www.davidkachel.com
david@davidkachel.com

Chapter 3 - How B&W Photographic Film Works

Sunrise Yucca

Knowledge is a thing that is easily lost to a society. Worse, it is even more easily discarded. We humans behave a lot like crows in one respect: if we see something shiny, we have to go get it, forgetting whatever it was we had just a moment ago. When we discard an old toy for a new one, we often also discard the knowledge it took to make that old toy. If you also count the destruction from wars and the intentional discarding of knowledge by the actions of the *enthusiasts* of the various forms of collectivist politics, I would not be surprised to learn that more of the human race's knowledge throughout its existence has been lost, than retained. The great libraries of Constantinople and Alexandria, come to mind.

It has only been a few short years since photographic film has fallen out of favor, yet the knowledge of how to use it to full effect has already been subject to substantial erosion. I never would have guessed it would occur anywhere near this quickly, but it clearly is happening.

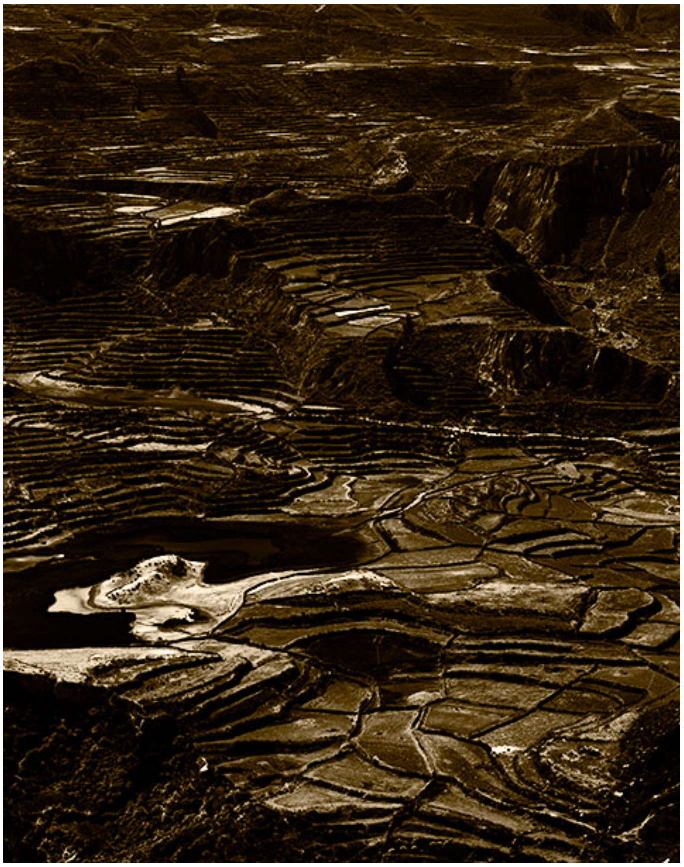
Some people are claiming that film is making a comeback. I don't really believe that. I think a few millennials have *discovered* film, will play with it for a little while and then discard it. I would very much like to be proven wrong: this being mostly for selfish reasons. I don't want to see that skill set get lost forever, especially since I made a few contributions to it of my own. The inventor of the buggy whip would prefer that people not stop using buggy whips.

Years ago I promised my readers a book entitled, *Advanced Zone System Concepts & Techniques*. Never promise anything! The digital cross-town bus promptly came along and ran right over that book, and me in the process. But between the highly dubious, yet nonetheless alluring, *comeback* of film and my personal desire to see valuable knowledge not get lost, in this, the first installment of a book on the art of the B&W photograph, both analog and digital, it is my intent to make sure the tools and more importantly the ideas that the B&W fine art photographer needs, do not disappear. Toward that end I hope to cram as much as possible and practicable into a single volume. I will seed the internet with this and perhaps another chapter or two of the book from time to time, in case that bus comes back before I can finish.

The approach to the B&W photograph is basically the same for both film and digital. It has to be, because regardless of the tools employed, a B&W photograph is a B&W photograph. You build the same house whether you use an old fashioned hammer, or a modern nail gun.

I used film from the 1960s through to today when I use both film and digital. During that time I became something of an expert on the use of analog B&W photographic materials, wrote a whole bunch of magazine articles, mostly on the Zone System of Ansel Adams, and invented over a dozen new techniques for contrast and tone control for both B&W and color analog photographic materials. I paid my dues and know what I'm talking about most of the time, and I can tell you that if you are expecting any sort of miracle from film, you are wasting your time.

The reasons to use film over digital are few and growing fewer by the day. In fact, for an artist, there may no longer be any reason to use the roll form of B&W film, at all. Only sheet film continues to provide any tangible advantages. Those number roughly two: higher resolution than even the best digital cameras can offer (soon to come to an end), and the movements unique to the view camera. (No, shift lenses are not the same!)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The higher resolution of large format film cameras is real, but not generally put to full use. I expect that some day, scanners will be able to pull information from film that they currently cannot, but in the mean time, if you are scanning film you are losing much of that resolution and if you are making digital prints, you are getting little or no additional resolution by using film over high end digital, once you get to the print end of the process. Some would make the argument that under certain circumstances, that resolution is useable and in some cases, that would be at least partially, correct. But for practical purposes, at least with today's scanners, you don't gain much, if anything. And if recent history is any indication, film scanners are very close to disappearing, entirely! Even printing on silver papers in the darkroom can't pull all the resolution out of a film negative so, this reason for using film is not a good one.

At this point you might ask me why I still use film for some of my images. Well, some photographs, particularly with buildings in them, just cry out for a view camera's movements. And, I tell myself that film is also a hedge against the day that better scanners appear. Scanners that can suck the juice completely out of a negative without also sucking it completely out of your bank account. And better inkjet printers may come along too, printers that can translate that increased resolution onto paper because having all that detail in a scan is completely useless if you can't get it onto paper. But the truth is that those are just excuses. I actually have no reason to use film at all, except for those rare occasions when only film can get the job done. I am using film because I want to and that is all the reason I need. It should be all the reason you need, also.

If you want to use film, then use film. Don't bother justifying it to anyone, including yourself. There is no point. Even if you can justify it today, you probably won't be able to, tomorrow. Just do it. Don't make lame excuses like, "*Film is more contemplative, dude.*" No, it isn't. You can be just as contemplative with a digital camera as a film camera.

If you are going to use film, regardless of justification, it is in your best interest to know how film works. You read the owner's manual for your car, right? Of course you did. This is the owner's manual for B&W photographic film. You can get by without it. Almost everyone using film is already doing exactly that. You will find that not one person in a thousand using film today knows much of any of what you will read here. That is *why* I am writing it. With this information, you will be able to answer your own questions about film in the future and you will immediately know which new wonder techniques are nonsense (HINT: pretty much, all of them!) and which might be worth trying.

This information is largely intended for the serious *fine art photographer* (I hate that term, but we are stuck with it.) The fine art photograph requires that *extra* something that banging away with a motor drive and mailing your fill to *the lab* can never offer. If you simply like film and want to take snapshots on the weekends, there is nothing here of benefit to you. Just go have fun. You don't need this. If you are after that level of proficiency and skill that turns an ordinary photograph into a precious object in itself, you need to know what is contained herein.

In the early 1990's I published a series of articles on B&W film development that addressed the subject of reducing contrast. I wrote a lot of other articles, but save one or two, this series was by far the most significant. In *Zone System* parlance, reducing film contrast is called *contraction*. (In either case, it simply means giving less than normal development to your film.) Much of what I wrote was fairly complex but one of the articles presented a new group of techniques for contraction that I had worked on for about a decade. The goal was to create an option for contrast reduction that was dead simple. I mean, *REALLY SIMPLE*!!! In fact, I designed these techniques to be used in place of a pre-soak in water, before development. Instead of a one minute soak in plain water, you substituted one of my ridiculously simple formulas, and pre-soaked in that instead, but for a few minutes longer, and with agitation.

These formulas never involved more than two chemicals, both VERY easily obtained, VERY inexpensive and simple, simple, SIMPLE! Well, the series of articles was a huge hit with readers. After the first one, which contained a teaser about what was to come in subsequent installments, some readers actually threatened to cancel their subscriptions if they could not get the editor to cough up advanced copies of the rest of the series. (This was a magazine called *Darkroom and Creative Camera Techniques* and at the time, it was edited by the late *David Alan Jay*, a skilled photographer and man of integrity who refused to give an inch. He also did something no other photography magazine editor has ever done, before or since: he tested every single new technique himself, before he would publish it.)


Laguna Salinas I

D&CCT was a magazine for photographers with a technical bent (think *New England Journal of Medicine* for working photographers) and that was the major reason for the success of that series of articles: I picked the right audience. Most photographers do not have a technical bent and of those few who do, many take off on tangents that don't make a lot of sense. My articles were quite well received at D&CCT, promptly lauded by experts and caused my immediate elevation to the status of *contributing editor.* This success led me to expect things that in fact, didn't happen.

I knew that I was writing that series of articles mostly for the D&CCT audience of tinkerers, but the one new group of techniques, the extremely simple one mentioned above, was designed especially for the most decidedly NOT technically inclined photographer.

With my very simple contrast reduction techniques I wanted to provide something for ordinary, Joe Blow, the fine art photographer. And Joe didn't like them. Well, that is not entirely true. Joe, for the most part, never heard of them. The series was published in magazines Joe didn't read. And the first two articles in the series would have scared Joe right out of photography, completely. The stuff I wrote specifically for Joe didn't appear until the third article. Joe would never have stuck around long enough to read that. And if Joe did stumble across it, that measuring and mixing stuff was more than he wanted to do. My ridiculously simple techniques were not simple enough. It seems Joe could just barely handle *develop, stop and fix.* He was content to continue to work with even simpler, older techniques (more than a century older) that Joe thought he could handle, but that I had thoroughly debunked in the first of the aforementioned series of articles (that Joe did not read). It's quite simple: mention the name of a raw chemical and Joe is out the door. This brings us to the following declaration that keeps Joe and the hard lesson I learned above, in mind:

The information found here is as un-technical as I can feasibly make it. Wherever possible I leave out math and graphs and all that stuff that usually kills photographers on contact. At least, it kills their interest. My goal in writing this is to make it so simple that if someone cannot follow it, that someone will also likely be incapable of loading film into a camera. Toward that end, the descriptions are simplified to the point where any scientist might very well shout, "HEY! Wait a minute!" This, because I have distilled a lot and skipped over much. But what I have distilled out or skipped over is information that will not be of any benefit to the working fine art photographer. Presented here, is only what you need.

Terlingua Cemetery

B&W photographic film is a piece of flexible clear plastic (used to be glass, long ago) covered with clear Jello™, with salt in it. No kidding. You can try this yourself. Find a flexible, thin piece of scrap plastic, shake some table salt into some fresh liquid Jello™, coat the plastic with the Jello™/salt mixture, throw the mess into the refrigerator and let the Jello harden. In fact, you can use flavored Jello™ (a red one) and even get some added benefit out of what you have done. (The red coloring would, in theory, make your film *orthochromatic*.)

Now, before you make that mess, you should know that you will not be able to take pictures with that particular piece of film, but only because you used the wrong kind of salt. The plastic (probably: I don’t now what kind of plastic you have laying around the house) and the Jello™ would probably have worked just fine, and even the red food coloring in the Jello™ would likely have worked to make the film *orthochromatic* if there isn’t too much of it. The salt is the problem. But, not so much as you think…

The secret to B&W photographic films and papers, color too, *is,* salt! Just another kind of salt. Some salts are sensitive to light and some are not. So, what is salt?

Here comes one of those photographer frightening, technical moments…

Table salt is *sodium chloride*. You’ve probably heard that before. But there is more than one kind of salt. For example, if you have blood pressure problems, you may be using what is often referred to as a *salt substitute*. Well, that is actually a lie, because the so-called *salt substitute* is not a substitute, at all. It is a salt, too. Just, another kind of salt. It is *potassium chloride* instead of *sodium chloride*. People who have to put *potassium chloride* on their food instead of *sodium chloride* say it tastes about the same, but a few complain that it also has a metallic taste. It has a metallic taste because it contains metal. *Potassium* is a metal. People do not complain that *sodium chloride* has a metallic taste, but it too contains a metal. *Sodium* is a metal. *Silver* is a metal. *Iron* is a metal. *Metals* make film photography possible. Without metals, photography might have never been invented.

But metals alone are not responsible for photographic materials. What do *sodium chloride* and *potassium chloride* have in common? They share the same last name: c*hloride.* And, they are both salts. So, the question again becomes, “What is a salt?” There are lots of different kinds of salts but for our purposes a salt is a combination of a metal (metals are a group of chemical substances that share similar properties and behaviors) and one of another group of chemicals that also have their own set of similar properties and behaviors. This other group of similar chemicals is called *halogens*. There are five of them (*chlorine, bromine, iodine, fluorine* and *astatine*), but only three matter to us: *chlorine, bromine and iodine.*

And for now, only one of them matters: *chlorine*. When you attach one atom of *chlorine* (yes, the stuff you put in your pool, but that has other additives) to a metal, you get a salt and the name of the *halogen* changes from -ine to -ide, which is just a shorthand way of saying it is attached to something else. *Sodium chlorIDE* tells you the *chlorINE* atom is attached to something else, in this case the metal, sodium.

So, a *salt* is a halogen atom attached to a metal atom. A metal and a halogen. A salt. That's it. That's about as technical as it gets. But, we do need to add a couple of extras to the terminology. Any metal attached to any halogen is referred to generically as a *metal halide*. *Sodium chloride* is a *metal halide*. (So is *potassium chloride.) Sodium chloride* can also be called a *sodium halide.* You will run across these generic terms from time to time.

The salts used to make photographic film are a combination not of the metal *sodium,* but of the metal, *silver,* plus a *halide*, instead of the *sodium* and a *halide* of table salt. The *silver halides* used to make photographic materials are in fact, *silver chloride, silver bromide,* and *silver iodide.* Three different kinds of silver salt, dissolved in Jello™ and poured onto a piece of plastic. The reason(s) for using three different kinds of *silver halide* salt instead of just one are simply to improve light sensitivity, and some of the other basic characteristics of film. The specifics are of interest to those who make film, not to those who use it.

This chapter is *not* about making your own film, though you can certainly do so. There are instructions on the internet that are quite complete. (http://www.thelightfarm.com) This chapter is about understanding film, whether you buy it, or make it. I prefer to buy it. Making a decent B&W photograph is hard enough without introducing unnecessary additional sources of potential error and despite the fact that one can make quite a respectable homemade B&W photographic film with little more effort than the tongue-in-cheek method I outlined above, Kodak and Ilford still produce a much more reliable and versatile product than you or I could ever whip up. They have the hardware. We do not.

It is now established that film boils down to primarily, the behavior of silver salts/halides. When a silver halide is struck by light the two halves split apart, the metal stops being part of a salt, and becomes simply a metal, again. The halogen part, the chorine or iodine or bromine, runs off to Disneyworld™. We are about to begin the part that you really need to know, but first we have to briefly go back a little and deal with the other two ingredients of film.

The plastic. The plastic is there because the gelatin has to sit on something. You can actually make a layer of gelatin all by itself, but it is too floppy, too fragile and would break apart from the vigorous agitation used in development. Any old plastic would probably work, but some plastics are better than others for photography. There are various kinds of plastic base used to make film, but no discussion of the differences would be relevant to our purpose. Simply know that the plastics chosen are selected primarily for their flexibility, permanence, their dimensional stability and their tendency not to burst into flames, as nitrate based films once did. Now, it's time for Jello™.

Jello™ is made with gelatin. Film is made with gelatin, but not Jello™. Though Jello™ could be used, it would be impractical. It has other stuff in it that makes it more *foody*.

Gelatin is made from animal parts that are boiled down to, well, gelatin! Which parts? Tendons, ligaments, all the stuff in an animal that connects parts of the animal to other parts of the animal (technically; *connective tissue*). A smelly, disgusting process that nonetheless produces something extremely useful, that is neither smelly, nor disgusting.

Gelatin is a complex chemical structure that you never need to understand. Gelatin has characteristics that are very useful in photography. It does not just serve as a form of transport for silver halides. It also makes the silver halides *more sensitive* to light. How is that?

Well, salts tend to dissolve in water. The metal and the halide separate, sort of, and go into *solution*. They hang there, as if floating in space, separated from each other. However, they and other dissolved photographic chemicals *DO NOT EVER* sink to the bottom of the fluid that contains them. They are *in solution*. They will stay in solution forever, if not interfered with by outside actions such as, evaporation of the water. I mention this because there are actually photographic print washers in existence whose designers proudly proclaimed and advertised that dissolved fixer sinks to the bottom of the wash water and that is why they designed their washers with water outlets at the bottom!

Dissolved chemicals *NEVER "sink to the bottom"!* No doubt, these are the same people who think that islands flip over if too many people stand on one side. One of the reasons you need to know how film works is so that you can spot many of these dumb ideas that you will *absolutely* encounter. You can't avoid them. Photography is drowning in them. It's like trying to dodge waves in the ocean.

A silver halide dissolved in water is not very light sensitive. In fact, for all practical purposes, it is not light sensitive, at all. Plus, it is very difficult to get a coating of silver halide that is dissolved in water to stick to a piece of plastic. But a silver halide dissolved in gelatin will tend to become *undissolved*, that is, to come out of solution and form crystals, as the gelatin dries and hardens, and gelatin has little trouble sticking to a piece of plastic. The silver halides in a gelatin-based photographic emulsion are not *dissolved* in the gelatin. They are *trapped* in it. Just like you might trap fruit in a bowl of Jello™. There it is, sitting there, surrounded by the solidified gelatin. Solid crystals. NOT dissolved chemical.

Doll & Trophy

Salt crystals are simply a lot of sodium chloride molecules (a *molecule* is just two or more atoms of any kind that come together to make a new substance. Sodium and chlorine atoms come together to make a molecule, a combined substance: table salt. They have linked together to form a larger, more complex substance with characteristics completely unlike either component, alone. When the water from a silver halide solution evaporates, those silver halide molecules will join together to form crystals. It is these crystals that are more reactive to light, largely because they are bigger than single molecules dissolved in water. The bigger the crystal, the more sensitive to light. Why? For one thing, they are a bigger target. It is easier to hit a target that is ten feet wide, than one that is an inch wide. Gelatin is the ideal substance for the formation of these crystals. Gelatin can hold a lot of water with silver halides in it and as the gelatin dries out, the silver halides come out of solution and form crystals held in the gelatin.

Gelatin has a strong ability to absorb water. This ability to absorb water means that developer can soak into the gelatin and gain access to the exposed silver halide crystals contained there, in order to develop them. Without this ability to absorb water, film would be of little use. You can make a photographic material without gelatin. In fact, there are lots and lots of photographic materials made without gelatin, but they are not very light sensitive. Most can be handled in dim room light for extended periods such that they are suitable only for making contact printing papers or similar materials. In fact, no practical photographic material has ever been devised that is anywhere near as light sensitive as silver halide crystals in gelatin.

Laguna Salinas I

Now we have the basics. In order to work effectively, film requires that silver halide crystals be held in a substance that can be coated onto a plastic surface. It has to be in the form of crystals or it won't work at all. Dissolved silver halide is no good. The very best thing to put it in is gelatin, because gelatin will force the silver halide to form crystals as the gelatin dries out, but will readily allow liquid back in, to bring developing chemicals into contact with those crystals. Why do the crystals not redissolve when film is put into developer? Because not enough liquid can be absorbed into the thin gelatin coating to dissolve the crystals, only enough to carry developer to them. This silver halide-containing gelatin material is, by the way, called an *emulsion*. (Dictionary: An *emulsion* is a mixture of two or more liquids that are normally immiscible: unmixable or unblendable). Possibly not applied entirely correctly, this term has been used practically since the beginnings of photography and is unlikely to be replaced now.

We now have a piece of plastic coated with a thin layer of gelatin containing crystals of silver salts that are sensitive to light. That, all by itself, will work. Just not very well. Lots of other stuff gets thrown in there, but none are essential. They only *improve.* For example, modern films have multiple coatings or layers of slightly different emulsions that blend together to form various kinds of improved behavior that no single layer can provide. They also have a coating on the back called an *anti-halation* layer that stops light from going all the way through the film, bouncing back and exposing the film again, ruining the parts of an image representing the brighter parts of a scene by creating a halo around them. In addition, the base of roll films is dyed a slight gray. This has no significant effect on the printing of a negative but viewed from the edge, this dye becomes very quickly opaque, blocking light from getting very far into a roll of film when light hits the edge. If you accidentally open the back of a camera without first rewinding the film, not all the images will be ruined. This dye blocks a lot of light and will protect some of the images wound up near the center of the roll of film on the take up spool.

Silver halide crystals perform better if they are not perfect. Impurities are intentionally included in the manufacture of film, to place imperfections into the crystalline structure. Gold for example, is added in minute quantities, as are other impurities. I'll discuss how these impurities contribute later.

B&W film is only naturally sensitive to ultraviolet and blue light, so color dyes are added that trap colors of light to which the silver halide crystals are normally not sensitive and force them to react to those colors.

I have seen the term *orthochromatic* incorrectly applied of late so here is how the terms work:

- A film that is sensitive only to ultraviolet and blue light is called *ordinary* (or, blue sensitive) film. This is the natural state of the basic silver-halogen photographic emulsion.
- Film that is also sensitive to green light is called *orthochromatic.*
- If the film is sensitive to blue, green and red light, it is termed, *panchromatic.*

Modern B&W general use films are almost all, *panchromatic*. *Orthochromatic* films used to be extremely popular but are now mostly confined to special purpose films, that are also, high-contrast films. This is too bad because they were popular for good reason, and remained so, long after *panchromatic* films were invented. *Orthochromatic* film can be mimicked with *panchromatic* film, by using a filter (Kodak Wratten #44) that blocks red light, but the real thing was much easier. There are also special purpose films that are sensitive to invisible parts of the light spectrum, such as infrared, but that starts to wander into silliness and gimmickry.

Most all B&W films are sensitive to UV light: ultraviolet. *Very sensitive!* Perhaps half as sensitive as panchromatic films are to red light. This is the reason for UV filters on lenses. (Mentally insert obligatory landscape photograph with hazy mountains in the distance, here.) But any of the filters commonly used in B&W photography also block UV just as effectively, so if you use B&W filters (*much, MUCH* more on this subject in a later chapter), you will seldom need a UV filter.

Okay. Now we have it. Plastic, Jello™, salt crystals and a dash of extras that add *enhancements,* but not essentials. We are ready to see how this stuff actually works.

Behavior of the Silver Halide Crystal Upon Exposure

Think, *one small cherry suspended in a big bowl of clear Jello™*. That is our representation, for the moment, of our B&W photographic film. The cherry represents a single crystal of light sensitive silver halide. If *cherry* doesn't work for you, try a giant grain of table salt. Nothing else in that bowl is sensitive to light. Just that one big crystal in a whole bowl of Jello™.

Let's shoot a single ray of light at it. A *photon.* A *photon* is the basic unit of light. There is nothing smaller than a single photon, so there is no possible exposure that is less than one photon.

Bang! Our photon zings through the Jello™, like a bullet. But, it misses the cherry completely. Hitting the gelatin has no photographic effect whatsoever. It is exactly as though no light hit the emulsion, at all. A photon must actually hit silver halide/cherry directly, to be effective.

HiWay Cafe

Let's fire another… Bang! Bullseye. The light struck the crystal and forced a single silver halide molecule to be *reduced* (*reduction* is a chemical term that means the molecule is taken apart) to its basic components: one atom of metallic silver that remains, and an atom of halogen, last seen boarding a plane to Disneyworld™. (Note to chemists: Shush! Greater elaboration on *reduction* is not required.)

Nota Bene: You will run across the term *photochemical*, from time to time. It simply refers to chemical reactions caused by light. Exposure is a *photochemical* reaction.

Bear in mind that we have struck a *single* molecule in a crystal containing many millions, if not billions, of molecules of silver halide. Just one, creating just one atom of pure silver, the stuff that blocks light and gives us a negative.

We can now take our piece of film and rush it to the darkroom. Develop, stop, fix, wash, dry, admire: nothing! Though we did in fact strike that silver halide crystal with a photon, the net result is exactly the same, as far as a useable negative is concerned, as when the photon missed the crystal completely. Nothing is there. No amount of development will make it be there. Why?

Photographic film emulsions only become *developable*… well, let's sidetrack for a minute to discover what that word *develop* means:

An exposed photographic emulsion is almost identical to an unexposed photographic emulsion. An extremely tiny amount of the silver halide contained therein has been *reduced* to silver. In fact, the amount is so tiny that if you were to skip the use of a developer and instead immerse exposed film directly in fixer, the reduced silver would of course remain, but the amount of it would be so tiny as to be absolutely invisible. No instrument could see it or measure it. For real world purposes, it would not be there, at all. You could of course, try again, using an exposure of ridiculously strong proportions, but the very most you would get without development might be an extremely faint and useless image, confounded by the fact that emulsions with that much exposure tend to reverse themselves and reduce the amount of exposure instead of increasing it.

So, what is development? Or developer? For now, a simple description will suffice. A developer is a chemical that has a strong tendency to turn silver halides into metallic silver. This characteristic of developers exists whether that silver halide crystal has been exposed to light, or not. In fact, if you place a completely unexposed piece of film into a developer and leave it there long enough, it will eventually develop absolutely all of the silver halides in that emulsion. A developer wants to turn them all into silver, regardless.

Nota Bene: This is a good place to insert a necessary tidbit. Normal development always works on a small percentage of unexposed silver halide crystals, too. This produces a uniform amount of developed grains across the entire negative that do not represent any part of an image. This is called fog. Every negative has a low level of fog produced by development that does not interfere with the printing of the image. Fog occurs because some silver halide crystals spontaneously form small amounts of reduced silver all by themselves, making them developable, cosmic radiation also reduces some and not going to church on Sunday causes fog, also. (Who knows?!) Fog will play an important role, later on.

When a silver halide crystal contains atoms of silver (is exposed), developer works on that crystal much, *much* faster than it can work on one that has not been exposed. The reason it works this way is that metallic silver acts as a *catalyst* (a chemical that assists and speeds up a chemical reaction that otherwise proceeds much more slowly). The existing *reduced* silver in an exposed silver halide crystal causes the developer to work far more quickly, on that crystal. In fact, the more atoms of silver contained in an exposed silver halide crystal, the sooner it begins to develop. This is easily seen if you have access to a darkroom with silver print making capacity. Just expose two pieces of paper to a negative. Expose one more or less normally and the other, give ten or twelve times that exposure. Put both into developer and watch under the safelight for when the images first appear in each. The overexposed image will appear far sooner than the normally exposed image. In both cases, the darker parts of the image appear first because they have received more exposure than the lighter parts. More exposure means that developer begins to work sooner. This is *not* just a curious phenomenon. This little tidbit plays a *huge* role, in every use of film.

Butch

Now we can get back to our bowl of Jello™ with a cherry in it. Remember that we exposed the cherry to a single *photon*, developed it, and got zip for our trouble? One photon striking a silver halide crystal gives us bupkis. Not only did we get nothing for our trouble, but that single atom of silver has a *very strong* tendency to grab onto its recently departed halogen counterpart, reunite with it and turn itself back into a silver halide. End result: absolutely nothing! No change. Same as before. Sorry, no refunds. No exposure!

Even if that particular atom of silver remains in its metallic form, it's crystal cannot be *developed*. At least not in any length of time during which developer is normally, or even abnormally, applied to film. That silver halide crystal is not *developable*. A silver halide crystal must have a minimal amount of exposure (atoms of silver metal in the crystal) before any developer can act on it in a reasonable period of time.

We need to add a little more terminology… When a silver halide crystal has been exposed to light sufficient to make it *developable*, that exposure is referred to as a *latent image*. (dictionary: latent image - (of a quality or state) existing but not yet developed or manifest; hidden; concealed.) An image that is there, but not there, until the film is developed. Remember, if you skip the developer and just fix the film, you will get nothing. The image is *potentially* there. It is *latent.* You have no doubt heard that term before now. Here's a completely new term: *sub-latent image*. A *sub-latent image* is one that is there but cannot be developed, at least not easily. Our single atom of reduced silver in a single silver halide crystal is *sub-latent image.* It is there, but is of no use. *Sub-latent image* will eventually play a major role in our pursuits.

Every emulsion is different and reacts differently to light, but there is sort of an average minimal amount of exposure that causes *sub-latent image* that cannot be developed to cross the boundary and become *latent image* that can be developed. It is different for every emulsion and for every individual silver halide crystal, but we need some point of departure, as arbitrary as it may be, so we'll pretend we know this number and say that it takes *four* atoms of reduced silver to make a silver halide crystal subject to the actions of a developer. For our purposes, it is as good a number as any, and closer than most. And, I didn't pick it. Some photo-scientists who should have known better, did, a long time ago.

So, one, two or three atoms of reduced silver in the same silver halide crystal all constitute *sub-latent image* and cannot be developed under normal processing treatment. But four atoms *can* be developed and constitute *latent image*. Of course, like anything else in life, it is really more complicated than that. But not a lot.

Let's pretend that we have a silver halide crystal that is a square. We hit it with four photons, forming four atoms of reduced silver which if we are lucky, do not spontaneously turn themselves back into silver halides, which they almost certainly would. But each atom of silver persists and exists at a corner of the square crystal, all far from each other. This silver halide crystal, despite having four atoms of silver, the minimum required, is still, *not* developable. It takes more. Not only must there be four atoms in the same crystal, they must all be together. They must form what is called a *development center* or a *latent image center* or a *sensitivity center*. (Think, *sensitivity center,* if not yet containing metallic silver and either of the other two terms if silver is already there.) A clump of silver atoms all in one place. This is where our intentionally created defects in the silver halide crystal come into play. Remember we discussed adding tiny amounts of gold (or any of a variety of other contaminants like sulfur or last Tuesday's leftover meat loaf) in order to make those crystals less than perfect? These imperfections create *sensitivity centers:* places where reduced silver atoms will have a strong tendency to accumulate.

When light strikes a silver halide crystal it forms an atom of metallic silver. As already discussed, that atom of silver has a very strong desire to turn right back into a silver halide, nullifying the exposure. But, if there is a defect in the crystal, a *sensitivity center*, a reaction to being struck by light anywhere in the crystal tends to hopscotch on over to the nearest defect in the crystal and leave an atom of silver there, instead of where light first struck. With *sensitivity centers* present, every light strike tends to hopscotch to the nearest *sensitivity center* and be far more likely to become developable with four or more atoms of silver in the same place. Silver atoms in a *development center* also tend to remain much more stable, lodged in that defect, instead of reverting to silver halide.

Most exposed silver halide crystals will have multiple *development centers*. The one that first sparks developer into action will likely be the one with the most atoms of reduced, metallic silver. Unless of course, the *development center* with the most atoms of silver happens to be located inside the crystal where the developer can't get at it. This is called *internal latent image.* Internal latent image is useless. Pointless. Might as well not be there. Water with developer in it, does not generally enter crystals.

There are two classes of latent image: *internal latent image* and *surface latent image*. Developer can reach surface latent image, but not internal latent image. Ever wonder how *T-grain* or *tabular grain* films came to be?

Nota Bene: I should point out here that the words crystal and grain are commonly used interchangeably. Strictly speaking, it is a crystal before development and a grain afterward, but even Kodak says "T-grain" instead of "T-crystal". Guilty of perpetuating the same lax usage myself, I apologize now for the inaccurate applications that are certain to follow.

Flattened out crystals of silver halide present proportionally more surface area and therefore dramatically increase the amount of latent image likely to form on the surface of the crystal, because the crystal simply has more surface and less innards. The result is a smaller crystal that is more likely to form surface latent image, and is therefore just as fast as larger crystal/grain films, but with better resolution. The only drawback is that *tabular grain* (that's Kodak saying *grain*, not me) films tend to be slightly more finicky about development. Big deal! (Actually, there are other drawbacks, one or two of which are *sort of* big deals, but that is for later.)

Tree In Doorway

Before we discuss the development of film in the overall sense, we have to take a slight detour to discuss development of a single exposed crystal. You will recall I mentioned that the more atoms of reduced silver there are in a *development center* in an exposed crystal, the more quickly the developer begins to act on that crystal. This period of time has a name: *induction time*. *Induction time* is the amount of time between the moment developer first comes into contact with the exposed crystal and the beginning of development. (*Induction time* is also used in the larger sense, when speaking of the whole photographic film. In that sense it refers to the time between first immersion of the film into developer and the start of visible development.)

It’s fun to think of the whole thing as a stick of dynamite. The silver halide crystal is the dynamite, the induction time is the fuse. The more exposure the *dynamite* has had, the shorter the fuse. And this silly analogy to dynamite has a basis. Both dynamite and exposed silver halide crystals *explode!* That is to say, development of a single silver halide crystal is for all practical purposes, like an explosion. It is instantaneous. (If you prefer, think *popcorn*.) Once development of an exposed silver halide crystal finally starts it is also, over. There is no such thing as a partially developed grain. It is *all or nothing*. This might lead you to ask the very reasonable question, “Why then are films not all high-contrast films?” Well, at the crystal level, they are. A crystal/grain is either fully developed, or it isn’t developed at all. But normal film has smooth, continuous tone because silver halide crystals are not all the same size and they do not all receive the same amount of exposure, even when the same amount of light strikes film in the same area. (With high-contrast films, crystal size is much more uniform.) Different size crystals combined with the different induction times for different size development centers translates into smooth gray tones in the negative, overall.

At this point someone might suggest that what I stated above can’t be true, because fine grain developers create smaller grains and therefore it must be possible to develop only part of an exposed crystal. This might seem so, but in reality fine grain developers contain chemicals that dissolve silver halide crystals, not silver. Grain turns out to be smaller because the crystal is partially eaten away, during the induction time! The exposed crystal is already smaller when development finally starts and is of course, instantly completed.

Induction Time is Everything

If you glossed over, slept through or in any way failed to understand *induction time* up to this point, go back and read it again. I understand that this is not the most *edge-of-your-seat* topic you have ever read, but it is not possible to understand how film really works and how to expose and develop film in the most proficient manner, without fully grasping *induction time*. It dramatically affects everything and is affected by everything.

You will recall that the more exposure a silver halide crystal has received, the shorter will be its *induction time* and the more quickly it will be developed. Once turned from a crystal into a grain by development, it is a little black lump in the emulsion that blocks light from getting through the film. The more grains, the more any given section of a negative blocks light and therefore, the lighter that part of the image results in a print made from that blackened part of a negative. Light parts of the image are represented by heavy deposits of silver grains in the negative and dark parts of the image by sparse populations of silver grains in the negative. More to the point, bright areas of the subject produce lots of exposure which results in large development centers in the silver halide crystals and very short *induction times*. Dark areas of the subject produce far less exposure which results in small development centers in silver halide crystals and very long *induction times*. Subject tones in between, produce proportional *induction times*.

Nota Bene: A second sort of induction time takes place in film development and precedes the induction time we have been discussing thus far. This is the amount of time it takes for the liquid developer to break the surface tension of the relatively dry film emulsion so that it can begin to soak into the gelatin and reach the silver halide crystals. Surface tension is not broken evenly across a piece of film. It is splotchy and surface tension is broken sooner in some parts of a negative than in others. Therefore, development begins sooner in some parts of a negative, than in others. This is the reason for presoaking film in water for a minute or so, before applying the actual developer. It assures that surface tension has already been broken by harmless water, over the entire area of the negative, before developer is applied. It is uncommon for this uneven breaking of surface tension to actually cause a meaningful defect in a negative, but it can happen. It is worth expending a small amount of water and a minute of your time. Mr. Murphy will make certain that the only time in your life the uneven breaking of surface tension actually affects one of your negatives, it will be the best image of your career. Or… might have been! Make sure the presoak is the same temperature as your developer.

Nota Bene: Some of Ilford’s literature specifically states that using a presoak may *cause* uneven development. I find this quite suspect. They give no explanation for this discrepancy and I have seen no reports by anyone, ever, of presoaking resulting in the same effect it is designed to prevent.

Before we can proceed we need to list all the things that alter induction time so that we can look at exposure and development in light of them. After all, exposure and development are really, all about induction times:

Induction times are:

- Lengthened by *less exposure* and shortened by *more exposure*
- Lengthened by *weaker developers* and shortened by *stronger developers*
- Lengthened by *more dilute developers* and shortened by *more concentrated developers*
- Lengthened by *colder developers* and shortened by *warmer developers*
- Lengthened by *reduced agitation* and shortened by *increased agitation*
- Lengthened by *exhausted developer* and shortened by *fresh developer*
- Lengthened by *approaching completion* and shortened by *falling significantly short of completion*

Private Property

If you have come this far, I feel I can safely assume that you are able to figure out the above list on your own, without my help. Except for the last item. That will require a little explanation.

There is a concept called *development to completion*. It refers to the overall negative (or selected areas of it) and not to the individual silver halide crystal since, as we know, all silver halide crystals that are developed, are developed completely. *Development to completion* is a state in which a silver halogen based photographic material has been developed for so long that there is nothing left to develop that has received anything remotely approaching a reasonable exposure. All exposed silver halide crystals have been developed and the only thing remaining is unexposed crystals which would eventually develop after an even greater period of development, but that is of no concern here. *Development to completion* refers to exposed parts of the film, only. Lastly, *development to completion* is not something you want to do, because your negative would be unusable. It is a concept you need to grasp, nonetheless.

Now, let's have a look at the development of a whole negative from the standpoint of induction times. The heaviest exposure areas of a negative represent the highlights of the subject, and will contain the largest *development centers* and therefore will have the shortest *induction times*. After our film is immersed in developer, those areas of greatest exposure will be the first to appear and will do so long before the areas representing the shadows of the subject have begun development. Once induction time has been reached, the highlights will practically flash into existence and then race ahead, becoming denser and denser.

Nota Bene: Density is a term that refers to the accumulation of developed silver grains. The more developed grains in an area, the greater the density. Like a forest, the more trees, the denser the forest. And of course, the greater the density in any part of a negative, the more light it blocks. Ever try to see anything through a forest?!

Areas of heaviest exposure in a negative, those representing the bright parts of a scene, have the most exposed silver halide crystals and the largest *development centers*. But not all crystals are the same size and neither are the *development centers*. Earlier we talked about crystal sizes varying throughout an emulsion as well as the amount of exposed *development centers*. This is what creates smooth tones instead of all-or-nothing blacks or whites. Since areas of heaviest exposure have the shortest *induction times*, they start developing very much sooner than the lesser exposed areas and race ahead very quickly before the areas representing shadows can even begin development. In those places, induction times are *much* longer and a substantial proportion of the exposed crystals straddle the line between having fewer than four atoms of reduced silver in their *development centers* and just barely more than four.

Because of the nature of the heavily exposed *development centers* and rapid *induction times* in highlight areas of a negative, development in those highlight areas quickly begins to slow, partly because developer is used up at a high rate of speed (the reason for agitation: to provide a constant supply of fresh developer) and partly because the remaining exposed crystals are the ones that have smaller *development centers*. They will take a bit longer to react. At about the moment that a *normal* development time is reached and the film must be stopped and fixed, there still remain a *lot* exposed silver halide crystals in highlight areas of the negative that have yet to reach their *induction times*. If the film is left in the developer for longer than a normal period of time, those crystals will be developed, resulting in a *higher contrast* (this will be explained later), denser negative that can be difficult to print.

At a point when a very substantial portion of the exposed crystals in highlight areas have already been developed, only then will some of the exposed crystals in shadow areas begin reaching their induction times. When they do develop, they will do so at a rapidly decreasing rate because the larger *development centers* in those areas will be used up first and all that will remain are the more reluctant development centers with comparatively little exposure. Much of the shadow areas will not be developed sufficiently until quite late in the development process, and once normal development is completed, there will be very little remaining silver halide crystals in shadow areas with enough exposure to be developable. Shadows are in a state of being developed *nearly* to completion. You cannot develop what isn’t there.

So, film development involves a case of well exposed highlights racing ahead during development while less exposed shadows are always trying to catch up, like a little dog running after a big dog. He just barely gets there. Anything that prevents shadow areas from achieving near complete development, seriously hinders them in the finished negative. They will be lacking in density and of low contrast. This means at the very least, they will be difficult to print and often, not printable at all.

Before being fixed, a properly developed negative of a normal subject has lots of leftover exposed but not yet developed silver halide crystals in highlight regions. These crystals simply did not reach their induction times. But it has very little of such crystals in the shadows. Most of what can be developed in shadow areas, has already been developed. If you were to intentionally continue development beyond this point, you would be able to get a lot more density out of all the undeveloped silver halide crystals remaining in highlight areas, but there is little or nothing left to develop in the shadows. You cannot develop silver halide crystals that have already been developed or that have exposures far below the level that makes them developable.

If you haven't yet realized it, you have just put this information on how film works to use by explaining to yourself why there is really no such thing as *pushing* film! Film speeds are based on *densities* in shadow areas. Those areas where everything is already more or less, fully developed. *Pushing* film just means developing it for a longer period of time. This will substantially increase development of exposed crystals with smaller *development centers* in highlight areas, but will do very little in shadows. The most you are likely to gain in film speed by *pushing* film is about a half stop. That is, turning a 400 ISO film into a 600 ISO film. I suppose that with just the right film, combined with just the right super-duper developer, you *might* achieve something approaching a full stop of speed gain, but it is unlikely. In the mean time, you would get an overly contrasty and very dense negative that is at best, difficult to print. You also get a lot more fog which just happens to look like denser shadows. It isn’t. *Pushing* film does nothing but partially hide the fact that the film has been underexposed, by adding density and contrast to the wrong end of the scale. But it does *not* hide that underexposure very well, at all. There is no magical developer that can change the laws of physics and put exposed silver halide crystals where they did not exist before.


Private Property II

Nota Bene: There is a long-standing, worldwide tradition in photography of perpetuating absolute nonsense. Magical developers, secret development methods, dance-like agitation routines, special developer additives, miracle films, all sorts of hokey, useless (and expensive) darkroom gadgets, and on and on. Oh, and we cannot forget the SYSTEMS! Ever since Fred Archer and Ansel Adams invented the Zone System, absolutely EVERYBODY has a *SYSTEM* to flog. If you hear the word *system*, RUN!! This has been going on since photography was invented and the defenders of such nonsense are always most vocal, even insulting. You can find thousands more people who will tell you film can be pushed than you will people who can explain why it cannot. I am hardly the first person to tell photographers that film cannot be pushed. Bigger names have been telling photographers this for many decades. It is made especially difficult when respected manufacturers produce products specifically marketed as being able to do something that cannot be done: like draining the hypo that has sunk to the bottom of a print washer!

Pushing film is really just increasing the contrast of an image in order to hide gross underexposure. But that does not mean the act of intentionally overdeveloping film is not useful at all. It is extremely useful for *gasp* *increasing contrast*! It is perfectly legitimate to extend film development to gain increased contrast when it is needed. It is not however, called *pushing*. In the language of the *Zone System* (later, *much* later), it is called *expansion*. In the rest of the photography world, it is called *overdeveloping* or *extended development*. It is done exactly like *pushing* (without the underexposure), but in this case it is based on a valid goal, a higher film speed is not expected and it is a very useful tool for those occasions when you realize your image will be lacking in contrast or will not have enough density in lighter subject areas.

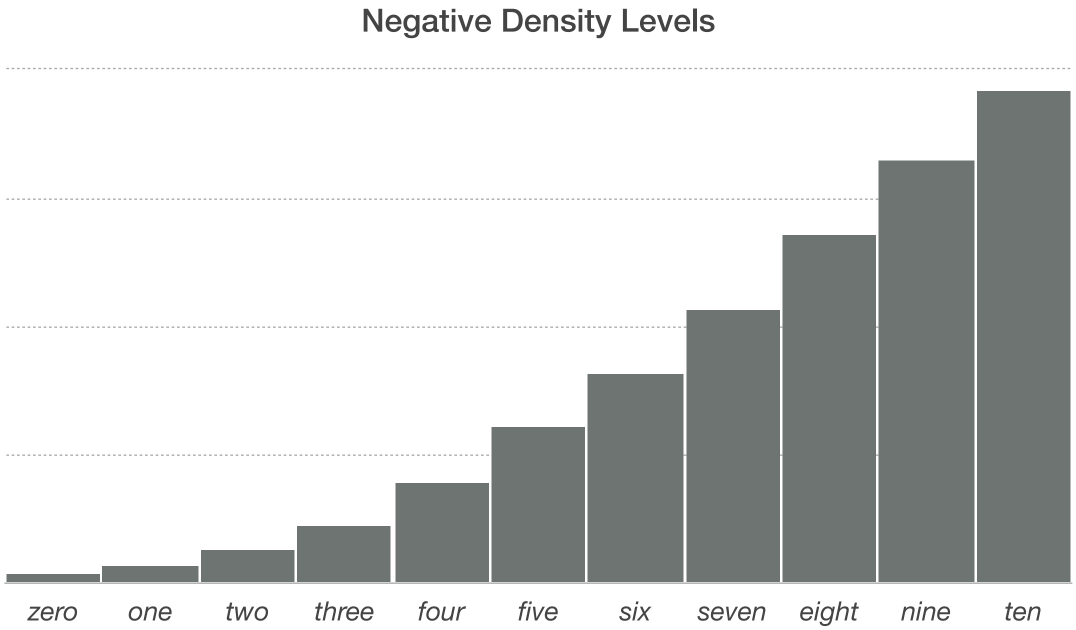
Nota Bene: I realize that I have not said anything about contrast up to now: what it is, where it comes from, etc. I will, in another chapter. For the time being, the understanding for the term that you have at the moment should suffice. But, be prepared to be surprised!

Now we come, very briefly, to the topic of *pulling* film. This is the opposite of *pushing*. It means cutting development short to compensate for having accidentally overexposed your film. *Pulling* reduces contrast and cuts off development of some of the silver halide crystals in the shadow areas, thereby lowering shadow density. However, the film was only, overexposed, *not* too high in contrast. So while *pulling* does in fact work, sort of, in the shadow areas, it severely weakens the rest of the image by reducing contrast that did not need to be reduced, making it hard to print.

Nobody *pulls* film. At least not very often. I never have and don't know anyone who has. I won't say there is *no such thing as pulling film* because there is in fact, one technique in existence for truly pulling film, that is, reducing its exposure without also reducing its contrast. It is one of the *easy* techniques of my own invention that I mentioned earlier. You don't need it. No one has ever asked me for a formula, in more than a quarter century. It is one of those inventions that no one really has a use for. But, this does not mean that there is no use for reducing contrast in film. In fact, not only does it give me the opportunity to mention my *dead-on-arrival* invention for pulling film that no one but me cares about (come to think of it, I don't care about it, either), it also provides the perfect lead-in, to…

The very same approach to *pulling* film (the traditional one, not mine), the act of reducing contrast, can be used not for overexposed film but for, *gasp*, *reducing contrast*! In Zone System parlance, cutting development short and thereby reducing contrast is called *contraction*. And that whole series of articles I mentioned earlier was almost entirely on the subject of *contraction.* In fact, *contraction* is a big deal in the B&W fine art photography world. It gets used a *lot!*

Unlike *expansion* (lengthened film development) to get increased contrast, a technique which is dead easy and has few if any problems, *contraction* has been nothing but problems, from the beginning. It always has been, and the reasons for it being problematic (and for me writing all those articles and inventing all those techniques) bring us right back to *development centers* and *induction times*. (I'll bet you thought I had strayed off course!)



Reduced development or *contraction*, is needed for subjects that have too long a range from dark to bright. Imagine you are standing in a coal mine, looking out the shaft to daylight and you want to make a photograph that includes both the dimly lit walls in the coal mine and the sunny day outside. Film can't handle that. Oh, modern films can probably record it all, but that is not the same as handling it. Film has an incredibly long potential density range. But you can't print it all, or scan it. It is simply too great from darkest to lightest either to print or scan. This is where *contraction* comes in. Reduced development lowers contrast and squashes all those really heavy exposure areas down into manageable levels of density that can still be printed. There are a variety of traditional techniques for doing this. Photographers have been reducing contrast since the beginning. As I said before, *contraction* gets used a *lot!*

All the ways of reducing contrast except those of my own invention are well over a hundred years old and are still in use today. They are comprised of any one, or various combinations of:

- *Developing for a shorter length of time*
- *Using a weaker developer*
- *Diluting your regular developer, thereby turning it into a weaker developer*
- *Reducing agitation of your developer*

- *Eliminating agitation altogether*
- *Soaking film in developer for a short time, then putting it into water to sit for a long time*
- *Soaking film in developer for a short time, then putting it into a chemical stimulator to sit for a long time*
- *Soaking film in a bath that contains part of the chemicals needed for development, but that is incapable of developing the film by itself, then putting it into a bath that causes the chemicals soaked into the emulsion in the first bath, to work*

Trapezoid House

No doubt someone will write to me mentioning some variation I forgot. But, all the techniques listed above, including the ones I forgot, are all the *same* technique. While some in fact do work better than others, they are all based on exactly the same premise and are intended to achieve exactly the same goal. (And, they all have exactly the same faults and risks.)

The premise of all the contraction techniques listed above is to deprive highlights (the more heavily exposed areas) of developer, while giving the slower developing shadow areas (little exposure) time to catch up and complete development before the highlights become developed so much as to be unprintable or unscannable. As mentioned previously, agitation is necessary in development in order to provide a continuous supply of fresh developer to heavily exposed areas (highlights) where developer is exhausted quickly by large amounts of exposed silver halide crystals. Developer weakened by whatever means, holds back and reduces development of highlights while shadows proceed to develop more or less, normally. That's the premise.

Weakened developer (all those old contraction methods are ways of weakening developer) means longer induction times. Longer induction times run the gamut of an entire image. If induction times are lengthened in highlights, then they are also lengthened in the shadows where the very last thing you need is longer induction times where they are already glacially long. This is why *contraction* always requires significant increases in exposure. Film speed, and therefore the shadow areas of an image, are lost when reduced contrast development is applied. You can compensate with more exposure, but more exposure means more exposure for the *entire* image, not just the shadows. More exposure in the highlights means larger development centers and therefore still shorter induction times and as a result, even more effort to try to hold back highlights, while shadows develop. It's a vicious circle. The more you expose, the greater the heavy highlight exposure problem you must deal with. The more you try to deal with overexposed highlights, the more shadows you lose to slower induction times there.

There are other problems associated with these old methods. One is uneven development. Agitation is required in order for development to be uniform. All the methods that reduce or eliminate agitation run the risk of blotchy and uneven development. The greater the degree to which development is reduced by these methods, the greater the risk of a ruined negative. Today's B&W films, all of them except possibly one or two coming out of communist or former communist countries are *thin emulsion films*. They are called this only because B&W film emulsions used to be thicker. Thick emulsion films reacted better to the *contraction* methods being discussed because they could simply hold more developer. Thicker gelatin can obviously retain more liquid and therefore more developer. Those old methods were designed when there was no such thing as a thin emulsion film.

All the traditional methods for *contraction/contrast reduction* do work. They just work the same way that putting cheap tires on your Ferrari works: not well, and not for long.

Because this is a *how-it-works* chapter and not a *how-to* chapter, I am not going to present any of my own techniques for contraction here. That comes later. I will tell you only that they are called *Selective Latent Image Manipulation Techniques (SLIMT)* and as the name implies, they go to work on the latent image *before* development takes place, thereby allowing film development to be *normal* instead of altered by one or more of the methods previously mentioned. In fact, once a *SLIMT* has been applied, the negative can be developed along with your other, normal negatives because the latent image in the film has been changed. No need for any exotic developers or development schemes. Just pre-soak in a *SLIMT* while also presoaking your normal negatives in plain water, then throw them all into the same developer together and process them all exactly the same: normally.

Beer

Exposure

Remember, this is not a *how-to* chapter, but rather a *how-it-works* one. So, I will not be discussing how to expose film either, but rather, how it becomes exposed.

Let's go back to our single silver halide crystal that has been exposed just enough to give us a development center containing the bare minimum of four reduced silver atoms. Ignoring for the moment that this crystal will probably not be developed at all due to this minimal exposure and because its very long induction time will not be reached by the time normal development of the whole negative is finished, let's pretend that it does indeed get developed. And accompanying it are a whole bunch of other crystals that had varying amounts of similar exposures, which also get developed. This will result in a part of the negative showing a slight image, corresponding to the original scene. You can see this image in the negative. What you cannot do is, print it!

There are densities in negatives that can be seen by you but that are so slight that they cannot be printed. There is a range of these densities and they are referred to as *sub-image.* (Not to be confused with *sub-latent* image which by definition, has not yet been developed; something else entirely.) They are there in the negative, but cannot be used. Photographic papers are simply not sensitive enough to pick them out and print them as separate tones. And densitometers cannot measure them because they are generally subtler than the densitometer's measuring capabilities. Only the human eye can see them. So, why am I telling you about these unusable parts of negatives? Well, first because I have made somewhat of a study of them and wanted to show off my knowledge (I am a proud pedant: look it up), but also because you will need to know that *sub-image* exists so that you will understand this…

There is a minimum negative density, much greater than the small densities contained in *sub-image,* that is required in order to be dense *enough* to be printable or scannable. It is a density that when printed, will create a black that is only very slightly less black than the darkest black of which a photographic paper is capable (this is often referred to as *D-Max* or *maximum black*). In fact, in order to see the difference, side by side, between the darkest black of a print and the black this minimal density creates, you may have to squint, stand on one foot and move the print from side to side under a bright light, to see it at all. This is the minimal amount of exposure a negative must receive before it can produce an image that can be printed as anything other than complete black. All sub-image prints as total black, unless the printing paper is intentionally underexposed. This minimum printable density required to make a just barely discernible lighter black, requires significantly more exposure than the amount needed to create a development center containing just four atoms of silver. All exposures greater than this minimum printable density will produce lighter and lighter tones in a print, if printed exactly the same way. For the time being we will call this *minimal density* and assign it an arbitrary number of *one,* just to keep things simple. While we're at it, let's establish that an exposure one full stop more than that will produce a density of *two*. Another stop, *three*, and another, *four,* etc. until we get to *nine* which is more or less the maximum *useable* amount of density above that first level. Level *nine* is just like level *one.* If printed at the exact same exposure as level *one, i*t can just *barely* be printed as a white that is only very slightly darker than the white of completely unexposed paper. Of course, you could continue adding more and more stops of exposure, but none of them beyond *nine* would be printable.

Grocery

Nota Bene: All of the forgoing about levels of density and how many of them can or cannot be printed is dependent on the film you are using, what kind of subject you expose it to, how much you develop it and what kind of paper you print it on. And even more things, still. Don’t take it as gospel, but just as a description of how things work, on average.

Now we need to add two more levels of density as reference points, *zero* and *ten*. *Zero* is the density that is achieved when one full stop *less* exposure is given than that which was required to produce the bare minimum printable density *one.* A density level *zero* will produce image in the negative, but that image is too weak to be printed so it will print the same as the maximum black of which the paper is capable. It is *sub-image*. Density level *ten* is one full stop more than the density required to print the lightest of grays, so it will print as the same white as unexposed paper. No effect at all. However, unlike density *zero*, density *ten* can be printed. Doing so would require a longer exposure of the paper which would darken the rest of the image, pushing density level *one* off the bottom and turning density level *two* into density level *one* in the print. Everything else goes down one notch, too. As mentioned previously, you could add densities greater than *nine* or *ten* but none would be printable, unless you continued to expose the print more and more. As the higher and higher densities got enough exposure to print as grays, the lowest densities would continue to fall off the bottom and be lost. After a short time, those densities that printed as the light parts of your image would now print as the dark parts and the original dark parts would all be total black. Paper can only print densities *one* through *nine.* (Unless you change paper contrast grades, but that is for later.) If you have *twelve* densities, all spaced by one stop increases in exposure, some must either be pushed over the top or fall out the bottom. And though scanners can often encompass a larger range of densities, they suffer from similar problems. Some negatives may have too long a range for your scanner to handle. At this point in time, film can successfully record more than most scanners can encompass without heroic efforts.

This is where reduced development comes in. *Contraction* development is used to lower contrast and therefore reduce negative densities *ten* and higher into proportionally lesser densities that can all be printed. But again, *how-to* comes later.

Now we need to go back to those lower density levels starting with *one.* With each additional stop of exposure, starting with level *one,* more density is added. Although one more stop of exposure means twice as much exposure, it does not result in twice as much density. It is something less than that, considerably less in fact. The numbers and the how are not important right now. What is important is that the increases in density are uniform each time an additional stop of exposure is added. Sort of. They are uniform when adding a stop of exposure to density levels *four,* on up. Each added stop of exposure after density level four adds more or less the same amount of density increase to the next level. Unfortunately this does not hold true for density levels *one* through *three.* Those first levels are kind of sluggish to respond to light. *Really* sluggish. The doubling of exposure used to turn a density level *one* into a density level *two* adds substantially less density than the same doubling of exposure added to density levels *four* and greater. About half or slightly less. This makes it somewhat difficult to see a lot of difference in a print between a density level *one* and a density level *two.* The problem lessens somewhat between density level *two* and density level *three*. The increase in density from a full stop of additional exposure goes up to about 75% of that achieved from full stop increases to exposure from density levels *four* on up. What this means is that the darkest parts of your image, the shadows, get short shrift from increased exposure. The result is a tendency, a strong one, for shadows to be a bit difficult to distinguish differences in. In a print, exposure level *zero* prints as completely black because it is not dense enough to create any difference from no exposure at all. Exposure level *one* prints just lighter than that, showing no detail from the scene, just a slightly less than fully black tone. Exposure level *two* prints slightly lighter than that and will show some hints of image detail but not much, at all. Finally, at exposure level *three* the image will still be quite dark, but you will have little or no difficulty seeing all the details that were in the original in that area of darkness/shadow.

Nota Bene: Some scenes don't have any real shadows. The term *shadows* is commonly used to refer to the darker parts of a subject, whether or not they are actually in shade. The term is also used for the darkest parts of your image. If you attach a piece of black velvet to a white wall that is lit by full, direct sunlight, you would refer to the black velvet as the shadow part of your subject, even though no shade is present.

Exposure levels *one* through *three* are the levels on which the darker parts of your image should be exposed. The less exposure given in this region of the film, the weaker the dark parts of your image will look, so it is very important to be sure that important darker areas of your subject receive sufficient exposure to result in densities well into this area. Whatever is exposed below density level *one* is simply lost, level *two* offers only a hint of detail in the subject and level *three* is still quite dark, though full of detail. Just one stop of exposure less than that required to get important darker image areas exposed to useable density levels can result in a negative that is really quite difficult to print. Now you know the reason for the century-old admonition to *expose for the shadows*. If you don't get those shadows onto the film, and with enough density to be easily printable, you will have a tough time getting a good print from that negative. By far the biggest problem encountered by beginning photographers is underexposure: like stupidity, there is no cure for underexposure.

Let's clarify this even more. Density level *three* is the lowest density level that will print with details of the original subject that you can actually see fairly well in a print. Everything below that level will just be a mixture of all black (density *zero)*, almost all black (density *one)*, and almost all black with a vague hint that there might be something there (density *two)*. So, anything that you wish to actually *see* in your photograph must receive enough exposure to at the very least, reach a density level *three.* You *cannot* try to make levels *zero, one* and *two* print lighter so that you can see detail. There isn't any detail to see. That is, *you* can see it in the negative. The printing paper, cannot. There is nothing in there but the faintest hint of detail: *sub-image.*

Exposure is everything. Problems at the other end of the scale, where the lighter parts of an image print in delicate light grays, can often be fixed, but underexposed subject shadows are simply ruined and heroic efforts in printing will very seldom save them. Most likely, not! Neither will *intensification*, one of the great magic tricks of photography that seldom works.

Overexposure on the other hand is simpler, as long as it is not a lot. If you happen to expose part of a scene that belonged at density level *three* in the negative by one stop more than necessary, putting it at density level *four,* then every part of the scene will be exposed one stop more than needed, so just exposing the print a bit longer will move everything back down the scale. Because of this, it is better to overexpose than to underexpose. And under some circumstances, as will be seen in another chapter, a *LOT* of overexposure can be very useful.

There is yet more to say about density levels zero, *one, two,* and *three.* They are so very important to high quality photography. Those four levels of density are called the *toe* of the film. That is a legitimate term. Don't blame me for it. Blame Kodak or whatever company came up with it many years ago. Those four density levels rise much more slowly than the density levels above them, as you can see in the illustration. But different films have different degrees of rise in density as those levels change from one to the next, and the different *toes* serve different purposes. If that rise is more abrupt, that is, density increases more sharply, then the term used is *short toe*. If the rise is slow and gradual, it is called a *long toe*. And, something in between the two is a *medium toe. Long toe* films are intended for studio use, *short toe* for outdoor use and *medium toe* as general purpose.

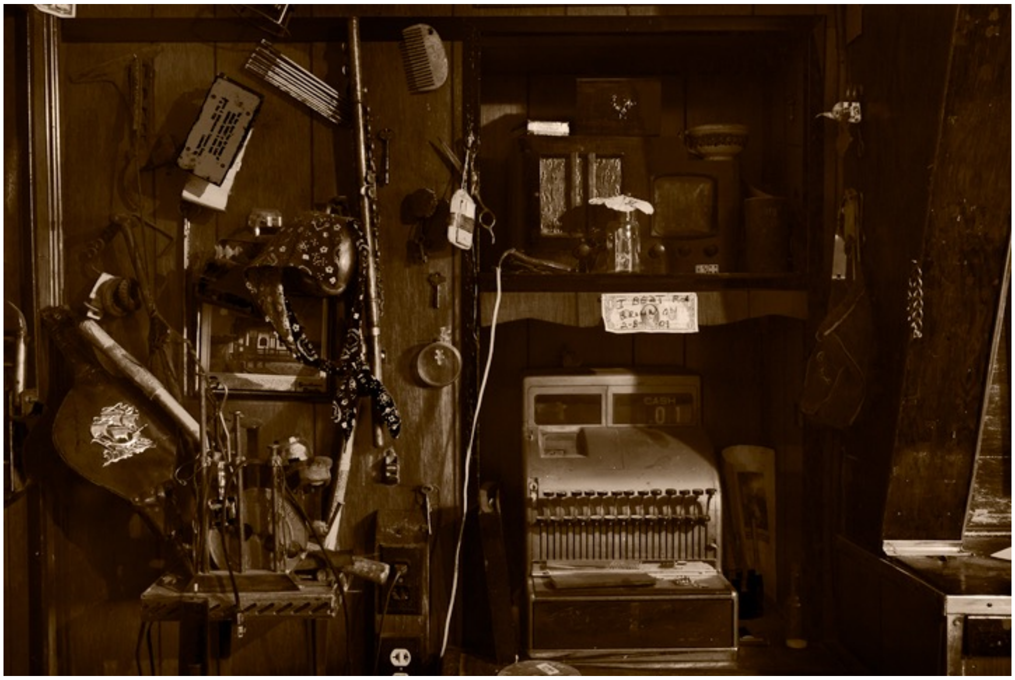
Unfortunately, not every film manufacturer tells you the toe shape of every B&W film they make. This is quite aggravating and forces you to determine it for yourself. Kodak sometimes does and sometimes doesn't. Also aggravating.

Nota Bene: In order to understand toe shapes you must first understand *flare*. There are various sources of *flare*, but they all boil down to the same result: light bouncing around inside your camera, *fogging* your film. (Remember when I told you fog would become important later? This is later.) *Flare* is the reason for lens hoods; to reduce *flare*. *Flare* is usually a very small amount of light that places an overall level of fog on your negative. Same thing as the fog that results from development, as mentioned previously. But flare adds its fog on top of density levels zero, one two and three. If we assume an amount of flare sufficient to create a density level *one* all by itself, then it adds that *one* to everything, turning a density level *zero* into a density level *one*, a density level *one* into a density level *two*, a level *two* into a level *three and a half* (or so), and a level *three* into something between levels *three* and *four*. In other words, it pushes up the density of all the lower density levels, but does the most damage at levels *zero* and *one*. The result is that the toe is lifted up and flattens out. The toe becomes longer. These small amounts of *flare* affect only the toes of film because they are simply not enough light to affect the much larger densities above the toe.

Flare turns a *short toe* film into a *long toe* film and reduces contrast in that region of your image. This is why *short toe* films are preferred for images made outdoors. They can deal with *flare* better than *long toe* films which are intended for studio use where the photographer has complete control over lighting and therefore, flare. (This *long toe for studio idea,* is also based on the silly idea that studio photographs are always portraits and a longer toe moves more tones into that part of the image that records skin tones.) The higher contrast in a *short toe* creates better image detail in areas likely to be affected by flair (the dark parts). If you use a *long toe* film outdoors your negatives will be more subject to degraded image detail in the shadow areas of your subject, than with a *short toe* film.

All that said, a lot of people use *long toe* films for outdoor photography. They simply have to do a little more wrestling with the image when printing. Well, OK, sometimes a lot more. Examples of *short toe* and *long toe* films are Kodak's Tri-X and, ummmm. well, Kodak's other Tri-X.

Tri-X (*TX*) in 35mm and with an ISO of 400 is *amateur* Tri-X and has a short toe. On the other hand, professional Tri-X (*TXP*) is ISO 320 and has a very long toe. In reality, they are two different films, with the same name. Don't blame me! I don't know how many different Tri-X films there have been over the years, but it is more than just three or four. Both types of Tri-X used to be available in 120 format film, but I believe only the TXP version remains. Looking just now online, it appears there may be yet another version of Tri-X because that film in 120 format is now rated at ISO 400, instead of 320, as it once was. Go figure!



I Beat Red Brown

Reciprocity Failure

Stop! Don't skip over this, no matter how boring you think it is going to be. And, well, frankly, I think it's boring, too. At least until you get to the good part that nobody tells you about, where you discover that you can actually benefit greatly from using *reciprocity failure,* on purpose. Manufacturers *never* explain *reciprocity failure* completely, they mostly just tell you what to do about it, which boils down to: *expose more and develop less,* and Ilford doesn't even tell you about the *developing less* part; at least not in the one brochure I checked. The longer your exposure beyond one-half second, the greater degree to which you must *develop less*.

Reciprocity simply refers to the fact that when you give one stop more or less exposure, the resulting densities in your negative also go up or down by the amount of one full stop of relative density: for that region of the film. In other words, add a brick, get another brick higher.

Reciprocity failure is when the above does not happen. When one stop more or less exposure fails to produce a one stop change in density. This happens with both very long and very short exposures. With short exposures, it is necessary that the exposure be one ten-thousandth of a second or shorter, which I have never done in my lifetime, and neither will you, unless you have lighting in your studio that causes blackouts of your entire city, every time you turn it on. Exposures that are too long however, are very common. To understand what reciprocity failure is really all about, let's go back to our single silver halide crystal…

Previously we talked about the necessity of having at least four atoms of silver that must all reside at the same development center of the crystal, etc., etc., in order for that silver halide crystal to be *developable*. What I did not tell you is that the accumulation of those atoms of silver is also time limited. If they are not all exposed within a certain short period of time, there is a tendency for them to revert to the silver halide state and become unexposed, again. This happens first in the areas of weakest exposure. Density levels *zero, one, two, etc.* The first level effected that is of importance is level *one.* With longer and longer exposures, the effected levels climb up the scale till all levels of exposure are effected to some degree.

Don't be misled here. The first step of reciprocity failure makes it necessary to give, for example, two seconds of exposure where a light reading indicates only one second is needed. This has an effect that spans several of the lower density levels by reducing the amount of effective exposure they receive. But it has no effect on the higher levels, because they naturally receive much more exposure and therefore suffer little, if at all, from reciprocity failure. Reciprocity failure occurs primarily in the lower density areas of a negative, only. The rest of the negative is normal. But, if you expose one stop more to compensate for reciprocity failure at density levels *one, two* and *three*, you will have overexposed all the density levels above those, because those upper levels did not suffer from reciprocity failure. This is why Kodak tells you to also reduce development time for negatives given extra exposure due to reciprocity failure. (And why Ilford should, but doesn't.) Each time you add another stop of exposure due to increasing reciprocity failure, you raise the density levels of the upper, unaffected density levels, increasing the need to reduce development time, to compensate. This can be a handy tool.

If you are using an exposure that requires compensation for reciprocity failure, but for an image that also needs an increase in contrast, simply add the extra exposure, but *do not* reduce

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development! This will give a similar result as having increased development to add density to upper levels. You fix two problems with a single action, allowsing you two ways of increasing contrast for any given image. You can either gain contrast by increasing development time, or adjust exposure to purposely cause reciprocity failure and therefore increased highlight densities when you purposely do not also reduce development time. Or, you can do *both* to gain substantial increased contrast.

Nota Bene: I promised to explain the term *contrast* and we are not yet at that point, but for any sticklers reading this, or those who have read some of my previous writings, strictly speaking, the doubling of exposure to compensate for *reciprocity failure* and subsequent standard development instead of reduced development time, does not cause an increase in contrast. It causes an increase in the range of densities in the negative. Only increased development time, as recommended by Kodak, causes an increase in contrast. That is, a range of densities from levels *one* through *nine*, becomes a range of levels *one* through *ten* when these reciprocity failure negatives are developed normally. Contrast is not altered.

Reciprocity failure and the required compensation are more or less universal among normal use films, even across manufacturers. If you know one set of rules for film X, you know the rules for film Y, with the exception of T-grain films. (I refuse to put reciprocity failure compensation tables in this book. All the other books on photography in the world contain them, and so does most of the literature included with new film, so you hardly need me to do it, yet again.) The rules for T-grain films are drastically different. Why?

The design of T-grain films is such that they receive exposure more efficiently, retain it better and build development centers more easily. They are simply less subject to *reciprocity failure* because of the flat, tabular shaped grain design. If you want the option to use reciprocity failure as a tool, you probably don't want to use T-grain films. If you make a lot of photographs of very dark subjects, T-grain films are by far the best option.

Nota Bene: I have just looked up Ilford's Delta 400 and Delta 100, both films I have never used. I had always assumed these were T-grain types of film, but their reciprocity failure compensation tables suggests that they are not T-grain films. Interesting.

Development

Entire volumes have been written on B&W film developers. At one time I owned most of them. There are general use developers, high contrast developers, low contrast developers, fine grain developers, high acutance developers, staining developers, push process developers, monobath developers and a panoply of others that will quite literally keep you occupied experimenting with different developers for the rest of your life, if that is what you really want to do, instead of making fine art photographs. And if you absolutely *must* canoe off the falls of utter absurdity, there are coffee developers, orange juice developers, and if not already existent, there will surely soon be nuclear waste developers, cow's blood developers and Jim-Bob's dirty socks developer.

In fact, there is only one type of developer that does not exist: the *magic developer!* You might be surprised to know that based on past experience I know that last sentence will result in a number of letters/emails to me that begin: "I completely agree with you that there are no magic developers…". And in every single case, the second half of that sentence will describe what the writer knows to be the singular exception, the one and only *true and real* miracle developer. There are *NO* miracle/magic developers. There can be and is, magic in photography, but it is never, *EVER* contained in the developer. No developer can turn bad photography into good photography. Magic is also not contained in the film. Or the camera. Or the location you choose to photograph. Or the enlarger, or the lens (though there certainly are some bad lenses). The magic is in the photographer and in that photographer's ability to capture a carefully envisioned image and to make a well-executed print. More specifically, it is the ability of the photographer to transform the raw information recorded on film into a new reality in a print that is *NOT* a simple, literal representation of what was in front of the camera, but something new in the world.

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No one believes that a good painting is the result of the brand of canvas or of *magical* tubes of paint. Yet millions of photographers think the secret to success is found in the film or the developer, or the camera or the lens. That is like a glass blower believing the bucket in which he brings sand home from the beach is what results in a beautiful piece of glass.

And while we are on the subject, there is no developer on Earth that can transform an image recorded on bad film into a masterpiece. A badly recorded image is a lost image. Just as there are no shortages of *miracle developers* being flogged on every street corner, there have always been lots of second rate, low quality films being sold as wonder films. No amount of savings can justify the loss of what might have been the best image of your life, to junk, ex-communist bloc (or for that matter, current communist country) film. Before they were all run over by the digital stampede, there were four film manufacturers you could trust: Kodak, Ilford, Agfa and Fuji. And even they screwed up from time to time.

Nota Bene: Big time! I once insisted that Ilford replace 50 rolls of defective 120 Ilford film with fifty rolls of Kodak 120 film, as a mini form of vengeance. All 50 rolls of Ilford 120 were shot during an expensive trip to Peru and not a single image was salvageable. But don't let that make you think that Kodak film is superior. Kodak recently suffered from the exact same defect in THEIR 120 film, more than 20 years after Ilford! The only difference being that Ilford refused to acknowledge the problem for 20 years or more (as far as I know, they never acknowledged it), while Kodak at least, owned up immediately.

Agfa is gone. I believe I read that Fuji is still making one B&W film, but am not certain. Currently Kodak's B&W films have, shall we say, *respectable* prices. If price is an issue for you, Ilford's films are in the same high quality class as Kodak's (always have been), with dramatically lower prices. The other B&W films I see being promoted are either about the same price as Ilford's or even higher, which is hard to imagine as justifiable. Ilford and Kodak films are a known quantity. Others are not. I have BTW, no relationship of any kind with Ilford and have not had any kind of relationship with Kodak since the late 1990's. I am currently using 4x5 and 5x7 Ilford HP5 because of the lower cost, the more traditional design and the shorter toe, not necessarily in that order of importance. I would not consider using any film other than a Kodak or Ilford film, without extensive testing which I see no reason whatsoever, to do. Currently, I am also using an X-ray film for 8x10 format images. It is a Kodak X-ray film that is orthochromatic, coated on only one side and has an anti-halation backing.

I have used Kodak's HC-110 developer for decades. HC-110 and HP5 are the film/developer combination I would recommend to someone just starting to use large format film. There is nothing special about that combination. It is a good general purpose film with a good general purpose developer that is also quite flexible. A good general purpose film and developer is precisely what you want. Rarely can such a combination not be bent far beyond their designed-in, *middle-of-the-road* uses. There is simply little or no reason for anything *exotic,* even if they actually work as advertised.

Or, you can try the eeny-meeny method. Put the names of four general purpose films and four general purpose developers in a hat and pick out one film and one developer. Use them and only them, for a decade or so, until you know exactly why you might want to change one or both, or add another option. Any combination of film and developer you pull out of that hat will give you roughly the very same results as any other combination you might have selected. A good film and a good developer are what matter. Which good film and which good developer matter much less. Any results you can get with combination X, you can also get with combination Y and a little tweaking: or quite possibly, no tweaking, at all.

There are other bits of information that can help when making a choice. In medium to large format work, a 400 speed film is just more versatile and grain will seldom if ever be a consideration. In fact, one of the ways to spot someone who really doesn't know what he is talking about is if grain is a significant consideration for him. Grain was a problem of the past.

As was sharpness. Fine grain developers and acutance developers no longer serve any meaningful purpose. Yes, they still work as advertised, but they are simply not needed. Modern films are already fine grain films and already have high acutance.

Short toes will give you more room for error than long toes. Traditional films will also forgive more than T-grain films. T-grain films are much more finicky about development and are severely more prone to scratching because they have no retouching surface on them. Retouching surfaces tend to hide scratches very well. (Kodak literature says, or used to say, that they do have retouching surfaces. That is a case of the marketing department copying literature from older films without stopping to ask questions. To my knowledge, no Kodak T-grain film in any format has ever had a retouching surface, despite what the advertising propaganda says/said. I have been trained in fine detail pencil retouching and know exactly what I am talking about. The lack of a retouching surface is one of the primary reasons I stopped using Kodak's T-grain films. Most standard B&W films do have retouching surfaces.) If you absolutely MUST use T-grain films early on in your career, consider rotary processing to be your only processing option because every other method will cause scratching nightmares. Great film, just too fragile for most any other kind of processing and of course, no retouching surface.

Pick any general use developer, but only one that is available in concentrated *liquid* form. Dry developers work exactly as well as liquid developers. BUT, stale liquid concentrate generally turns funny colors to let you know it has gone bad. Dry developer that has gone bad will look exactly the same as dry developer that hasn't, unless it has also formed clumps, a dead giveaway. The biggest risk with dry developer is processing film in developer that has not yet completely dissolved. It will look dissolved when it is not. This is the reason to mix dry developer and then let it sit overnight before use. It needs the time to completely finish dissolving. Stale dry developer mixed, then left to sit overnight will look exactly as good as fresh dry developer treated the same way. But the stale developer can/will have microscopic grains of undissolved chemical that will *never* dissolve, and that can create tiny pinholes in your negatives that you cannot see, even with a loupe. Only when you make that first test enlargement, will you see them. Perhaps hundreds of them, on every single negative. Dry film developer is simply not worth the risk when there are equally effective liquid concentrate developers that never present any such risk and are much more convenient to use. Chances are good you will never have this problem with a dry developer. But it does happen. It happened to me with a batch of D-76 and an entire summer of work. I believe the correct term is: *no-brainer!*

Especially, do not buy someone else's dry film developer and trust it with important images you may not try to print for months or years. If he is selling it, that means he has no use for it, which means he has probably had it for a long time. He clearly had a use for it when he bought it! And while I am at it…

Harpers

You will from time to time, run across some old geezer selling outdated film out of his garage. *He uses it himself*, he will tell you. And, he only brought it out to his garage yesterday. Before yesterday, it was in the freezer since before the 1962 expiration date, he will say, as you look around to see shelf after shelf covered with film and paper. (Must have been a really big freezer.) There is simply no such thing as out of date film you can trust, unless that film has been in *YOUR* freezer since before the expiration date and *YOU* are the one who is certain you did not keep it in the trunk of your car over the summer.

Think of film as being a food product, which with all that gelatin, it essentially, is! It is perishable, like any food product. Kodak and Ilford DO NOT put expiration dates on their films as an attempt to sell more film. The expiration date is NOT decorative. Why on Earth would you even consider risking a potentially priceless image on out of date film? Even absolutely fresh film from the most reputable manufacturers often spends days or weeks sitting inside hot trucks in the middle of July! In fact, Kodak (and I presume, Ilford too, but I only know about Kodak) includes expected time in hot storage in their calculations for expiration dates and at what point the film will be at its peak performance. It's a bit of a crap shoot, but they pay attention to these details because they *do* matter. Professional films are supposed to be kept refrigerated all the time, because they are at their peak when they leave the factory. Amateur films are expected to reach their peak at some time after leaving the factory and being stored unrefrigerated, and also considering average time on the shelf before being sold and then used. No one in their right mind goes to this kind of trouble for something that doesn't matter. Expiration dates matter! Do not cut corners with film or developer.

B&W Papers

You don't need much information here. B&W silver-gelatin papers work the same way as film, with the following exceptions:

- *Papers are inherently higher in contrast*
- *Paper developers are higher contrast than film developers (still, no magic)*
- *The toe of paper is in the highlights as opposed to the shadows*
- *Papers are chemically prevented from forming any fog at all, because basic development fog would show in a print's highlights: not in film shadows*
- *Modern B&W photographic papers tend to experience an increase in overall density with extended development time, not increases in contrast, like film. In other words, increased development of B&W paper DOES increase paper speed, where increased development of B&W film DOES NOT increase film speed*

Otherwise, everything you know about silver halide crystals and exposure and induction time, etc., etc., about film, is also true of paper. It just isn't quite as important with paper as it is with film. If you mess up a print, you can simply get out another piece of paper and try again. With film, you often cannot retake the photograph and even if you can, chances are the scene will be very much different when you go back.

The question arises, "If fog can be completely prevented with paper, why not do the same with film?" Because eliminating the minor development fog that occurs with film would also dramatically reduce film speed. With paper, that doesn't matter. With film, it does. Plus, the fog in film can simply be made to disappear by printing through it with a longer paper exposure. Not possible with paper fog. All paper fog shows.

But Wait, There's More!

Yes, there is more to understanding how film works. But it all has to do with forcing film to give you what you want from it, rather than just accepting a generic, one-size-fits-all exposure and development approach. What you have learned thus far in this chapter is essential to understanding film. What remains to be covered in other chapters is the knowledge of how to use film most efficiently for the specific image you envision, including an in-depth understanding of the word *contrast* and the important knowledge of how to manipulate the gray scale for your own needs.