The Pixel

The word pixel *is a combination of the words* ***picture*** *and* ***element*** *and is the smallest unit of measurement in digital capture. The process of capturing a digital image starts with the mechanical or analog process of shutter and aperture depositing light on a* ***diode,*** *which is sensitive to light.*

The diode sits below a ***Bayer*** *pattern which filters* ***red, green, and blue light*** *onto light sensitive diodes. For the camera to render an image, the diode expresses the amount of brightness to a processing unit in the camera which then transforms it into a bit-mapped image. The* ***points*** *of this bit-mapped image are called pixels.*

A pixel can be thought of as a reservoir, from the meaning "storehouse" in French, or like a bucket. I use the phrase pixel bucket due to the fact that a pixel can only store the amount of brightness deposited by shutter and aperture. A digital sensor does not capture color. Color information must be interpolated by filtered light from a Bayer pattern.

Depending *on the strength or amount of light falling on a diode (and then being processed in the camera) a pixel can have 256 possible tonal values in an 8-bit file.*

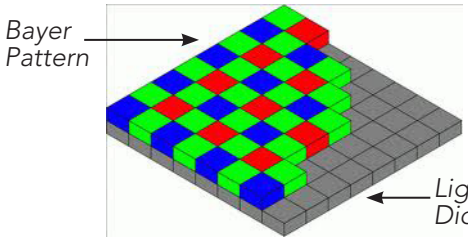
Empty pixels *receive a digital value of "0" and appear black on the grid.*

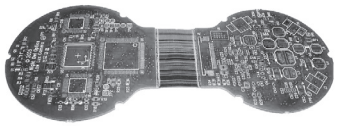
Half full pixels *receive a digital value of "128" and appear gray on the grid.*

Full pixels *receive a digital value of "255" and appear white on the grid.*

The camera *used to shoot the pictures for this chapter of the book had a pixel grid of 10,077,696 pixels or 10.1 Megapixels (3888 x 2592). The 10,077,696 pixels can be displayed with a graph called a histogram.*

A histogram *is a graph which displays the dynamic range of a digital file. Its peaks and valleys are caused by similar pixels having more or less of the same digital values.*





Camera Processing Unit

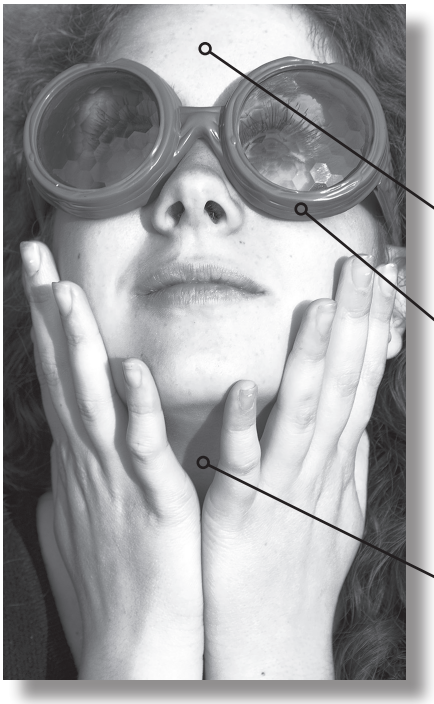
(1) Dynamic Range

The Three Dynamics Of Photography, (1) Dynamic Range, (2) Resolution, (3) Color

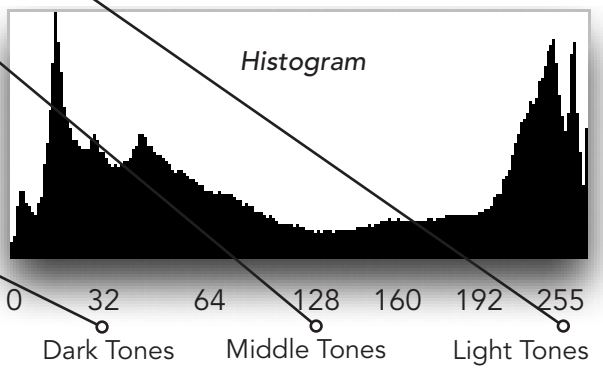
Dynamic Range *is the amount of tone in a photographic image. In an analog photographic print, each level of tone equates roughly to one stop. Human vision can see twenty stops of tone.*

Ansel Adams, using black and white film, could compress and hold ten stops of tone in a black and white photographic print. Careful exposure using slide film (positive transparencies) can record only about six stops.

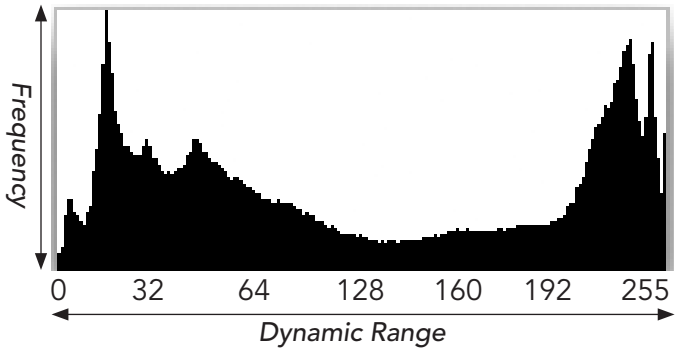
The same goes for digital sensors; they have about six to seven stops of dynamic range and some of that range has been extended by the use of Dynamic Exposure. This for example allows white wedding gowns to retain some tone when captured by a digital sensor. This Dynamic Exposure has a tendency to render the dark values of a scene with less detail than when Dynamic Exposure is turned off in the camera's menu.



Kasi Jorgensen's *portrait (left) is portrayed in the histogram below. A histogram is a graph of tonal values represented in Kasi's digital file. Histograms were used to test the first digital cameras and they were so useful they became part of the menu in digital SLRs. The tones in a digital file can be directly related to the histogram's peaks and valleys. A greater amount of pixels with similar tones creates a peak in a histogram and vice versa; similar tones with fewer pixels create valleys.*



The two main parts of a histogram (shown below) are dynamic range and frequency. The horizontal part of the histogram is called ***dynamic range*** *and the vertical part of the graph is called* ***frequency****. The dynamic range part is identified with numbers 0 through 255 for an 8-bit file, which allows 256 tonal steps. The vertical part of the graph (frequency) describes the amount of pixels having the same digital values. A single histogram represents the millions of pixels making up a digital image. To handle these large numbers of pixels, frequency is calculated in percentages.*



8-Bit Histogram

(2) Resolution

Film Capture

For Photographic Film Capture, *resolution is calculated by counting dye locations. Photographic color film has more than 10 million dye locations per square inch and a 35mm frame size of 1"x 1½" has 15 million dye locations. If each dye location equals one of three primary colors in a digital sensor to capture an image, this would mean a 35mm frame would have an excess of 15 megabytes of resolution.*

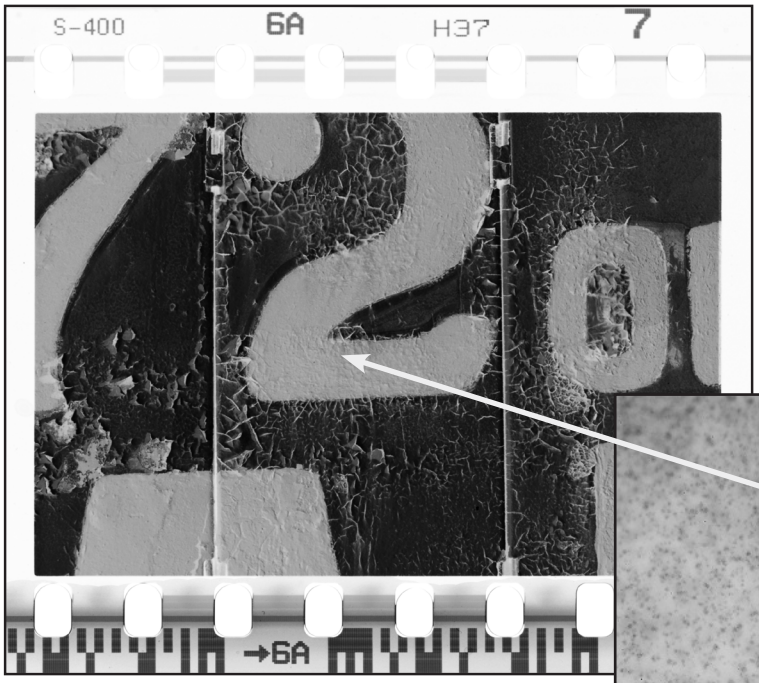
Currently, the Nikon D800 DSLR has a 36 megapixel (FX) full frame sensor. Most consumer grade digital DSLRs have half that amount of megapixels, which are still three times the size of the original Canon Digital Rebel 300D which contained 6 megapixels.

Suspension of Disbelief

To compete with film, *all digital sensors are made to supply a certain amount of resolution for a given output device. To make color prints from digital files, Costco uses a color process which produces color prints on RA-4 photographic paper which is sensitive to red, green, and blue light. Upon processing the RA-4 paper, color couplers produce cyan, magenta, and yellow dyes, representing the true colors of the subject photographed.*

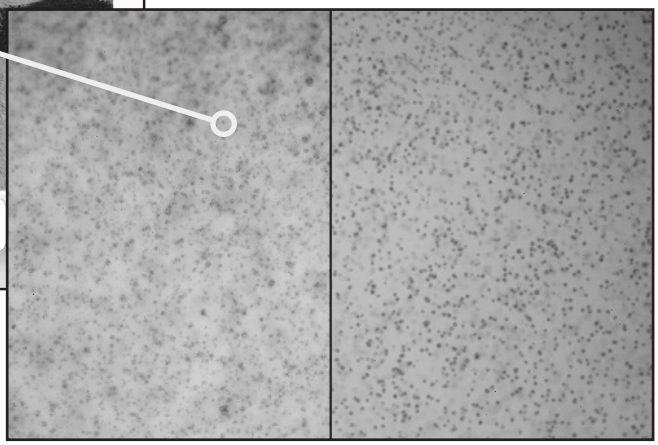
Most RA-4 printers need a minimum of 225 to 300 pixels per inch in a digital file to make a believable photographic image without pixelation, or lack of pixels, to form a smooth image when viewing or create a ***"Suspension of Disbelief."***

"Suspension of Disbelief" is a quid pro quo, or equal exchange*, where the viewers of your photographs agree to provisionally suspend their judgement in exchange for the promise of being shown reality when looking at your photographs. The term "Suspension of Disbelief" was coined in 1817 by poet Samuel Taylor Coleridge who suggested that if a creator could infuse a semblance of truth in his work, the reader of that work would suspend judgement on the implausibility of that narrative.*



35mm *photographic color negative film*

A positive image from the 35mm Negative



A 35mm frame size of 1"x 1½," has ***15 million*** *dye locations*

(2) Resolution

Image Capture & Output

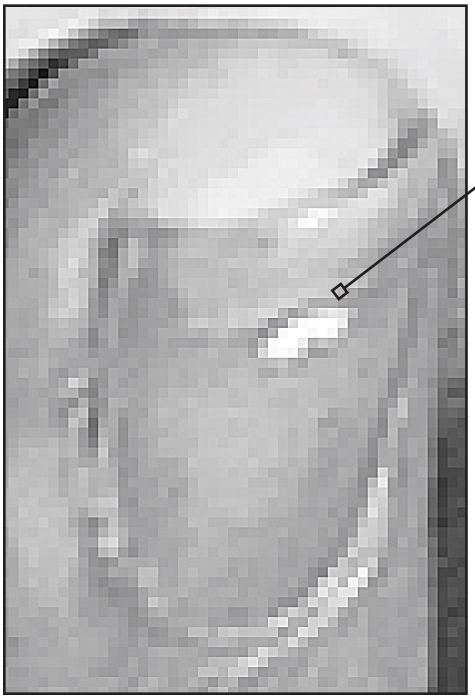
When Photoshop is used to zoom into Kasi Jorgensen's portrait it's easy to see the edges of the pixels. *They make up the resolution that allows a smooth image to be rendered in a photographic print, or reproduced in a printed document or on the Web.*

Resolution has only one purpose in digital imaging, to supply enough pixels for a given output device. *When pixels are being captured by an imaging device such as a camera or flatbed scanner, they are designated as Pixels Per Inch (ppi). When being printed or displayed, the term Dots Per Inch (dpi) is used.*

The process of outputting images to devices such as RA-4 photographic printers (Costco color prints), image setters, or film recorders, usually demands at least two pixels (based on the line screen) for each dot created by an output device. A photographic printer with a line screen of 150 would demand that an image be captured at 300 ppi to avoid pixelation and to exhibit a smooth appearance when viewed.

A ***pixelated*** *or jagged reproduction of the image would defeat the psychology of* ***"Suspension of Disbelief"*** *described earlier.*

To read a long range continuous *tone image without pixelation, one must have enough pixels to satisfy the line screen of the output device. Most photo-based printers use between 225 to 300 pixels to achieve a smooth, believable, non-pixelated image on paper.*

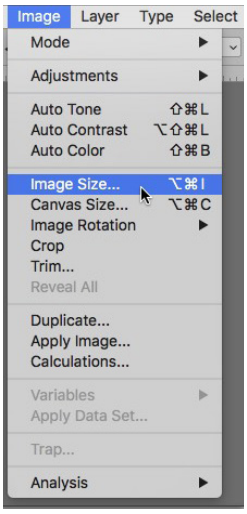


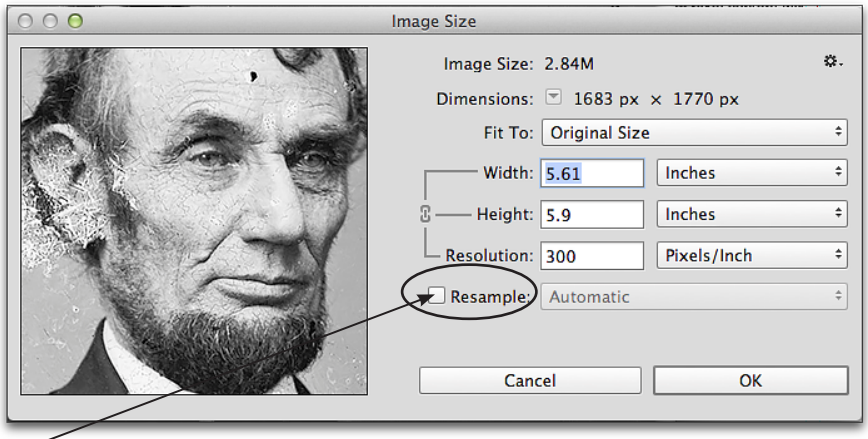
Resolution is how tightly packed *the pixels are after the image is processed by the camera's processing unit.*

Photoshop's Image Size Dialog Box

The Image Size Dialog Box states the physical size of a digital file in pixel dimensions, *and then displays how those pixels can be interpreted through width, height, and resolution of the image file. The top screen capture shows the* ***Image Size*** *with the* ***Resample Image box unchecked****.*

Photoshop's Image Size Dialog Box

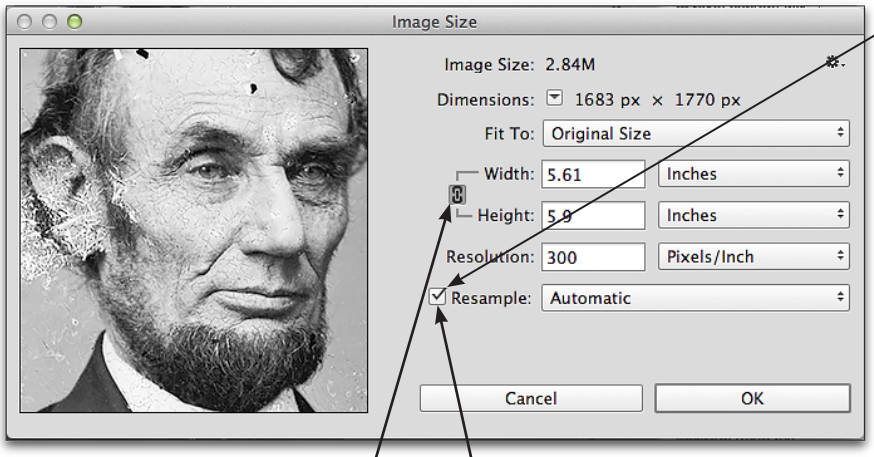




With the Resample Image box ***unchecked,*** *you can exchange or trade the width, height and resolution of the file and the file size will not change.*

Resample Image Box Checked

With the ***Resample Image box checked,*** *the physical size of the file stated in pixels can be* ***resized.*** *Keep the Constrain Proportions boxed checked and locked brackets will indicate that the width and height of pixels will be in proportion to the change in document size. For sizing larger files, use the algorithm* ***Bicubic Smoother;*** *for reductions, use* ***Bicubic Sharper.***



Automatic Interpolation

Another feature of the Mercury engine (if set in preferences) is automatic interpolation. In previous versions when you reduced a file size you had to set the algorithm to bicubic sharper, and for larger file sizes you would set it to bicubic smoother. When the image size dialog box is used to reduce or enlarge a file, bicubic sharper or bicubic smoother is now automatic.

Locked Proportion Brackets

Resample Box Checked

<u>Hint:</u> double check this if you resample your file, or strange looking proportions will appear.

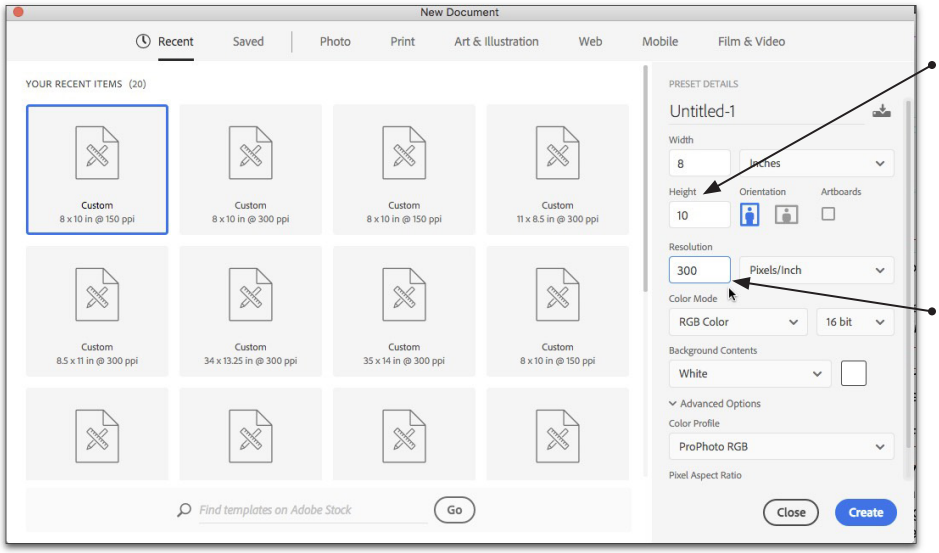
(2) Resolution

Photoshop's New Document Command

Calculating Files Sizes With New Document Command [Command-N]

Select File>New or (Command–n) and the New Document dialog box on the Photoshop work screen will appear. This dialog box allows you to indicate height and width in picas or inches (use inches), mode, and resolution.

You can also name the file, decide the content of the file (i.e. RGB or Grayscale), its background content, and its color profile (our class color profile is ProPhotoRGB).



Width/Height: These two boxes indicate the physical size of the file. You can highlight the numerical value and enter new sizes.

Resolution: This indicates how many pixels are packed together per inch. For example 150 dpi resolution is OK for a 80 line screen school laser printer.

When calculating a New Document file size, start with the resolution *(or how tight the pixels must be packed together for any given output device) first. Look ahead to the final output devices resolution requirements.*

Image Size Table

Pixels Per Inch (PPI) Table • 8 Bit Images — Grayscale

Image	*Image Dimensions (rounded)*				
Resolution	*1x1"*	*1x 2.5"*	*4x5"*	*5x7"*	*8x10"*
75 ppi	*6K*	*28K*	*110K*	*193K*	*440K*
100 ppi	*10K*	*49K*	*196K*	*342K*	*782K*
150 ppi	*22K*	*110K*	*440K*	*770K*	*1.72M*
200 ppi	*40K*	*196K*	*782K*	*1.34M*	*3.05M*
300 ppi	*88K*	*440K*	*1.72M*	*3.00M*	*6.87M*
400 ppi	*157K*	*782K*	*3.05M*	*5.34M*	*12.2M*

Photoshop's Channels Panel / Pixel Depth

Color is a sticky issue in digital photographic capture. *To capture color, the available amount of pixels must be divided in thirds (really, there are two green filtered pixels to each red and blue filtered pixel). To make up for the loss of available pixels to capture an image, a technique called interpolation is used to compensate for the difference. Interpolation relies on sampling surrounding pixels to fill in information not available at the pixel level. As you probably can guess, it is not the most accurate method to determine the color of color.*

Pixel Depth Stores Color

As shown below, an 8--bit gray scale file can display 256 gray levels. 0 is a black pixel and 255 is a white pixel. The counting starts at 0. That's why there are 256 possible levels in an 8–bit file. It takes three 8-bit gray scale files or channels in Photoshop to describe a color image. Red, green and blue each are represented by an 8--bit channel, and each channel describes 256 tonal steps, so … 256 x 256 x 256 = 16.7 million possible colors in a 24--bit color file.

The Color Matrix Channel in the channels panel is the combination of all 3 gray scale channels so that a 24– bit file can be seen in color on a computer monitor.

Pixel Depth	
Bits Per Pixel	**Gray Levels**
1	2 (black & white)
2	4
3	8
4	16
5	32
6	64
7	128
8	256

8-Bit Red Channel + 8 Bit-Green Channel + 8 Bit-Blue Channel = 24-Bit Color Photoshop Document

Interpolation with Demosaicing, Again

Sensor diodes are arranged under a Bayer pattern, which assigns what pixels will hold information for red, green and blue. The diode arrays actually assign two green pixels for each red and blue, so it's really a GRGB configuration. Any missing color information must be shared between neighboring pixels. This sharing of pixel color is called ***interpolation****, and it is done by an algorithm called* ***demosaicing****. The Adobe Raw file converter interprets this process of interpolation and demosaicing.*

Exposing for Digital Capture

When taking pictures with your digital SLR you are actually exposing the sensor to fill 8-bit (really 12 to14) pixel buckets. Overexposing with digital capture would fill up these pixel buckets with too much information and it would cause it to "spill" out of the bucket. Underexposing with digital capture is also to be avoided. Exposure must be done to fill the pixel buckets to the rim (or a few drops over) and then by developing your Raw file in Adobe Camera Raw. One safety tool in Adobe Camera Raw, the ***Highlights Slide (CC 2014 process)*** *allows you to sponge up some of the information spilled from the bucket during exposure.*

Bits & Bytes & More

Measuring Digital Files

Computers use a single binary digit, or bit, sign language. *If you were in a room with a computer with all the lights off, a computer would say "Off" and call it the binary digit "0". If you turned on the light, the computer would say "On" and call it the binary digit "1". Examine an on/off switch on any computer device. You might see the character "I" representing on, and "0" representing off.* **On="1" and Off="0."** *Each on or off represents one bit of information to the computer. In order to say more than on or off, we can string together a bunch of on and off messages such as 01000001. This bunch of 8-bits is called a Byte of information and represents the letter "A."*

1-Bit = On or Off, 1=On, 0=Off

8-Bits = 1 Byte or (01000001=A)

1024 Bytes = 1 Kilobyte

1024 Kilobytes = 1 Megabyte

1024 Megabytes = 1 Gigabyte

It was on an episode of Star Trek Voyager when I first heard the character "7 of 9" use the term "Terabyte."

1024 Gigabytes = 1 Terabyte

And so it goes, like…

1024 Terabytes = 1 Petabyte

And again like…

1024 Petabytes = 1 Exabyte

1024 Exabytes = 1 Zettabyte

And, at last …

1024 Zettabytes = 1 Yottabyte