CHAPTER 2

Film

William A. Garnett, Four-Sided Dune, Death Valley, CA, #2.
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Light-Sensitive Materials

It was the discovery that certain materials changed when struck by light that made photography possible. Silver salts—usually silver halide crystals, which are metallic silver in chemical compound with iodine, chlorine, or bromine—are the most commonly used light-sensitive (photosensitive) materials. When light strikes these silver salts, it reduces some of the salts to their components, giving metallic silver. Since silver in this form normally appears black, the light darkens the silver salt.

It takes a large amount of light to directly create a visible darkening of silver salts. For photographic purposes, this would mean a long exposure to the image formed by the lens on the film. Luckily, even small amounts of light create tiny specks of silver, which are not visible to the naked eye. The pattern of these invisible silver specks is called the latent image. The developing process causes more silver to be deposited around these latent image specks, creating a visible image composed of silver. The accumulated silver in the image is called density. The greater the amount of silver present in the image, the higher the density and the darker the appearance of that area of the image. The chemical development of the latent image gives usable photographic images with small amounts of exposure to light.

Since the effect of light is to turn the silver salts dark, the resultant pattern produced on the light-sensitive material is normally reversed from the tones of the subject. The result is a negative image. Through special development techniques—as with color slides—the silver image can be reversed again, resulting in a positive image, with the same tonal relationships as in the subject.

The support that carries the silver salts is called the base of the light-sensitive material. Two general types of base are used: photographic films use a transparent base; photographic prints use an opaque base, usually of paper.

Note that the lighter parts of the subject are represented in the negative as dark tones, and the darker subject areas are represented as light tones.
Black-and-White Films

A simple photosensitive silver salt material will not show the colors of the original subject but will show only the shades of light and dark. These images are called monochrome images, or more commonly black-and-white images.

Structure of Black-and-White Films

Silver salts will not adhere to a film base without a carrier, so the silver halide salts are mixed with gelatin to form an emulsion, which can then be coated onto the base. The gelatin also makes the silver salts more sensitive to the action of light. Certain dyes, called sensitivity dyes, are mixed with the emulsion to improve the film’s response to some colors of light. Though only a few thousandths of an inch thick, the film contains several layers.

The manufacture of photographic film is a highly complex process. Many additional ingredients are used by manufacturers to improve the quality of the films. Mixing and coating of the emulsions are especially sensitive to contamination and environmental conditions. The emulsions are manufactured in large batches, which are generally consistent in quality, but small variations from batch to batch are unavoidable. Manufacturers identify each batch with an emulsion batch number, which is printed on each box of film. For critical work requiring strict film consistency from roll to roll, make sure all rolls are from the same emulsion batch and have been stored under the same conditions.

Characteristics of Black-and-White Films

A number of characteristics of a film, such as sensitivity to light, grain structure, color sensitivity, contrast, exposure latitude, resolution, and acutance are determined in the manufacture of the film. Choice of film depends on how well these characteristics match the intended use of the film.
Sensitivity to Light. Film sensitivity, also called film speed, indicates the amount of exposure required to produce a given amount of density in an image. More sensitive (faster) films require less exposure than less sensitive (slower) films to produce the same amount of density.

Various systems have been devised for measuring the sensitivity of film to light and assigning a number indicating the speed of the film. This film speed number is called the exposure index. In the United States, American Standards Association (ASA) numbers are most widely used. In Europe, Deutches Industrie Norm (DIN) numbers are used. The International Standards Organization (ISO) number combines the two systems. The number before the slash of the ISO number is the ASA. The number following the slash is the DIN. In all systems, the higher the exposure index number, the more sensitive the film to light. Films are generally categorized by speed:

- Slow: About ISO 50/18° or lower
- Medium: About ISO 100/21°
- Fast: ISO 200/24° to ISO 400/27°
- Ultrafast: Higher than ISO 400/27°

Grain Structure. The silver particles resulting from exposure and development in the film do not collect in a perfectly smooth fashion, but tend to gather in clumps. In the film this clumping is not visible to the naked eye, but when the image is magnified, as in printing, a granular texture called grain is seen. The size and appearance of this grain depend on a number of factors, including amount of exposure and amount and type of development, but the major influence on grain structure is the film itself. In general, faster films exhibit coarser grain. The T-grain emulsions—used in T-Max films—introduced by Kodak achieve higher sensitivity with finer grain by use of a silver halide crystal that is flatter and more tabular in structure, exposing more of the crystal surface to light.

<table>
<thead>
<tr>
<th>ISO</th>
<th>ASA</th>
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<tr>
<td>25/15°</td>
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Color Sensitivity. Light is a form of energy, and our perception of its color depends on the particular wavelengths in the light (see the boxed section “Wavelength of Light”). The sensitivity of photosensitive materials to various colors of light may vary from the sensitivity of the human eye. Several categories of films with different color sensitivities are available:

- Panchromatic. Panchromatic films are sensitive to all the colors visible to the human eye, but their sensitivity to individual colors varies somewhat from the
Light that is visible to the human eye is related to other forms of energy, including television and radio waves, radar, X rays, and gamma rays. All belong to the spectrum of electromagnetic energy. Visible light is only a tiny part of this spectrum. The energy in the electromagnetic spectrum is carried in the form of linked electric and magnetic waves. As these waves travel from a source, the energy increases to a maximum, then decreases to a minimum, and continues in this cyclical pattern. The distance the wave travels while going through one complete cycle is called the \textit{wavelength}. 

The characteristics of electromagnetic energy are determined by the wavelength. X rays have a very short wavelength—approximately 10 billionths of a centimeter—and gamma rays have even shorter wavelengths. Radio waves, on the other hand, can have wavelengths of several kilometers. The measuring unit used for the small distances in the middle of the spectrum is the nanometer, which is 1 billionth of a meter ($10^{-9}$ meter). 

The visible portion of the electromagnetic spectrum is from 400 nanometers to 700 nanometers. The color we see in light is dependent on the wavelength, from violet at 400 nanometers to red at 700 nanometers. Mixtures of wavelengths are also seen as specific colors. A mixture of nearly equal amounts of all the wavelengths in the visible spectrum creates white light, which we see as colorless. When you see a rainbow or sunlight dispersed through a prism, you are seeing the component wavelengths or colors of the white light that is emitted from the sun.

The wavelengths adjacent to the visible spectrum, including infrared and ultraviolet, are important in photography even though invisible to the naked eye, since some films are sensitive to them. Most general-purpose films, both black and white and color, have some sensitivity to ultraviolet light, which is usually undesirable. Techniques for using filters to control ultraviolet light are discussed on page 306. Special films sensitive to infrared are used for various scientific and creative purposes.
Orthochromatic. Orthochromatic films are sensitive to all colors but red, making them useful in graphic arts darkrooms where they may be used under red lights.

Blue sensitive. Blue-sensitive films are sensitive only to blue light and are safe to handle under yellow or amber light, making them useful in black-and-white copy work and lithographic work (the making of plates for printing).

Infrared. Infrared films are sensitive to infrared radiation near the visible spectrum. They are also sensitive to some visible light and must be used with special filters if only the effect of infrared is desired. Since infrared films are not sensitive to the long-wavelength infrared associated with heat, special imaging techniques must be used to record heat radiation.

Contrast The contrast of a film is the amount of density difference obtained for a given change in exposure on the film. Films that produce little density difference for relatively large changes of exposure are low in contrast. Since contrast may also be changed by altering the amount of development, films with inherently low contrast can produce images of normal contrast by being given more development. In general, slow-speed films have more inherent contrast than fast films and therefore usually require less development. High-contrast films are designed to produce only two tones, black and white, eliminating the intermediate tones of gray. These are used in graphic arts or for special creative effect.

Exposure Latitude Exposure latitude is the ability of a film to withstand overexposure or underexposure and still produce a usable image. The latitude for overexposure is usually greater than that for underexposure. In general, slow-speed films have less exposure latitude than fast films.

Resolution The resolution of a film is its ability to resolve fine detail, tested by exposing the film to a test target with closely spaced parallel lines. A high-resolution film can distinguish up to several hundred lines per millimeter, whereas a low-resolution film would distinguish fewer than fifty lines per millimeter. A film’s resolution is dependent upon other factors, including the amount of exposure and development it receives.
**Acutance** The *acutance* of a film is its ability to produce a sharp edge between two tonal areas in an image. Acutance is tested by placing a knife-edge on the film and exposing it to light. Thick, coarse-grained emulsions tend to diffuse the light around this edge, producing a less sharp image. Fine-grained films with thin emulsions will produce better acutance and thus more apparent sharpness in the final image.

**Characteristic Curve** Imagine a test with a particular film on which successive exposures are made, starting with a very small amount of exposure, then doubling the exposure on each frame. When this film is developed, we would see a gradually increasing amount of density as the exposure increased. If we measured the density of each frame, we could make a graph of density versus exposure.

The curve shown here is typical, but a change in film, developer type, or developing techniques will change its shape. Since these curves are characteristic of particular film and developer combinations, they are called characteristic curves. Most manufacturers publish characteristic curves for their films. The appearance of a film’s curve can give photographers information about how that film reacts to varying amounts of exposure and development.

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**Characteristic Curve.** This graph shows that the increase in density is not always the same for a doubling of exposure. The area labeled the **toe** on the curve shows a very small change of density with exposure. The **straight-line portion** shows a greater change of density with exposure. In the **shoulder,** the density change becomes small again, gradually leveling out.
Chromogenic Films

Chromogenic films are monochromatic—black-and-white—films designed to be processed with standard color print film chemistry, called C-41. Since C-41 processing is widely available at photofinishing labs, chromogenic films offer a black-and-white negative without the need to process it yourself. The most commonly available chromogenic films are Ilford XP2 Super and Kodak Black and White +400. Chromogenic negatives may be printed on black-and-white papers as described in chapter 6.

Color Films

Color films are also based upon the use of silver halide emulsions, but since the silver itself does not have any color, dyes must be introduced into the film to reproduce the color we see in the subject. The following information is enough to allow you to choose and use color films.

Positive and Negative Color Film

Two basic types of color film are available. Color negative film, or color film for prints, produces on the film an image that is reversed in both tone and color. When a color negative is printed directly onto color printing paper, a color positive print is obtained. Color positive film, or color film for slides or transparencies, produces a positive transparency suitable for projection. Using special processes, color prints can be made from transparencies, but they are more expensive than those from color negatives.

Color Balance

The light from various light sources does not always contain the same mix of colors as the white light from the sun. Even sunlight can vary in color, depending upon the time of day or year and the weather conditions. This is not a problem for people in everyday life, because the brain has the capability to adjust for the color of the illumination so that the colors of objects look normal to our eye. Unfortunately, color films do not have this ability, so films must be manufactured for a specific color of light. This is called the color balance of a film.

Most color films are daylight balance, designed for use with daylight illumination—average direct sunlight in the middle of the day. If daylight balance film is used with illumination of a different color, that color will show in the resulting image. Light from household tungsten bulbs has a higher percentage of yellow or orange light than daylight, producing orange-tinted prints or slides with daylight films. Fluorescent lights usually have more green than daylight and will produce green prints or slides. If warned, some processing labs can correct somewhat for these problems when printing color negatives, but the color balance of slides cannot be corrected in processing.

A few films are designed for use with nondaylight sources. The most commonly available are tungsten balance films, designed to give correct color rendition with the tungsten light used in professional photography studios. Tungsten films will also give better results than daylight films with household tungsten lights. It is also possible to correct the color of the illuminating light with filters.
Characteristics of Color Film

**Sensitivity**  Color film sensitivity or speed is rated using ISO numbers, just as with black-and-white film.

**Grain**  As in black-and-white film, increasing speed means coarser grain. Color positive films generally have finer grain than color negative films of the same speed.

**Exposure Latitude**  Color negative films can withstand some underexposure or considerable overexposure and still produce usable images. Color positive materials have little exposure latitude—sometimes as little as one-half stop each way—and require extremely accurate exposure to achieve good results.

■ **Instant-Print Film**

Instant-print films give a finished print on the spot. Polaroid pioneered these materials, and they are now available in black and white or color and in several different formats. Some instant-prints develop right before your eyes. One type of professional black-and-white Polaroid produces both a positive print and a negative that can then be printed by standard enlarging techniques. Polachrome is an instant color slide film that can be exposed in a normal 35mm camera and then processed on the spot.
The advantages of having the results in a few seconds or minutes are obvious. Photographers use Polaroid materials to check lighting setups, which they then photograph using regular films. Polaroids are also useful as proofs to show a photographer’s client how the finished photograph will look. A number of photographers are also using instant-print materials as the finished photographic product.

Film Formats and Packaging

The size of the image produced on a film, called the format size, varies from just a few millimeters up to 4 × 5 inches and larger. Format size is determined by the camera design. The same film size may be used by cameras of different image formats, but the size of the film obviously limits the maximum format size possible.

The packaging of a film protects it from light and usually also holds the film for use in the camera. Strips of film allowing several exposures are pack-
Film Selection

A great variety of brands, types, sizes, and packaging of films is available, with new films introduced regularly. No single film will serve for all purposes, so the type of photography you do will govern your choice of film. Subtle differences in the tonal or color qualities of a film may also determine a choice for aesthetic reasons. Preliminary choices can be made on the basis of the manufacturer's description of the film's qualities or by referring to film tests periodically published in photography magazines. To decide which film is best for you, test different films yourself under the conditions you plan for use.

Color versus Black-and-White

Black-and-white photographs are more of an abstraction of a subject than are color photographs, and some photographers feel they more readily convey drama or allow for creative interpretation of the subject. Color, on the other hand, gives more information about the subject and can carry its own aesthetic messages. A photojournalist who is photographing for black-and-white reproduction in a daily newspaper may choose a black-and-white film, whereas a photojournalist who may be published in either black and white or color may choose color film, converting the color photograph to black and white through darkroom techniques when necessary. The demand in portrait or wedding photography is predominantly for color photographs, with only a few photographers offering black-and-white prints.

Color Negative versus Color Positive

The desired final image presentation is usually the determinant in a choice between positive or negative color. If the end result is to be a color print, either material can be used. Prints from color negatives are cheaper. Prints from slides have better sharpness, more brilliant color, more resistance to fading, and generally longer print life, though in recent tests one negative print material (Fuji Crystal Archive) showed better permanence than any other traditional print material, negative or positive. Slide films have finer grain for equivalent film speed.

A great deal of color reproduction in magazines for advertising and editorial work is done from color transparencies, so photographers doing advertising, fashion, travel, and similar work normally use color positive films. Photojournalists who work under difficult conditions may prefer color negative films for their greater exposure latitude. Wedding photographers prefer color negative films for the lower print costs and greater exposure latitude.

If the end result is to be a projected image, as in slide shows, then a color positive film should be used. Films that provide both slides and prints—actually designed for movies—are color negative films, with the slides produced from the negatives. As a result, these slides cannot match the quality of original slides from a color positive film.
Advanced Photo System (APS) Film. Advanced Photo System (APS) film is packaged in a self-contained cartridge. Cartridges are inserted directly into the camera and require no handling of the film itself. After processing, APS films are returned to the consumer still in the self-contained cartridge, so the film is never handled directly. APS films also incorporate special features, such as a choice of formats (including panoramic) and a magnetic strip for data recording.

135 Film. Commonly called 35mm film, 135 film is 35mm in width with sprocket holes on both sides, packaged in cassettes for twelve, twenty-four, or thirty-six exposures. Cassettes require a take-up spool in the camera. The film must be rewound into the cassette after use. 35mm film is also available in long rolls—bulk film—which can be cut into strips and loaded into reusable cassettes. Bulk loading reduces film costs, but the extra handling required gives a higher risk of scratches or damage to the film.
120 and 220 Films. The 120 and 220 films are packaged as roll film, which is a strip of film for several exposures rolled with protective opaque paper onto a spool. Roll films are threaded onto a removable take-up spool in the camera. The exposed film is taken from the camera on the take-up spool, and the original spool then becomes the take-up spool for the next roll of film. The film—60mm in width with no sprocket holes—and spool are identical for 120 and 220, the difference being that the opaque backing continues throughout the roll for 120 but consists only of leader and trailer taped to the 220 film, allowing twice as many exposures on 220.

4 × 5 and Larger Films. Film sizes 4 × 5 inches and larger are commonly available only as sheet film. Sheet film comes as individual sheets, one for each exposure, packed in a lighttight box and must be loaded into lighttight film holders or magazines for use. Unprocessed film must be handled in total darkness.
**Film Speed**

Choice of film speed depends upon the amount of light illuminating the subject, the desired camera settings (shutter speed and aperture), and the desired fineness of grain. Although faster film speeds give faster shutter speeds or smaller apertures, they also produce coarser grain. The general rule is to use the slowest possible film that will give the needed shutter speed and f-stop settings for the available illumination.

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**Film Care and Handling**

Photographic films are relatively fragile and require care in handling and storage. The proper techniques are the same for unexposed and exposed films; however, exposed films should be processed as soon as possible for best results. If exposed films must be held for some time before processing, the tips for longer storage given below will help preserve the latent image. In general, color films are more sensitive to storage conditions than are black-and-white films.

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**Film Storage**

Several environmental conditions can affect film quality:

**Humidity** Exposure to high relative humidity or liquids is damaging to film. The moisture-proof packaging should not be opened until a film is loaded into the camera. After exposure, the film should be stored in a moisture-proof container. 35mm film usually comes in a small plastic can, which can be reused for moisture protection. Zip-loc plastic bags can be used to protect films whose foil packets are destroyed by opening.

**Temperature** Higher temperatures cause deterioration of film; lower temperatures—the lower the better—maintain the condition of film. Do not leave film or loaded cameras in automobiles, where in the summer temperatures can soar. Films can be frozen in home freezers or kept in refrigerators to extend their useful life. Films labeled Professional require refrigerated storage to maintain optimum quality.

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**Warm-up Times for Refrigerated Photographic Film (in Hours)**

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<th>FROM 35°F TO 70°F</th>
<th>FROM 0°F TO 70°F</th>
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<tbody>
<tr>
<td>One roll (35mm, 120, 220)</td>
<td>1</td>
<td>11/2</td>
</tr>
<tr>
<td>Bulk roll (35mm, 100 ft)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Sheet film (10-sheet box)</td>
<td>1</td>
<td>11/2</td>
</tr>
<tr>
<td>Sheet film (100-sheet box)</td>
<td>3</td>
<td>4</td>
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Refrigerators and freezers contain high humidity, so films must be in moisture-proof packages before they are refrigerated or frozen. Allow films to warm up to room temperature before opening to prevent condensation of moisture on them.

Accidental Exposure to Light Accidental exposure of unprocessed film to light causes fogging of a film, giving undesirable streaks and ruining images. Be careful not to disturb the lighttight packaging of the film. Although a film may be packaged for “daylight” loading, cassettes, cartridges, roll film, and sheet film holders should not be exposed to the direct rays of the sun but should be handled in subdued light. If forced to load film into a camera in direct sunlight, do so in the shadow of your body if no other shade is available.

General-usage films removed from their lighttight containers for processing or other purposes must be handled in total darkness.

Exposure to X rays The use of X-ray devices at airports and other high-security locations puts film at risk. Even though security personnel may claim that the machines are safe, all photographic films are sensitive to X rays and can be fogged, especially with repeated exposure. Fast films are particularly susceptible to X-ray damage. Hand inspection is the best protection for your film. Most U.S. airports will hand inspect on request, but many areas in the world with high security risks will not. An alternative is to place your films and loaded cameras in lead-foil bags—available at camera stores—which offer some protection from X-ray exposure. Checked baggage is also often subjected to X-ray inspection.

Age Although proper storage extends film life, over time a film will deteriorate. Manufacturers stamp an expiration date on the film package. This is an estimated date for which the film retains optimum quality with “average” storage conditions. For normal or “amateur” films, this means storage in the original packaging at normal room temperatures. For professional films, it means refrigerated storage according to the directions. Storage of any film in a freezer at 0°F can extend the usable life well past the expiration date.

Film Handling Photographic films are sensitive to scratching and fingerprints. Take care that the image-bearing surfaces of a film are not touched or rubbed against abrasive surfaces. This caution applies before and after processing of the film. Film can also be scratched by dust or dirt inside the camera. Keep the camera clean as instructed in chapter 4.

When advancing or rewinding film, use a slow, steady motion to prevent static electricity discharge from marking the film. Dry weather increases the possibility of static discharge.