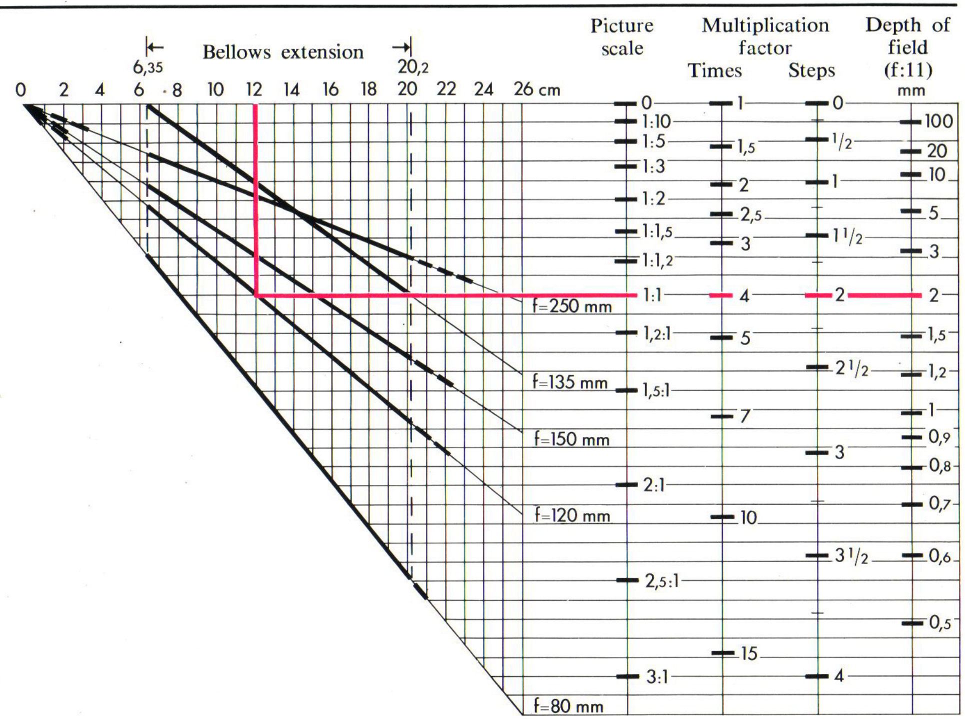
The possibilities of getting larger picture scales are very much better when extensions are used. As mentioned previously, there is a choice of either extension tubes or the bellows extension. *Extension tubes,* Type 21 and Type 55, provide extensions in millimeters equivalent to the type number of the tube. These tubes can be used in pairs, in combination or (in theory) several in conjunction, but if a longer extension than 2×55 mm is desired then it would be better to use the bellows extension.

The automatic diaphragm-control mechanism, which is fitted to all Hasselblad lenses, keeps the diaphragm fully opened for maximum light upon the ground glass screen in focusing, examination of the image, and so on. The diaphragm automatically closes down to the pre-set stop selected upon exposure. This means that one always has the best possible control of the picture being taken, right up to the moment of exposure. A shaft in the extension tube carries this automatic lens-function to the camera mechanism. Data on the different combinations are provided in the tables in this booklet.

The *bellows extension* permits *variable extensions,* from 63.5 to 202 mm (2.5 to 8 inches). This means that the smallest extension is 2.5 inches for all lenses when the distance scale is set at ∞. This explains why the picture scale, for example on the Planar 80 mm, begins at about 1:1.3. The maximum extension in this case is 202 mm plus the extension possible at the lens itself, i.e., approximately 211 mm, equivalent to the scale 2.6:1.

The bellows extension has two separate sets of gear racks. The lower set is geared to the base frame; this means that *the entire camera assembly can be moved forwards and backwards upon a stationary frame* without altering the setting of the bellows extension itself. The value of this arrangement cannot be overemphasized. It is possible to set the bellows for a predetermined scale and then, by using the lower set of gears, to make a fine adjustment in focusing without disturbing the position of the base frame. This arrangement is especially useful when the picture scale is large because whenever the frame and the entire camera assembly have to be moved, focusing has to be done all over again to compensate for the change in extension; much time is saved and the desired picture scale is retained.





The upper set of gears regulates the actual extension of the bellows, and the extension made can be read off on a engraved scale (reading towards the rear). The necessary additions to the various exposure times, to conform with the focal length of the different lenses, are also given.

LIGHT, SHARPNESS AND DEPTH

There are still a few other important technical phrases especially in connection with the use of extension equipment, which have to be explained; these are *maximum aperture, increase in exposure, sharpness* and *depth of field. Maximum aperture,* practically speaking, can be taken as a measurement of capacity in order to create a well-illuminated picture. It is proportional to the greatest, usable cross-sectional area of the lens, but in inverse ratio to the picture area projected. When distance measurements are concerned, it is also relative to the diameter of the diaphragm stop and the image distance involved. The latter, when the lens is at infinity, is the same as the focal length; thus the *relative aperture* = diam. of the effective aperture: focal length — this is a value which is engraved on the lens in a mathematical form; for example, 1:2.8 (meaning that the focal length is 2.8 times greater than the aperture diameter).

The primary function of the *diaphragm* is to regulate the quantity of light passing through the lens, and this is best done if the diaphragm values are stated. The appropriate *f-numbers (indicating the relative apertures)* are engraved on the lens as a series of settings, and each change in diaphragm stop corresponds to an alteration in the flow of light: closing the diaphragm by one stop halves the flow of light, and opening it by one stop doubles the flow of light. This relation is based on the fact that the f-numbers actually represent the reverse of the relative aperture (in other words, the diaphragm stops 2.8, 4, 5.6, and so on, are equivalent to the relative aperture, say, 1:2.8, 1:4, 1:5.6, and so on). Furthermore, the halving-and-doubling used in the step-by-step scale system corresponds to the divisions used on the shutter scale; that is, 1 sec., 1/2 sec., 1/4 sec., and so on. However, the diaphragm values are only a relative measurement of the light intensity in a camera system (see above). Strictly speaking, this form of measurement only applies when the image distance is equal to the focal length. As longer and longer extensions are used, the deviations from the norm become increasingly greater and this fact can be more readily grasped when it is remembered that the flow of light passing through the diaphragm stop used has now to cover a considerably larger picture area. According to a well-known formula used in other connections, the area scale corresponds to the square of the length scale, and this leads us directly to the fact that the picture area is in proportion to the square of the image distance. But in this case, the intensity of light falling upon the picture plane must also be *reversed in ratio,* and the important, practical conclusion is this: *For correct exposure, the amount of light required is in direct ratio to the square of the image distance.* It should also be pointed out here that, of the entire image projected by the lens, only a small portion (equal to the size of the film) is used. This relationship, which is so important, is shown in the tables, list of formulas and the scales on the bellows equipment. So you do not have to make your own calculations, but as they can easily be made once you are familiar with the rules, and as the tables may not be available when you want them, a few simple examples should prove helpful.

Increasing the Exposure

By making use of the *multiplication factor,* it is easy to obtain the data needed for increasing the exposure.

Example 1. The exposure data for a 100 mm image distance is known. If this distance is increased to 200 mm, the picture scale is two times larger, and the multiplication factor is the square of this, that is: $2 \times 2 = 4$.

Example 2. The exposure data, without extension, when the image distance = focal length, is known. We want to ascertain the multiplication factor for the picture scale: 3:1. Write this down instead as the enlargment to be made, that is: 3 x. The value of this is then increased by 1. This gives us $3+1 = 4$, and the answer is squared (that is, multiplied by itself). This gives us the multiplication factor: $4 \times 4 = 16$. If the picture scale instead had been 1:2, the enlargement would be 0.5, and the multiplication factor (calculated by squaring 0.5+1) becomes $1.5 \times 1.5 = 2.25$.

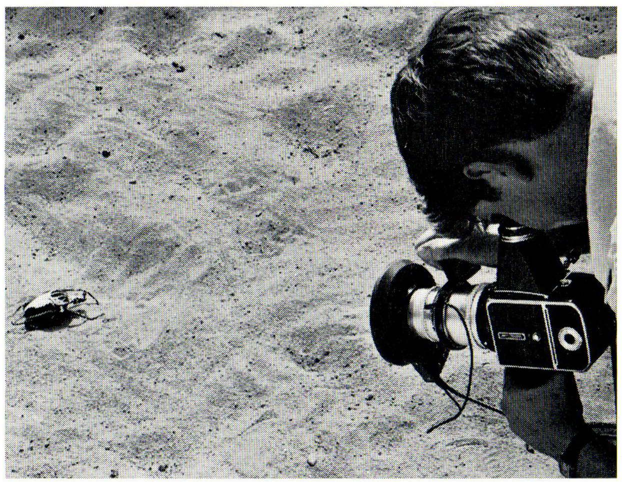
Example 3. If the image distance and the focal length are known, the square of the ratio between these two numbers will give us the multiplication factor directly. If the two numbers are, say, 240 mm and 80 mm, then 240 divided by 80 is 3, and $3 \times 3 = 9$.

After the multiplication factor has been ascertained or taken from the tables, the shutter speed or the diaphragm stop is correspondingly increased; or possibly both. In the first case, all that need be done is to multiply the shutter speed originally known (usually decided with an exposure meter) by the multiplication factor.

Example 4. The shutter speed (known or measured) is 1/10 sec. Let us, for example, use the multiplication factor obtained in *Example 3,* which is 9. Then the correct exposure time is $9 \times 1/10$ sec. = 9/10 sec., and for practical purpose we round this off to 1 sec.

Occasionally, however, a shutter speed of too long duration is unsuitable, especially when photographing an object in motion. In that case the diaphragm is opened instead provided this alternative is feasible. The scale for this is divided in steps (see Page 14); *i.e., exposure is doubled successively for every step increased.* This naturally means also that the step-by-step increase of the diaphragm (or

Photo, above: Clifford Healey. *It's not considered good sportsmanship to "shoot a sitting bird" but it's the simplest way to "shoot" a butterfly. This is done best with a lens of average focal length (e.g., Sonnar 150 mm). The use of electronic flash makes it possible to avoid blurred movement in the subject, and if care is taken to see that there is no light-reflecting object immediately behind the flower chosen while waiting for a shot, then a dark background is obtained — this effect intensifies the rich colors still further.*



Above: *Fine details can be brought out by using a suitable lighting arrangement. Spot lighting from somewhere behind the object helps to bring out the details against a dark background, but don't forget to use a lens shade with the lens.*

Below: *The ringlight provides a convenient and easily moved source of light. It is unexcelled, for example, in color photography and freehand work. In the latter case, a quick-focusing handle also helps greatly. The shot is of a Goliath beetle.*

shutter speed) corresponds with the successively doubled exposure, so that this is equivalent step-by-step, to the series of numbers: 2, 4, 8, 16, and so on: (mathematically this geometrical progression is written as 2^n, when n = the number of steps).

Example 5. With the use of the exposure meter, the diaphragm determined is 11. Let us, for example, use the multiplication factor obtained in *Example 2,* which is 16. The diaphragm is opened step-by-step, from 11 to 8, to 5.6, to 4, to 2.8 — in other words, four steps.

The *exposure value,* usually abbreviated to EV, provides a simple connection, in figures, between various combinations of the exposure data, inasmuch as both the diaphragm scale and the shutter-speed scale are similarly divided. An EV scale, which is engraved on every Hasselblad lens, consists of a series of numbers, 18, 17, 16, 15, and so on, and each interval is equivalent to one step, so finding the appropriate exposure is greatly aided by the use of this scale.

Depth of Field

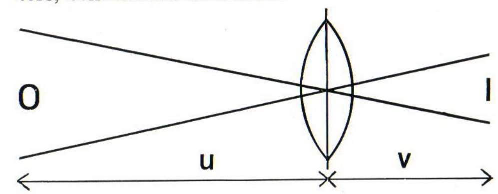
Theoretically speaking, a sharp picture can only be obtained at a certain distance from the object. Small details, closer or further away, are only recorded less sharply on the film plane (but sharply either before or behind this plane). A certain, defined point in the neighborhood of the distance focused thus grows into and is recorded on the film as a little, diffused patch, the so-called *circle of confusion.*

A point, however, has no dimensions theoretically (as we all remember from our schoolbook geometry). If such a point is slowly allowed to grow into a little circle, it can first be noted by the naked eye only when it is about 1/20—1/30 mm in diameter. We can, of course, accept the fact that the circle of confusion is of the same size, and this means that the focus set is acceptable for the object distance involved anywhere within the narrow compass of this zone. This zone is known as the *depth of field of the lens.*

The size of the diaphragm opening, however, affects the depth of field, but not *the focal length as long as the picture scale remains unchanged.* If the image distance is only barely longer than the focal length, the depth behind the distance set on the lens is much greater than the depth in front of it, but this distinction becomes more symmetrical as the image distance (and the picture scale) is enlarged; for example, as in close-up photography. *The depth of field is reduced as the picture scale is enlarged* (see list of formulas and the tables). Minor movements in the diaphragm plane and the character of the light waves reduce the general sharpness of the whole picture when extremely small apertures are used, in spite of the basic fact that depth of field increases as smaller apertures are used. Therefore, it is advisable to avoid maximum stopping down, as this immediately lowers the quality of the picture. Finally, remember to make use of the automatic diaphragm catch to check the depth of field on the ground glass screen through the viewfinder after focusing is done.

FORMULAS

The tables cover a great number of fixed combinations of course, and they are quite sufficient and easy to apply for successful close-up work. A collection of actual formulas would, however, be useful to those photographers who want to make their own calculations based on other starting values. It should be noted in all these calculations that the formulas are effective only when all the distances are expressed in the same unit of measure; i.e., in millimeters, centimeters or inches.



Size of Object: O

Equivalent size of Image: I

Distance between Object-Picture Planes (photographing distance): u+v

Lens Formulas: $\frac{1}{F} = \frac{1}{u} + \frac{1}{v}$; $F = \frac{u \cdot v}{u+v}$

Diopter Unit: $d = \frac{100}{F}$, where F is given in cm.

Focal Length of Lens System:

$F = \frac{100}{d_1 + d_2 + d_3 + \ldots}$ d_1, d_2, d_3, and so on, are the diopters of the respective lens-elements which, in combination, comprise the camera lens. The formula only applies exactly to thin lens-elements placed closely to one another.

Image Size: $I = \frac{v \cdot O}{u} = \frac{F \cdot O}{u-F}$

Image Distance: $v = \frac{u \cdot I}{O} = \frac{F \cdot u}{u-F}$

Picture Scale: $M = \frac{I}{O}$; or $\frac{v}{u}$; or $\frac{v-F}{F}$

Increase in Exposure: $y = \frac{v \cdot v}{F \cdot F}$ or $(1+M)^2$

Because a camera lens is a complicated lens system which actually has two main planes at some distance from each other, the above formulas provide only approximate relationships, but they are perfectly usable for all practical purposes.

Degree of magnification	Reproduction scale	Area covered in inches for format 2¼"×2¼"	Depth of field inches f:11*	Reduction of exposure value by steps	DISTAGON f. 4 50 mm: Distance to film plane inches	DISTAGON: Focusing range of lens, in feet	DISTAGON: Close-up equipment	PLANAR f. 2.8 80 mm: Distance to film plane inches	PLANAR: Focusing range of lens, in feet	PLANAR: Close-up equipment	S-PLANAR f. 5.6 120 mm: Distance to film plane inches	S-PLANAR: Focusing range of lens, in feet	S-PLANAR: Close-up equipment
0.1	1:10	21.6	4.3		26.80	26"		39.3	3.3		56	4.8	
0.2	1:5	10.8	1.18	½				21.15	7.5	P 0,5	33.8	15	M 21
0.3	1:3.3	7.2	0.55	½				17.75	7.5	M 21	26.2	4	M 21
0.3	1:3.3	7.2	0.55	½									
0.4	1:2.5	5.4	0.31	1				14.83	6	M 21+F 1.0	22.8	8.5	M 21+M 21
0.4	1:2.5	5.4	0.31	1				15	3.3	M 21+P 2.0			
0.5	1:2	4.3	0.23	1	11.25	29"	M 21	13.1	5.6	M 21+P 0.5	20.85	3.4	M 21+M 21
0.5	1:2	4.3	0.23	1							20.85	10	M 55
0.6	1:1.7	3.6	0.17	1				13.40	3.8	M 21+M 21	19.70	3.6	M 55
0.6	1:1.7	3.6	0.17	1							19.10	3	M 21+M 21+P 2.0
0.7	1:1.4	3.1	0.13	1½				12.95	13.7	M 55	19.10	7	M 55+M 21
0.7	1:1.4	3.1	0.13	1½							19.10	14.8	B 8 cm
0.8	1:1.2	2.7	0.11	1½				12.24	3.5	M 55+P 1.0	18.70	3.2	M 55+M 21
0.8	1:1.2	2.7	0.11	1½							18.70	4	B 8 cm
0.9	1:1.1	2.4	0.09	2	10.28	32"	M 21+M 21	12.6	8.2	B 7 cm	18.55	∞	M 55+M 55
0.9	1:1.1	2.4	0.09	2							18.55	3.4	B 9 cm
1.0	1:1	2.16	0.08	2	10.25	18"	M 21+M 21	12.35	5.2	M 55+M 21	18.52	5.3	M 55+M 55
1.0	1:1	2.16	0.08	2							18.52	3.3	B 10 cm
1.1	1.1:1	1.97	0.065	2	10.27	6,9	M 55	12.58	∞	B 9 cm	18.55	16.4	B 13 cm
1.1	1.1:1	1.97	0.065	2				11.68	3.6	M 55+M 21+P 0.5			
1.2	1.2:1	1.80	0.06	2½	10.32	22,5"	M 55	12.65	3.6	B 9 cm	18.70	4.6	B 13 cm
1.3	1.3:1	1.65	0.053	2½	10.4	3,3	B min	12.78	4.8	B 10 cm	18.85	3.6	B 14 cm
1.3	1.3:1	1.65	0.053	2½				12.5	13.1	M 55+M 21+M 21+P 2.0			
1.4	1.4:1	1.50	0.047	2½	10.47	19"	B min	12.92	7.3	M 55+M 55	19.10	3.3	B 15 cm
1.4	1.4:1	1.50	0.047	2½				12.92	7.3	B 11 cm			
1.5	1.5:1	1.44	0.043	2½	10.6	10	M 55+M 21	13.08	18	B 12 cm	19.30	3.1	B 16 cm
1.5	1.5:1	1.44	0.043	2½				12.58	4	M 55+M 21+P 1.0			
1.6	1.6:1	1.35	0.039	2½	10.70	5,3	B 8 cm	12.76	6	B 12 cm+P 1.0	19.50	4.8	B 18 cm
1.7	1.7:1	1.27	0.036	3	10.82	22"	B 8 cm	13.47	3.9	B 13 cm	19.90	4	B 19 cm
1.8	1.8:1	1.20	0.033	3	10.98	5,3	B 9 cm	13.68	4.4	B 14 cm	20.05	4	B 20 cm
1.9	1.9:1	1.14	0.031	3	11.15	20"	B 9 cm	13.90	6.5	B 15 cm	20.55	4	B 16 cm+M 55
2.0	2:1	1.08	0.029	3	11.25	4,3	B 10 cm	14.15	14	B 16 cm	20.90	3.6	B 17 cm+M 55
2.5	2.5:1	0.86	0.021	3½	12.05	20"	B 12 cm	15.45	10	B 20 cm			
3.0	3:1	0.72	0.017	4	12.93	3,3	B 15 cm	16.83	3.4	B 18 cm+M 55			
3.5	3.5:1	0.62	0.014	4½	13.85	18"	B 17 cm						

M 21=Extension tube 21
M 55=Extension tube 55
P 0.5=Proxar 0.5
P 1 =Proxar 1.0
P 2.0=Proxar 2.0
B=Bellows extension

*At aperture 22 the depth of field will be doubled and at aperture 5.6 the depth of field will be halved.

Degree of magnification	Reproduction scale	Area covered in inches for format 2¼"×2¼"	Depth of field inches f:11*	Reduction of exposure value by steps	S-PLANAR f. 5.6 135 mm: Distance to film plane inches	S-PLANAR: Focusing range of lens, in feet	S-PLANAR: Close-up equipment	SONNAR f. 4 150 mm: Distance to film plane inches	SONNAR f. 4: Focusing range of lens, in feet	SONNAR f. 4: Close-up equipment	SONNAR f. 5.6 250 mm: Distance to film plane inches	SONNAR f. 5.6: Focusing range of lens, in feet	SONNAR f. 5.6: Close-up equipment
0.1	1:10	21.6	4.3		66.39		B 7.73 cm	72.9	6.1		118	10	
0.2	1:5	10.8	1.18	½	39.7		B 9.12 cm	40.1	9.2	M 21	72	8.9	M 21
0.3	1:3.3	7.2	0.55	½	31.1		B 10.50 cm	33.6	23	M 21+M 21	56.7	1.2	M 55
0.3	1:3.3	7.2	0.55	½							49.5	14.1	M 21+P 2.0
0.4	1:2.5	5.4	0.31	1	27.19		B 11.88 cm	29.3	16.4	M 55	49.5	10.5	M 55+M 21
0.4	1:2.5	5.4	0.31	1							49.5	23	B 9 cm
0.5	1:2	4.3	0.23	1	25.0		B 13.26 cm	26.9	4.8	M 55	45.5	16	M 55+M 55
0.5	1:2	4.3	0.23	1				25.4	5.2	M 21+M 21+P 2.0	45.5	50	B 12 cm
0.6	1:1.7	3.6	0.17	1	23.74		B 14.65 cm	25.5	6.2	M 55+M 21	43.3	24	B 14 cm
0.6	1:1.7	3.6	0.17	1				25.5	100	B 9 cm			
0.7	1:1.4	3.1	0.13	1½	22.99		B 16.03 cm	24.6	14	B 10 cm	42	50	B 17 cm
0.7	1:1.4	3.1	0.13	1½									
0.8	1:1.2	2.7	0.11	1½	22.56		B 17.41 cm	24.2	7.5	M 55+M 55	41.2	25	B 19 cm
0.8	1:1.2	2.7	0.11	1½				24.2	65	B 12 cm			
0.9	1:1.1	2.4	0.09	2	22.3		B 18.79 cm	24	13	B 13 cm	40.8	11.1	B max
0.9	1:1.1	2.4	0.09	2									
1.0	1:1	2.16	0.08	2	22.29		B 20.18 cm	23.9	65	B 15 cm	40.7	60	B 19 cm+M 55
1.0	1:1	2.16	0.08	2									
1.1	1.1:1	1.97	0.065	2	22.3		B 18.83 cm+M 55	23.95	12.5	B 16 cm	40.75	13.4	B max+M 55
1.1	1.1:1	1.97	0.065	2									
1.2	1.2:1	1.80	0.06	2½	22.4		B 19.46 cm+M 21	24.1	46	B 18 cm			
1.3	1.3:1	1.65	0.053	2½	22.6		B 17.45 cm+M 55	24.3	12	B 19 cm			
1.3	1.3:1	1.65	0.053	2½									
1.4	1.4:1	1.50	0.047	2½	22.9		B max+M 55	24.55	8.5	B max			
1.4	1.4:1	1.50	0.047	2½									
1.5	1.5:1	1.44	0.043	2½				24.9	40	B 17 cm+M 55			
1.5	1.5:1	1.44	0.043	2½									
1.6	1.6:1	1.35	0.039	2½				25.2	11.5	B 18 cm+M 55			
1.7	1.7:1	1.27	0.036	3				25.6	7.2	B max+M 55			
1.8	1.8:1	1.20	0.033	3				26	5.9	B max+M 55			
1.9	1.9:1	1.14	0.031	3									
2.0	2:1	1.08	0.029	3									
2.5	2.5:1	0.86	0.021	3½									
3.0	3:1	0.72	0.017	4									
3.5	3.5:1	0.62	0.014	4½									

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