CS 200

Lecture 03

Pixel Graphics

Miscellaneous Notes

Abbreviations

dpi	=	dots per inch
ppi	=	pixels per inch
FAQ	=	frequently asked questions
lpi	=	lines per inch
RWS&HT	=	Real World Scanning and Halftones
NDWB	=	The Non-Designer's Web Book

Optional background reading

"Beyond the Mac is not a typewriter," by Robin Williams   (http://www.ratz.com/robin/realbio.html)

Administrivia

Remember . . .

UNDERSTANDING what you're doing in lab, and why, is more important than how to do it

So in lecture today

- focus on WHAT we're doing, not how

This week's reading

- both supplements and *complements* this week's lecture

- from Learning Web Design

Topic	Page
RGB colour	234-6
Indexed Colour	363
Bit Depth	391
Monitor Resolution	40-44
Resolution of Images	373-75
File Formats (gif, jpeg, png)	115-116, 362-371
Anti-aliasing	
File size of images	373-75
The aesthetics of colour	

- Please ask questions!

Assumptions

- You have used a camera.

- You may have done some photo editing.

- Terminology in this lecture may be brand new.
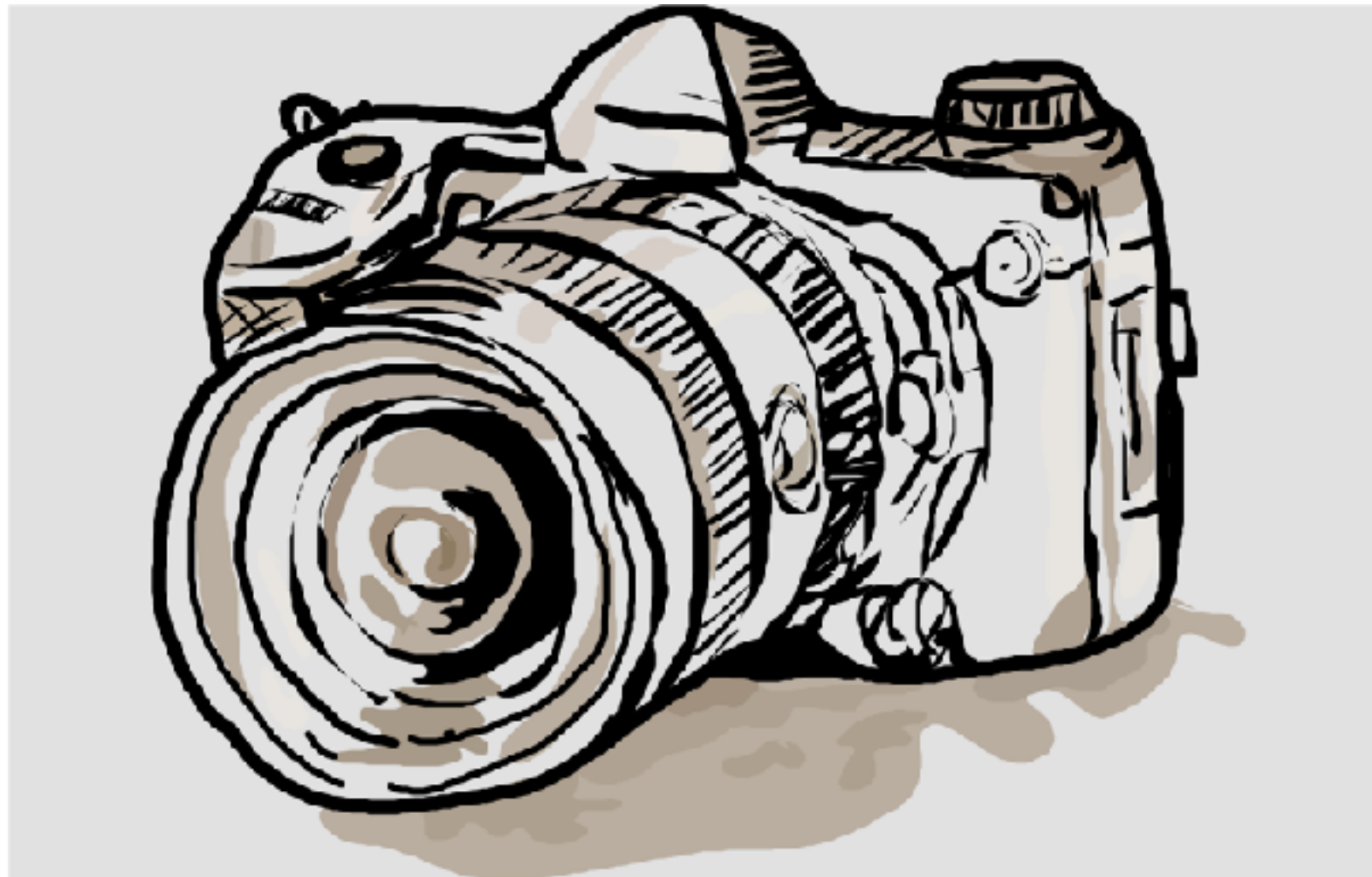
Things to Think About

- What are the data objects in a Pixel Graphics program?

- Is there more than one way to do any given task?

- What are the deficiencies of the interface?

- What are the efficiencies of the interface?

What *is* "Pixel Graphics?"

Everything you see on the screen is composed of "pixels"

- imagine the screen as a piece of graph paper

- draw an object by colouring in squares

    "painting" with a "brush" (ie the "tracker")

- the squares are called "pixels"

- "pixel" is short for PICture ELement (from "pix" for picture)
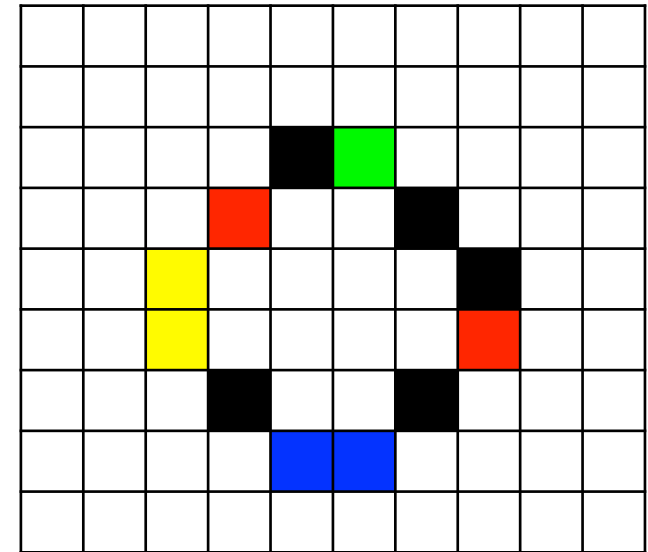
Each pixel (usually) has

- a red intensity (0...255)

- a green intensity (0...255)

- a blue intensity (0...255)

— vary these to get a variety of colours
Thus typically $0 \leq R, G, B \leq 255$

- 255 is the largest integer that fits in a byte (character) of memory

EVERYTHING displayed is represented by a pattern of pixels

A piece of my Dell 2001FP LCD at 50x.

For more information on how LCDs — and CRTs — actually work, see

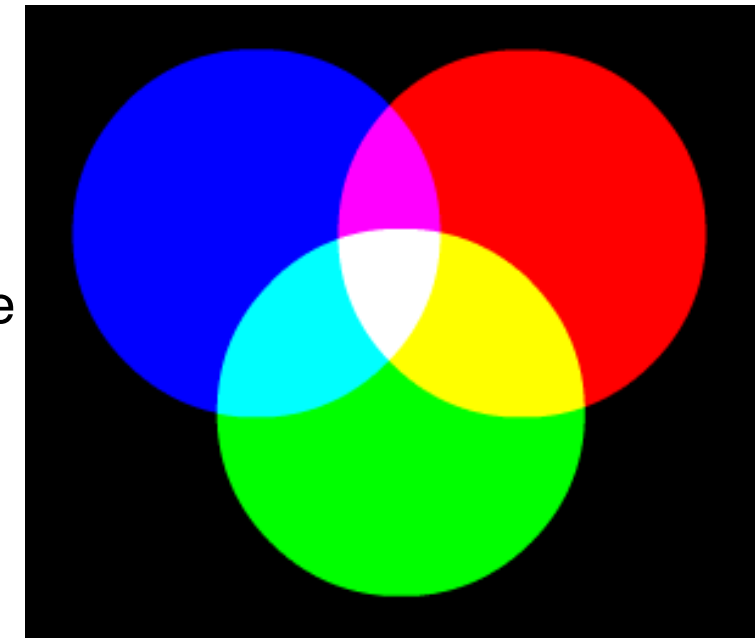*http://www.bit-tech.net/hardware/2006/03/20/how_crt_and_lcd_monitors_work/3.html*

or Wikipedia
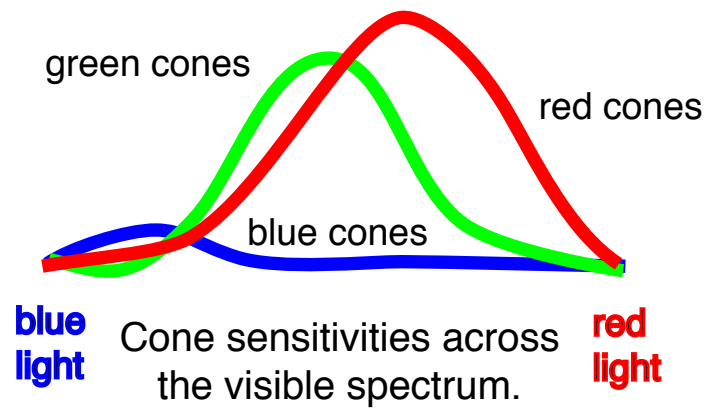
Why does pixel graphics work?

RGB-based colour is "additive colour"

As distinct from the "subtractive (CMY-based) colour"
you may have seen in an art class

Additive colour is based on the red-, green-, & blue-sensitive "cones" in your eye
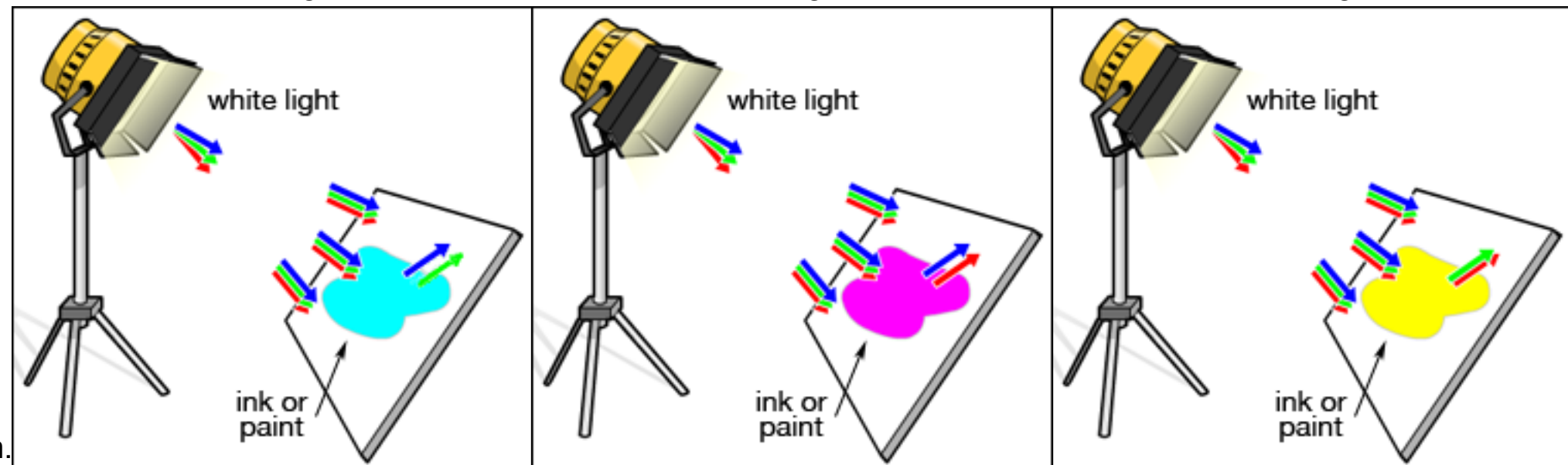
red, green and blue are said to be the "primary colours"

Additive Colour — eg an LCD

green cones

red cones

blue cones

blue light   Cone sensitivities across   **red light**
the visible spectrum.

Subtracting Red | Subtracting Green | Subtracting Blue

white light | white light | white light

ink or paint | ink or paint | ink or paint

"Subtractive Colour" — eg printing
(Adapted from www.edumedia.com.

Some facts about additive colour

Some colour facts & terminology

- red + green $\qquad$ = yellow $\qquad$ ie R + G $\qquad$ = Y

- green + blue $\qquad$ = cyan $\qquad$ ie G + B $\qquad$ = C

- red + blue $\qquad$ = magenta $\qquad$ ie R + B $\qquad$ = M

- for us, yellow, cyan and magenta are said to be "secondary colours"

- red + green + blue $\qquad$ = white $\qquad$ ie R + G + B = W

The "Colour Wheel" — a model for mixing colour
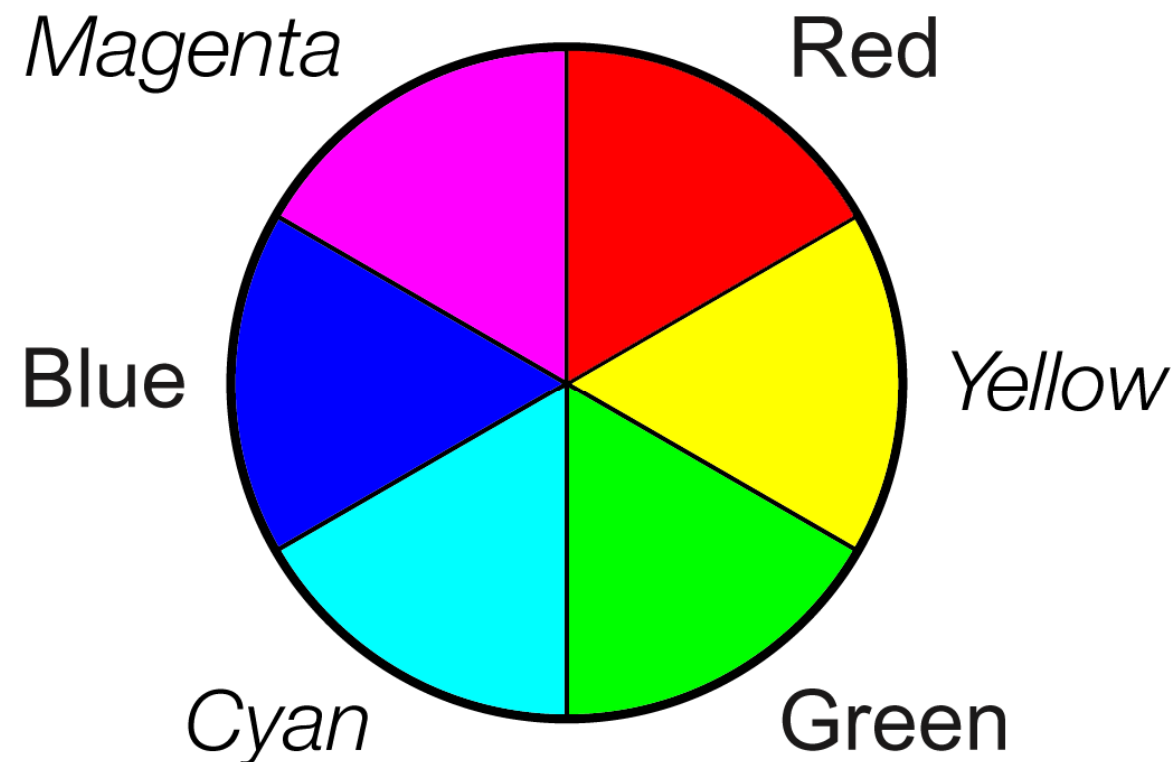
More facts about additive colour

Therefore: white – blue = red + green = yellow (etc)

"nothing" is black, represented by K (because B is already taken for blue...)

"equal" amounts of red, green and blue combine to form grey

"hue" is what we usually think of as "colour"
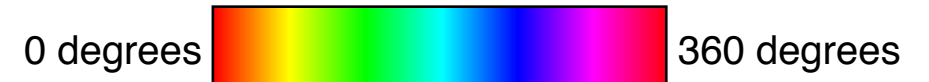
    as in reddish, greenish, etc

0 degrees   360 degrees

"saturation" refers to how "pure" or "vivid" the colour is

    ie how much a colour departs from gray

0 %   100 %

"brightness," "lightness," & "luminance" refer to overall intensity

0 %   100 %

you can specify colour in terms of hue, saturation, & brightness

there's an arithmetic transformation between the two

similarly for cyan, magenta and yellow, the (subtractive printing primaries)
or CMYK (printing with the four inks cyan, magenta, yellow and black gets better results)

A Hue, Saturation & Brightness Model for Mixing Colour

In Gimp

- click on foreground or background colour in the Tools Palette
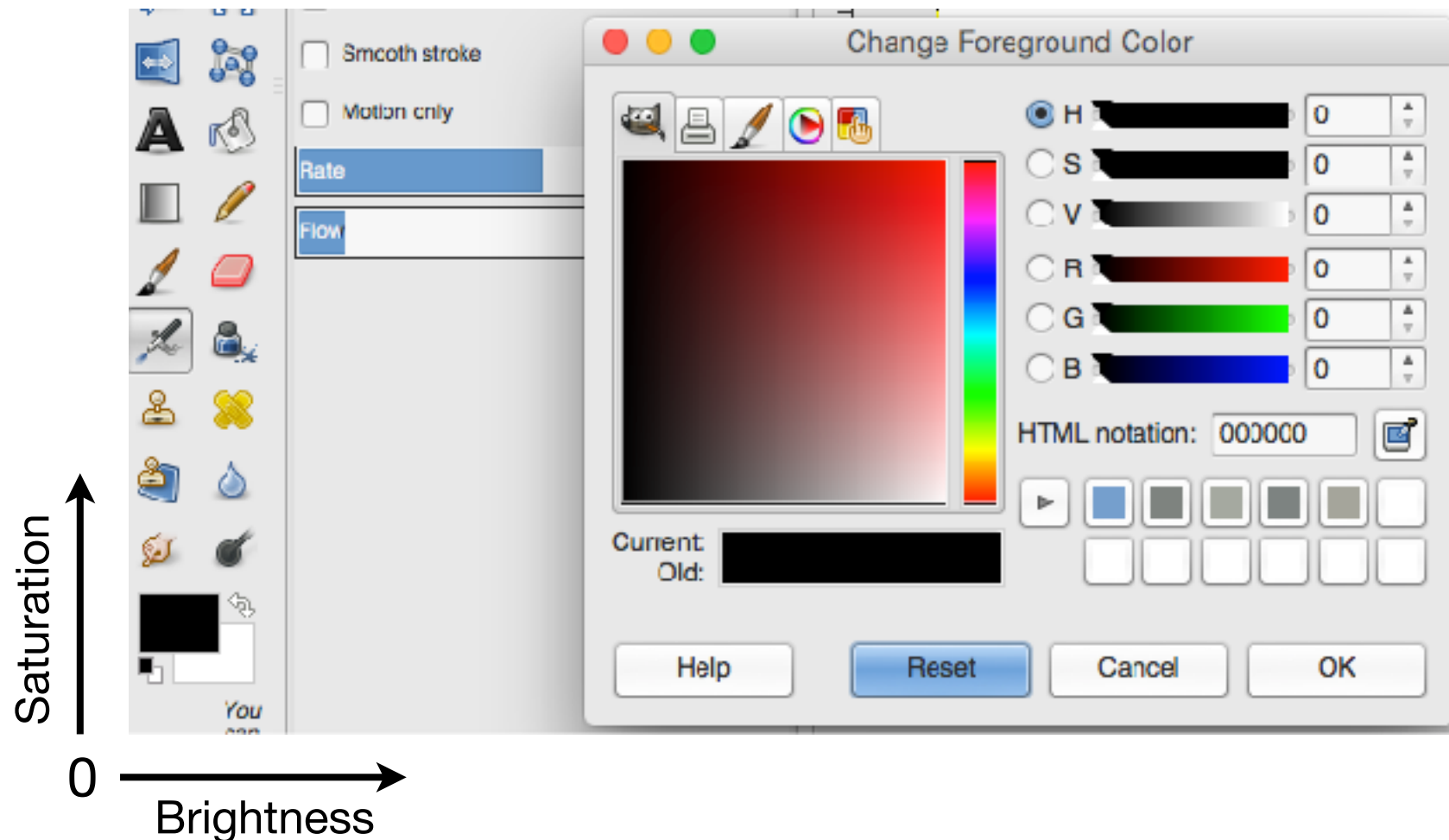
  "paint colour" = "foreground colour"

  "paper colour" = "background colour"

Desaturate by moving down, saturate by moving up

Darken by moving left, brighten by moving right

Click on the spectrum to change the hue

Or ... type R, G, B or H, S, B values into the text edit boxes

2 ^{N} Patterns for N Bits

1 bit
0
1

2 bits
0 0
0 1
1 0
1 1

3 bits
0 0 0
0 0 1
0 1 0
0 1 1
1 0 0
1 0 1
1 1 0
1 1 1

4 bits
0 0 0 0
0 0 0 1
0 0 1 0
0 0 1 1
0 1 0 0
0 1 0 1
0 1 1 0
0 1 1 1
1 0 0 0
1 0 0 1
1 0 1 0
1 0 1 1
1 1 0 0
1 1 0 1
1 1 1 0
1 1 1 1

5 bits
0 0 0 0 0
0 0 0 0 1
0 0 0 1 0
0 0 0 1 1
0 0 1 0 0
0 0 1 0 1
0 0 1 1 0
0 0 1 1 1
0 1 0 0 0
0 1 0 0 1
0 1 0 1 0
0 1 0 1 1
0 1 1 0 0
0 1 1 0 1
0 1 1 1 0
0 1 1 1 1
1 0 0 0 0
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1 0 1 1 1
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1 1 0 1 1
1 1 1 0 0
1 1 1 0 1
1 1 1 1 0
1 1 1 1 1

Typical Display "Resolutions" ("Addressability" Would Be Better)

"Spatial Resolution"

- h × v: eg   1024 × 768,   1152 × 870,   1280 × 1024,   1600 × 1200,   2048 × 1536

- h = horizontal, v = vertical

- pixels per inch (aka dots per inch, or dpi) is then determined by the screen's actual size

"Pixel Resolution" (bits per pixel)

- 24 bits per pixel — 8 for red, 8 for green, 8 for blue

    8 bit => 256 different values (intensities), so

    256 reds × 256 greens × 256 blues

    = 16,772,160 combinations — "millions" of colours in Apple-speak

    = "true colour" in Microsoft-speak

- 16 bits per pixel — 5 for red, 5 for green, 5 for blue

    5 bits => 32 different values (intensities), so

    32 reds × 32 greens × 32 blues

    = 32,768 combinations — "thousands" of colours in Apple-speak

    = "high colour" in Microsoft-speak

- 8 bits per pixel — is different: 256 "colour numbers" defined elsewhere in a "colour table" or "palette"

    each pixel consists not of an (R,G,B) triplet of intensities, but instead specifies an entry in the colour table
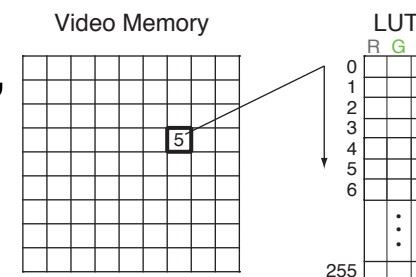
Changing Display Settings on a Mac

Lets you choose

- ~~between grayscale and colour~~

- how many pixel bits to use ("colour depth")

- among available spatial resolutions & "display rates"

The higher the resolution, the longer it takes to scroll

- more bits to move around in display memory!

For Windows

- use the Settings tab in the Display control panel

Multiple displays (both Mac & Windows now)
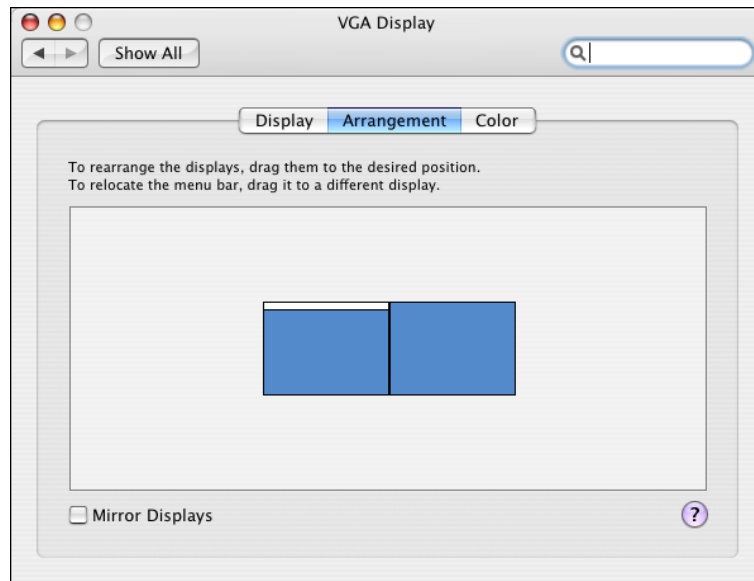
> System Preferences > Displays
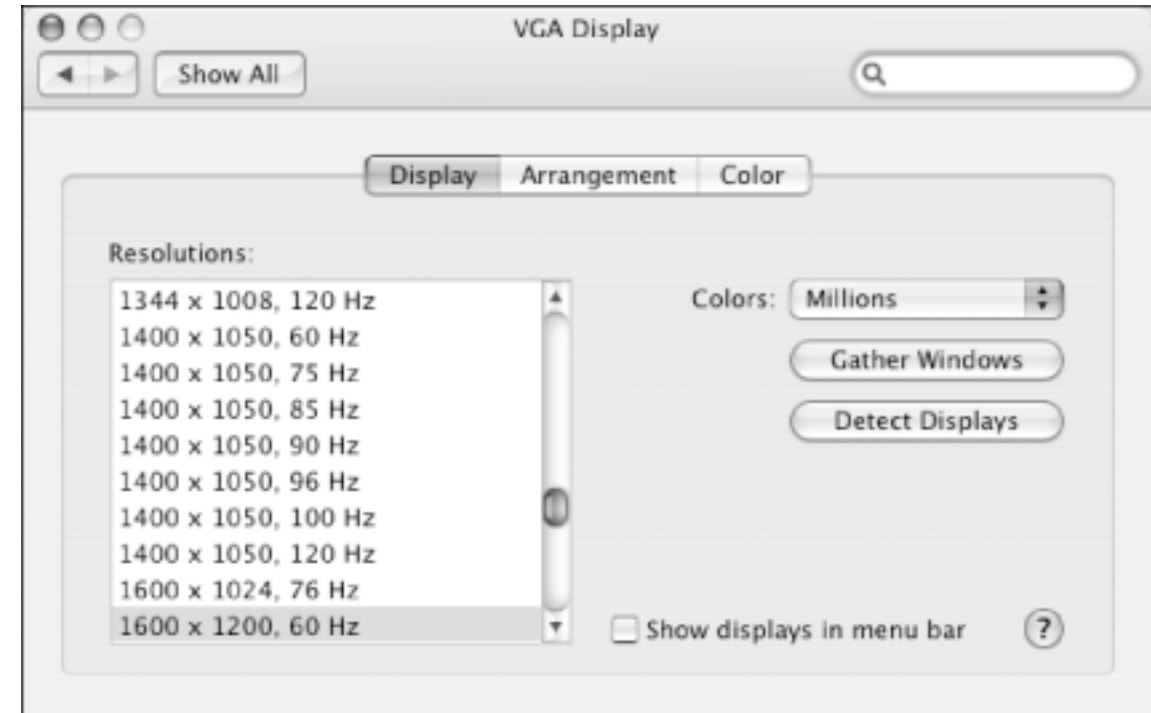
> Settings > Control Panel > Display
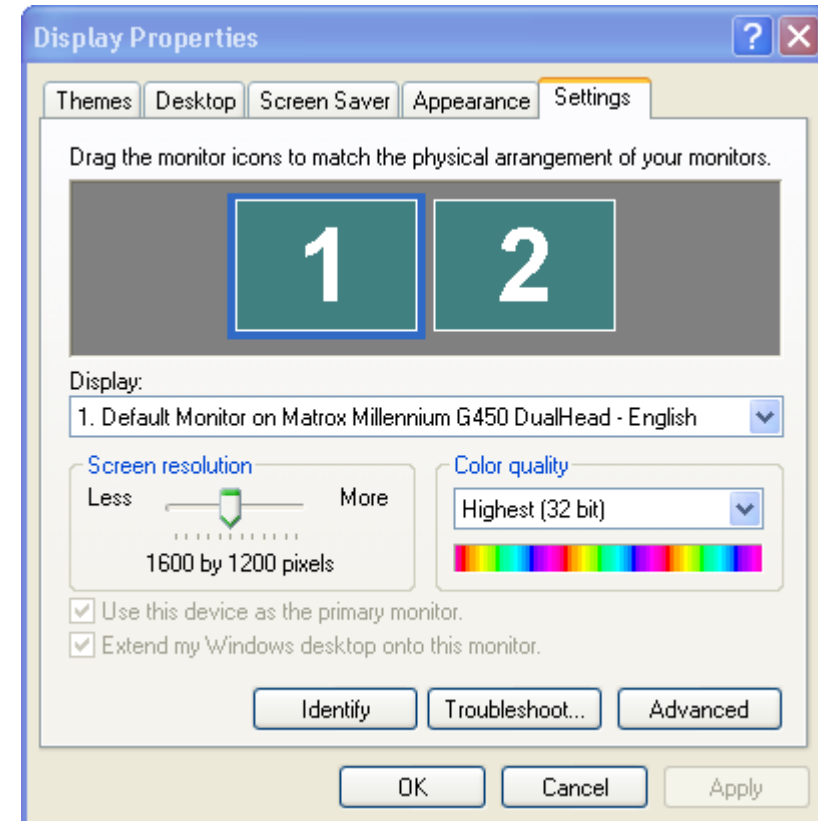
Pixel Graphics File Formats

Stored paintings/images are large
and take a long time to transmit over the internet

- 640 x 480 x 3 bytes = 0.92 Megabytes

    roughly analog TV resolution

- 1280 x 1024 x 3 bytes = 3.75 Megabytes

- 1600 x 1200 x 3 bytes = 5.76 Megabytes

- If you scan an 8.5" by 11" page in colour at 300 dpi ...

    2550 x 3300 x 3 bytes = 22.275 Megabytes

So often you compress them

There are lots of different file formats for storing pixel images

- of varying appropriateness for different kinds of images

- some reflect different compression techniques

- others reflect a programmer's choice

Some Common Graphics File Formats (1)

GIF (Graphics Interchange Format)

- common on the internet (the "original" internet format)

- "loss-less compression"

- 8-bit colour only, & supports simple animation

  each "8-bit colour" actually refers to an entry in a separate 256-entry "colour table" that defines each colour to be some particular 24-bit (R,G,B) triple

- was licensed by Unisys, and use required a fee (paid by the software vendor; included in the purchase price of software) — however, the patent expired in 2004
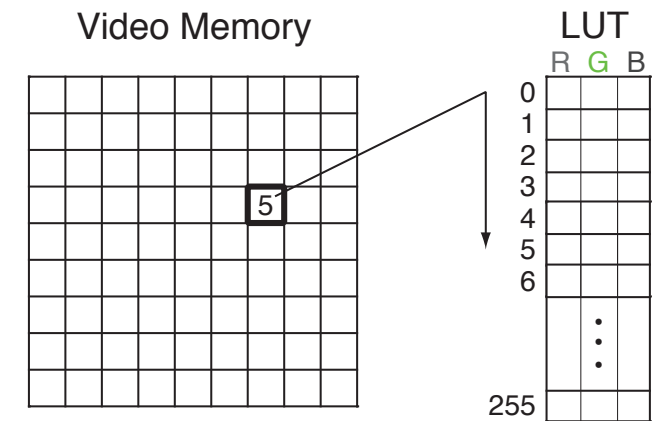
PNG (Portable Network Graphics)

- invented in 1996 because of the GIF licensing fee

- true-colour capable

- loss-less compression

- very flexible & cross-platform, but no animation (which GIF supports)

- current and recent browsers support it; really old browsers didn't (eg IE 3)

JPEG (Joint Photographic Experts Group, aka JPG)

- true-colour

- supports "lossy compression;" variations trade smaller file size for loss of detail

PNG vs JPEG Example (1) — Actual Size

The original "raw" data: 1,350 KB becomes an 887 KB **png** file. (1.5x)
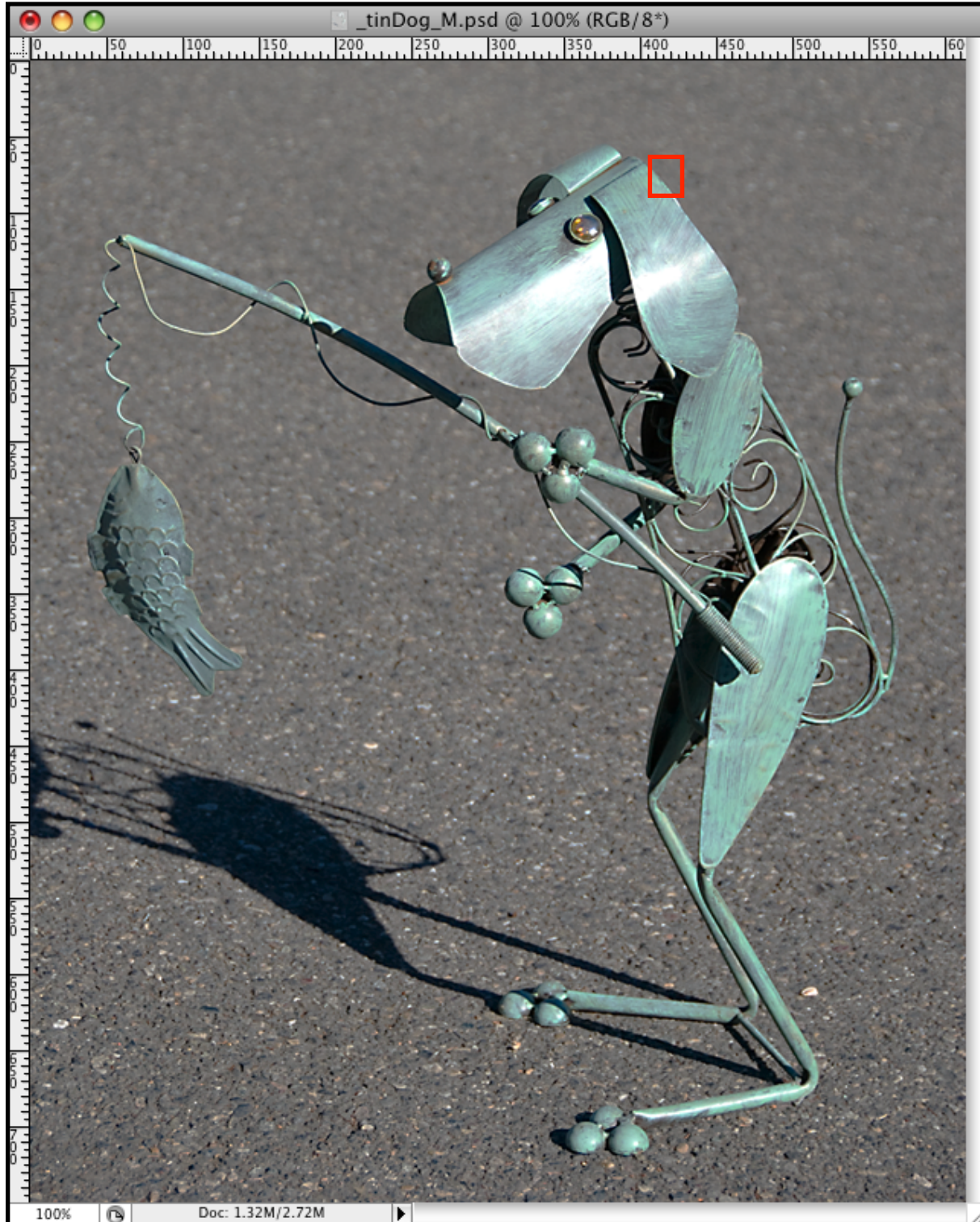
The same data as a "lowest quality" 56 KB **jpeg** file. (24x)
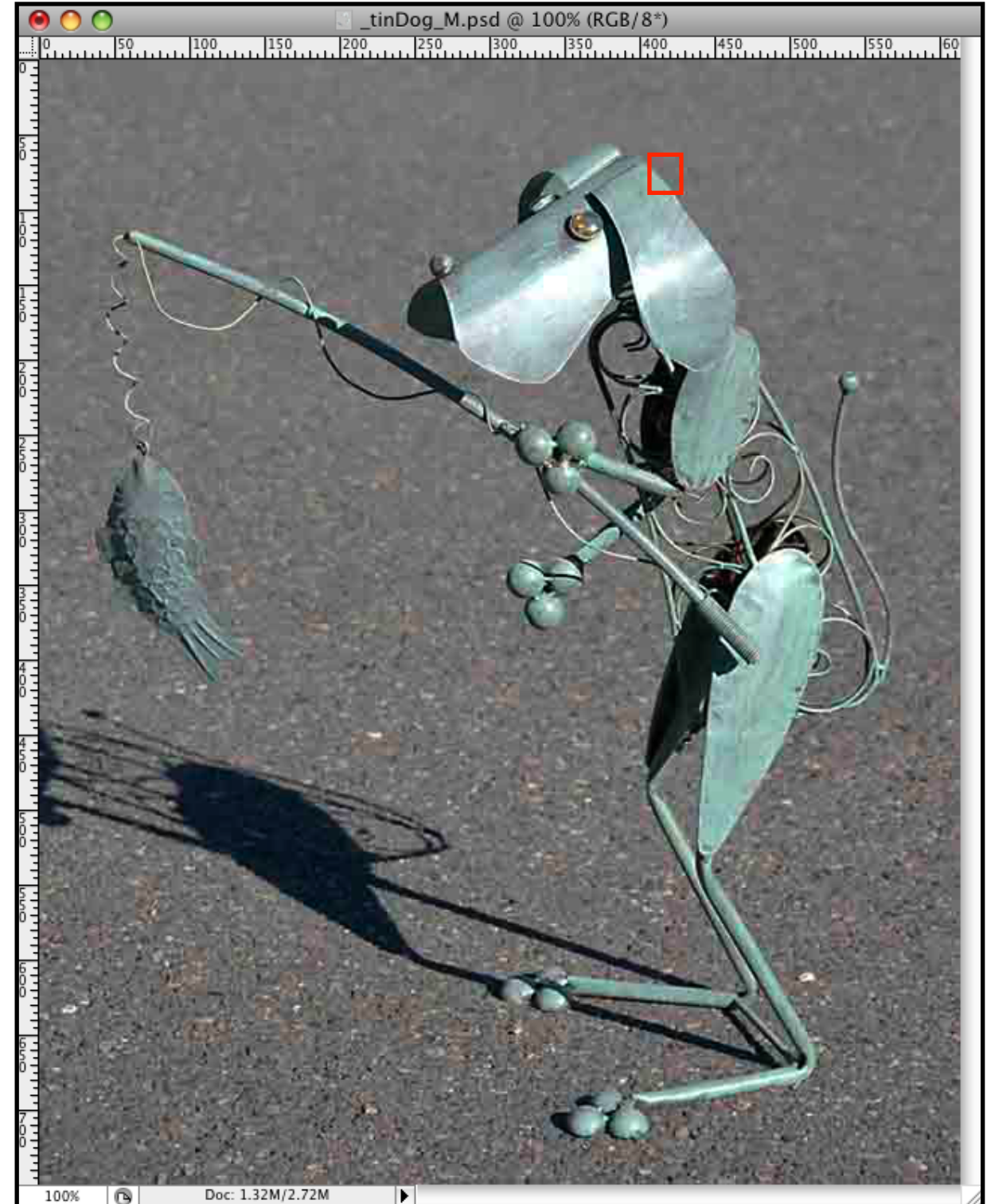
PNG vs JPEG Example (1) — The Selected Area Zoomed 2885 %

The highlighted raw pixels
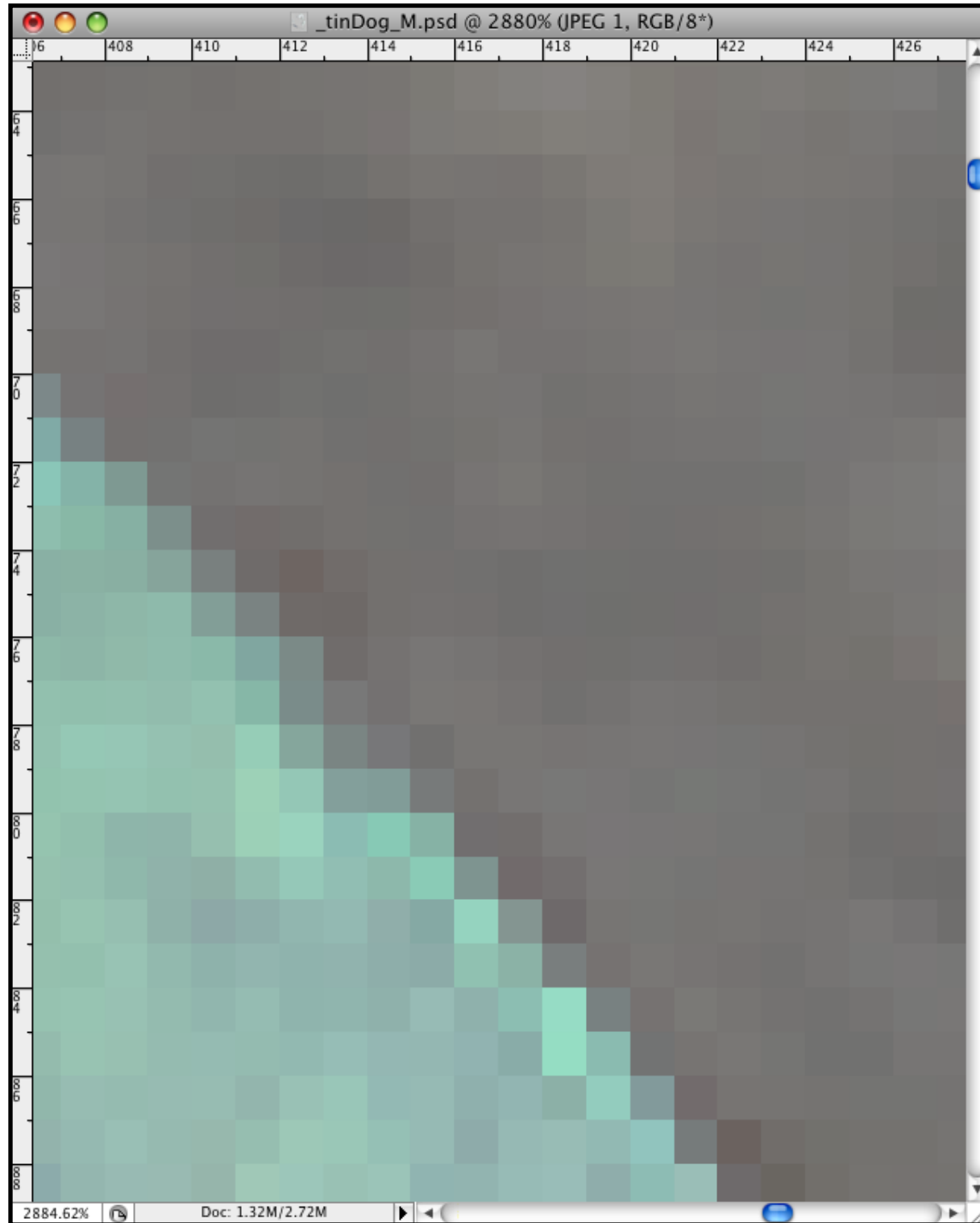
The highlighted jpeg-compressed pixels
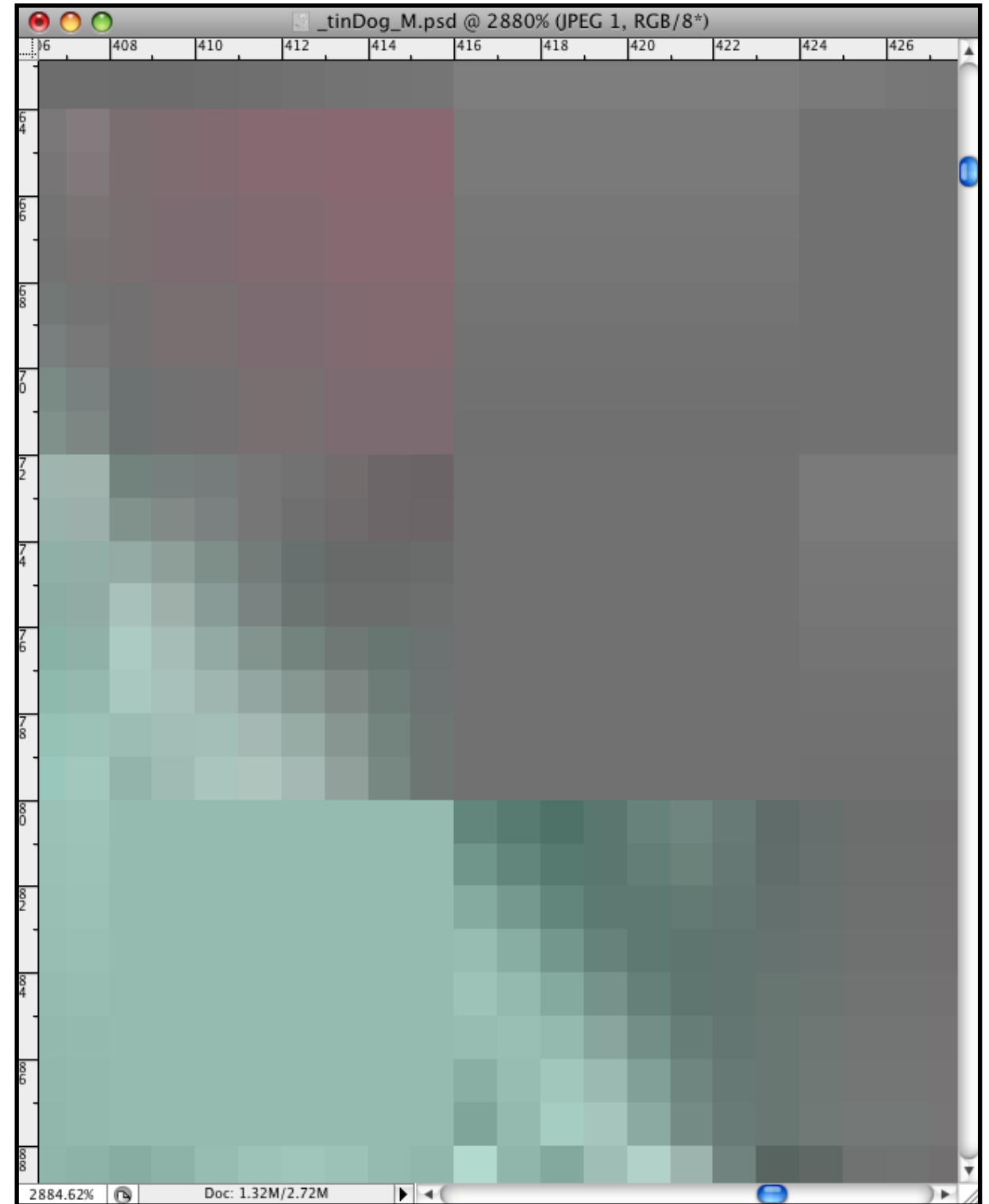
PNG vs JPEG Example (2)

The original – a perfectly sharp boundary.
219 KB of raw data;
728 bytes of **png**-compressed data. (**309x**)
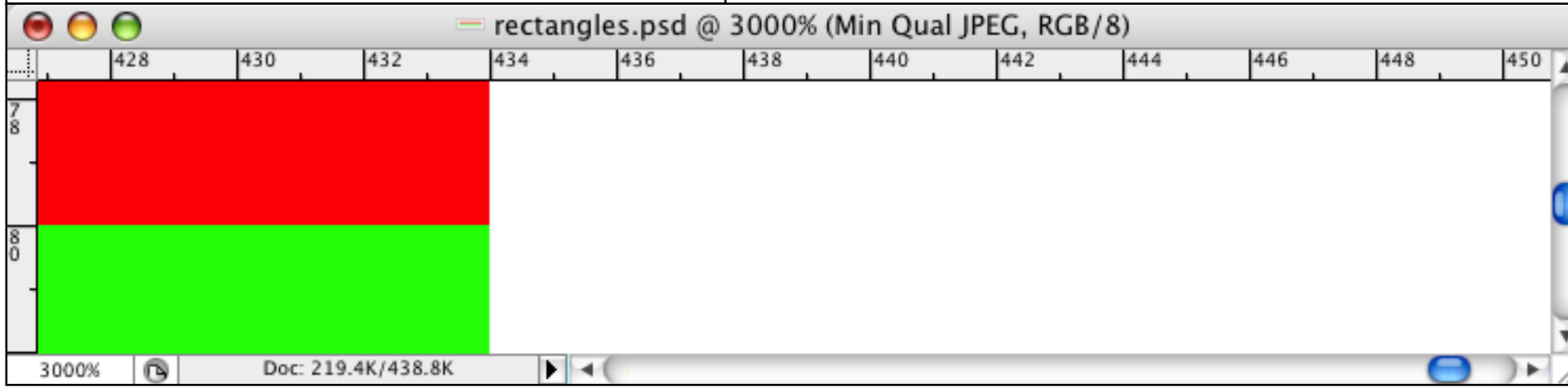
Minimum jpeg quality - border artifacts.
219 KB of raw data;
2,500 bytes of **jpeg**-compressed data. (**89x**)
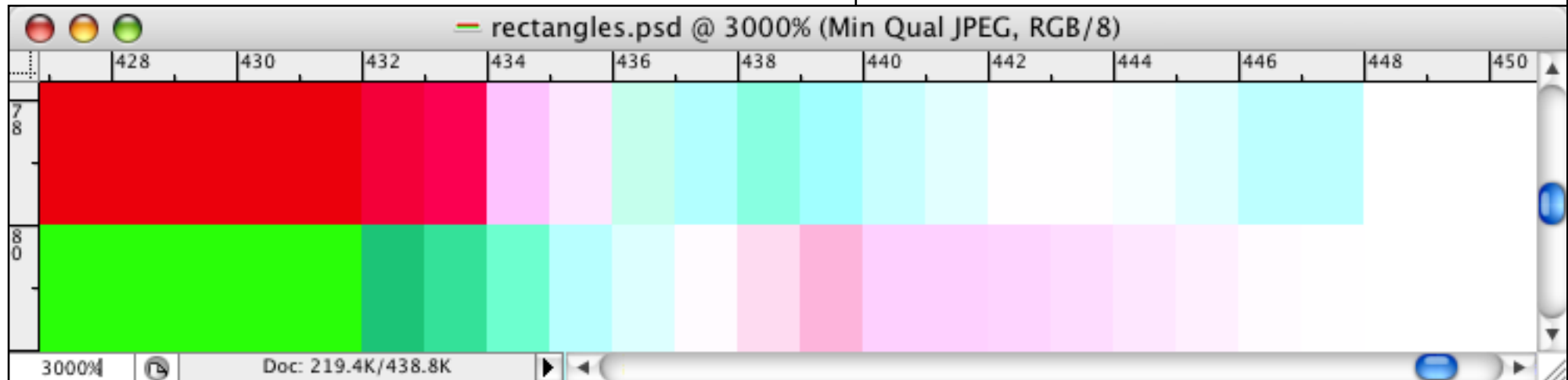
Some Common Graphics File Formats (2)

TIFF (Tagged Image File Format)

- both 8-bit & true-colour

- loss-less compression

- a cross-platform standard

- some browsers don't support

BMP (Windows Bitmap)

- both 8-bit & true-colour

- loss-less compression

- standard Windows format

"Raw" digital camera format

- just the RGB pixel intensities measured by camera
  (as distinct from JPEG, which is always an option)
  and w/o in-camera image processing (eg noise reduction)

- the file format produced is typically proprietary, however

Final words

- *"Different file format" means "the bit representation of the data is different."*

- *Renaming foo.png to foo.jpg doesn't change the file's format.*

Pixel Graphics with Gimp — Painting (1)

The tools palette ➡

You "paint" by click-dragging the mouse

- which controls a "brush" (the tracker) (Paintbrush Tool)
- whose width, shape, colour, etc, you control
  - (see "Paintbrush Tool" in online Help)

As you move the mouse

- pixels over which the brush passes are modified
- may be completely replaced by the brush colour
- may be combined with the brush colour
  - — in Adobe-speak, according to the painting "mode"

A hard, opaque brush

A hard, semi-transparent brush

A soft (50%), opaque (50%) brush

A soft (50%), semi-transparent (50%) brush

applies the "Paint" colour (aka the "foreground" colour)

erases to the "Paper" colour (aka the "background" colour)

(Bucket Fill Tool) pours the "Fill" colour (which is, in fact, the current foreground colour)

Both and are applied with a brush you can reshape

How do you select a Paint / Paper / Fill colour?

The options panel

Paintbrush
Mode: Normal
Opacity   50.0
Brush
2. Hardness 050
Size   44.43
Aspect Ratio   0.00
Angle   0.00
Dynamics
Pressure Opacity
Dynamics Options
Apply Jitter
Smooth stroke
Incremental

The brush tool

The foreground colour

Pixel Graphics with Gimp — Painting (2)

Brush "transparency" (the reverse of "opacity")

- the percentage of what's underneath that shows through

"Wet" or "soft" edges

- ~ transparency is added to the edge of a brush stroke
- 0% for none (a "hard" or "sharp" edge)

Painting or filling a region: use the "marquee tool"

- then you can only paint within the "selected" region
- the remainder of the image is "masked"

"Feathering" a mask by some number of pixels causes smooth blending across the mask boundary; the "number of pixels" controls the width of the blending

To feather a selection, right click and then click Select >
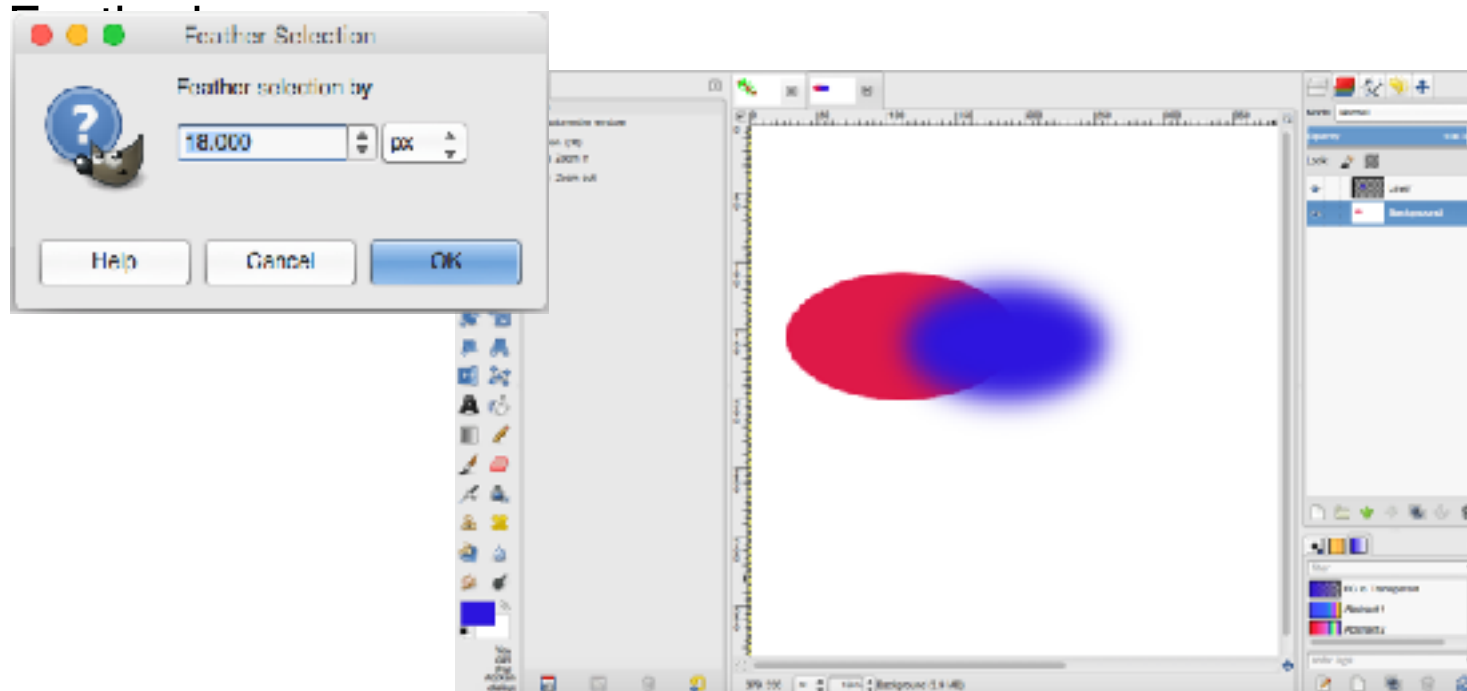
Selection tools

Rectangular Select Tool	▢ ◯	*Ellipse Select Tool*
Free Select Tool		*Fuzzy Select Tool*
Select by Colour Tool		*Scissors Select Tool*

The selection
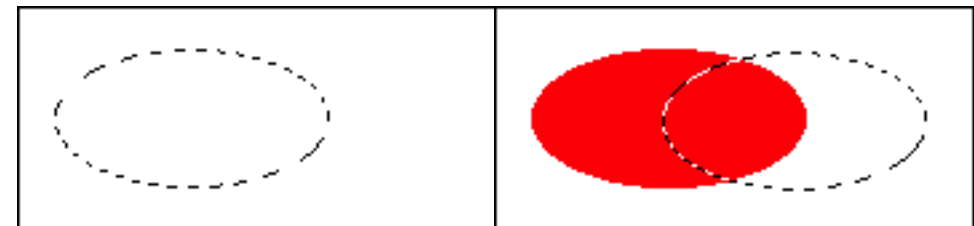
The mask

The fill
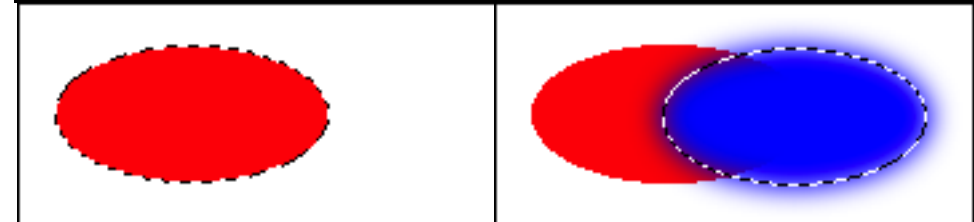
No feathering or anti-aliasing (a hard edge).

A feathered (5-pixel) fill.

Image Manipulation

Examples

- Level (Re)mapping

- Sharpening

- Colour Balance

- Brightness / Contrast

- Hue / Saturation / Lightness

These may be applied

- to the image as a whole

- to a selected portion of the image
  There are a variety of tools and techniques for selecting portions of an image.
  We will mostly use direct rectangular or elliptical selections
  Other useful tools include the "fuzzy select tool" and the "scissors select tool"

For the images used to illustrate these, see

- Learn/ Week 3: Pixel Graphics: Files from Pixel Graphics Lecture

- NB: the manipulations we discuss don't print accurately
  (the "colour matching problem")

Retouching Scanned Images & Digital Photographs

Can be digitally manipulated in many interesting & useful ways

"Retouching" consists of such operations as manually

- moderating highlights
  (eg from flash reflection)

- painting (or cloning)
  over blemishes

- — generally speaking, using a mouse to point to pixels
  that should be altered in some way, often based on the
  color of the pixels underneath the tracker

- perhaps just changing the hue, the saturation, the
  brightness, etc (the painting "mode" again)

Demo!
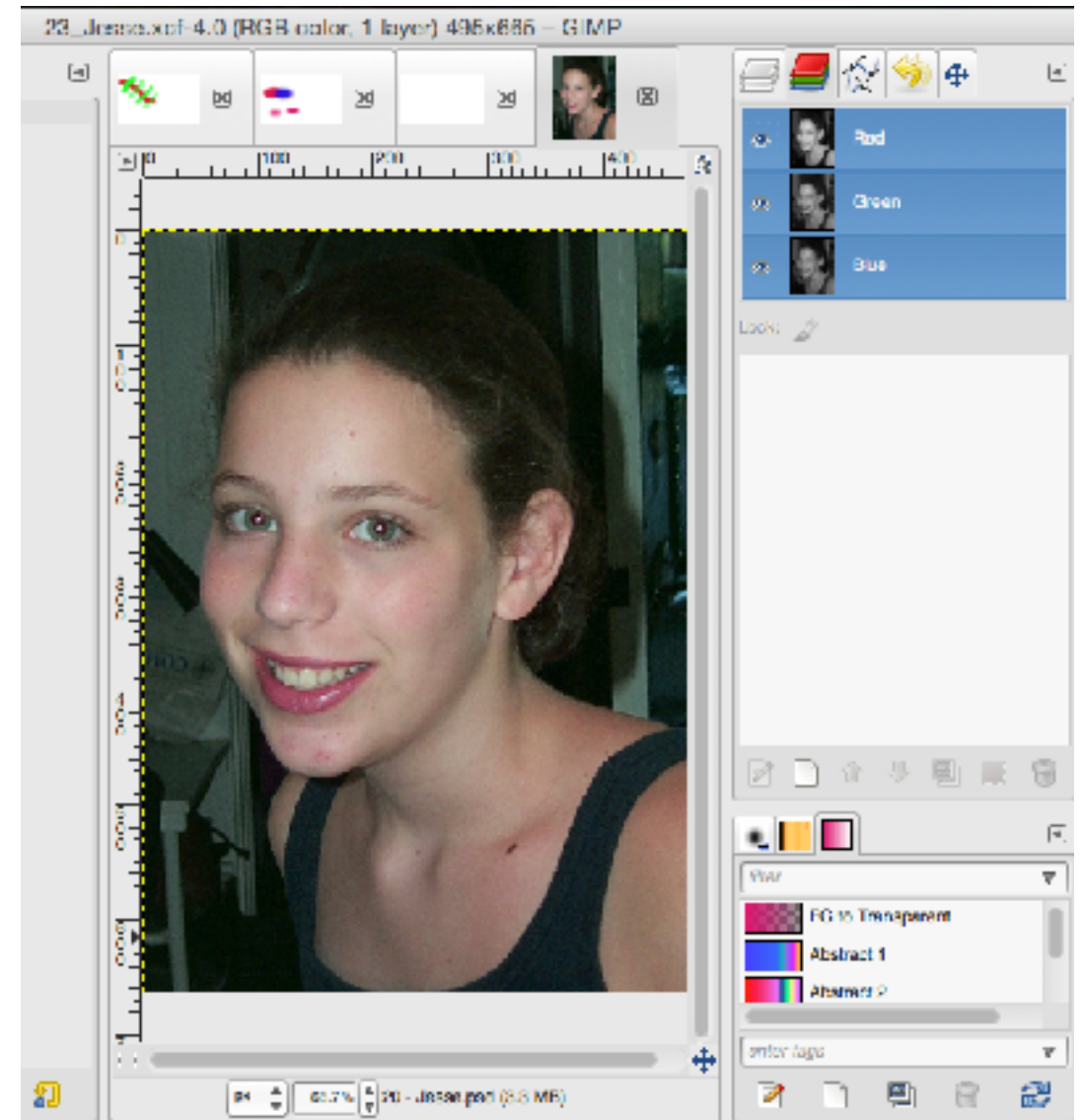
Irrelevant aside: for lot's more interesting stuff about vision & the eye, see
"The Eye—A Natural History," by Simon Ings, $15 at Chapters.
(Ings is an excellent science writer.)

Scanned Images & Digital Photographs (Channels in Color)

Are arrays of pixel intensities

- that come from a scanner or digital camera
- that MEASURES (R,G,B) pixel intensities on a rectangular g
  usually producing one byte (8 bits) for EACH of R, G and B
  at each grid position
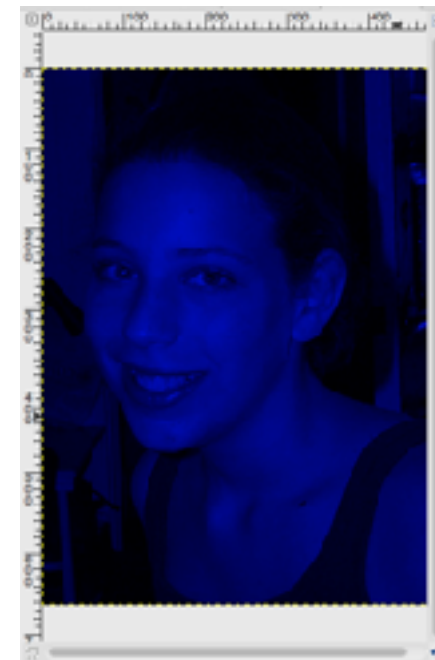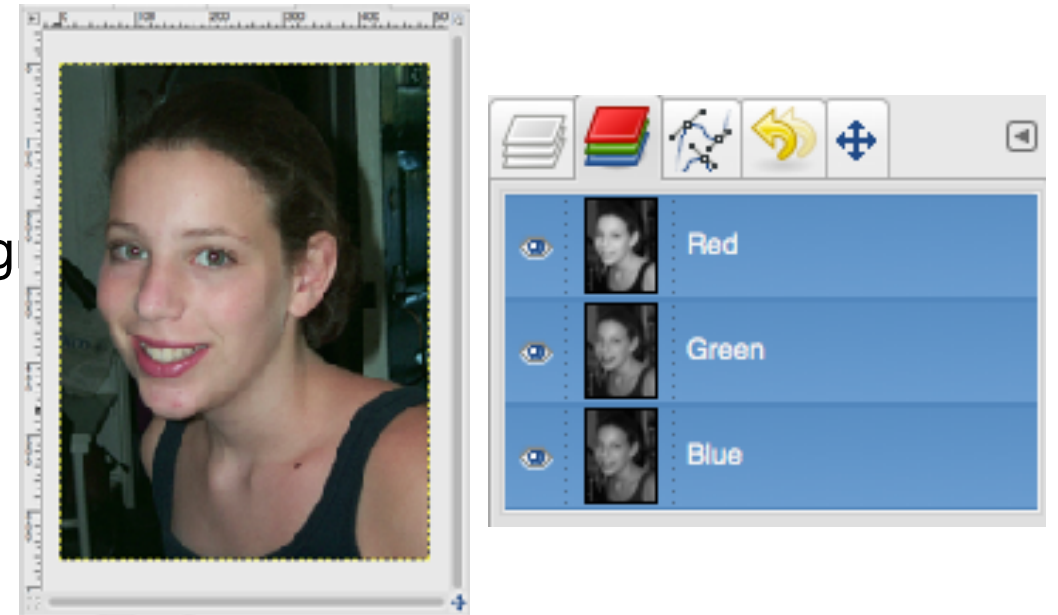
In the rightmost of these three images, which shows only the blue channel, the red and green intensity values at each pixel are temporarily set to zero while generating the display.

The red and green channels are handled similarly.
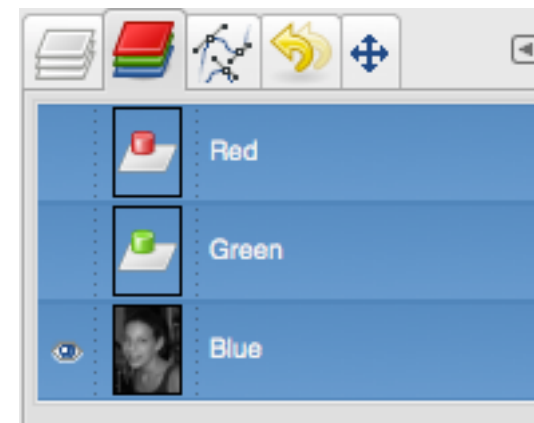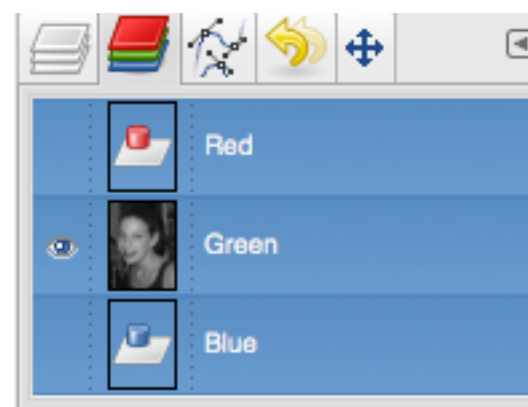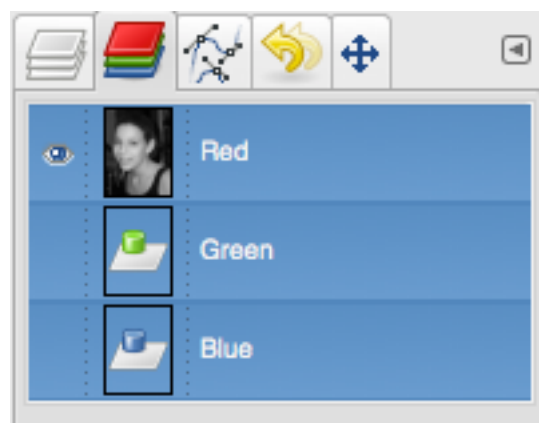
Selections (1)

Recall that a selection

- is a "mask"
- is an 8-bit grey-scale image in which
  - white represents complete selection,
  - black represents no selection, and
  - gray represents partial selection

When you apply color ("paint"), the more fully selected a pixel is, the more paint is applied.

In Gimp you can

- save a selection as a "channel,"
  (*aka* an "alpha channel")

- restore a selection from channel
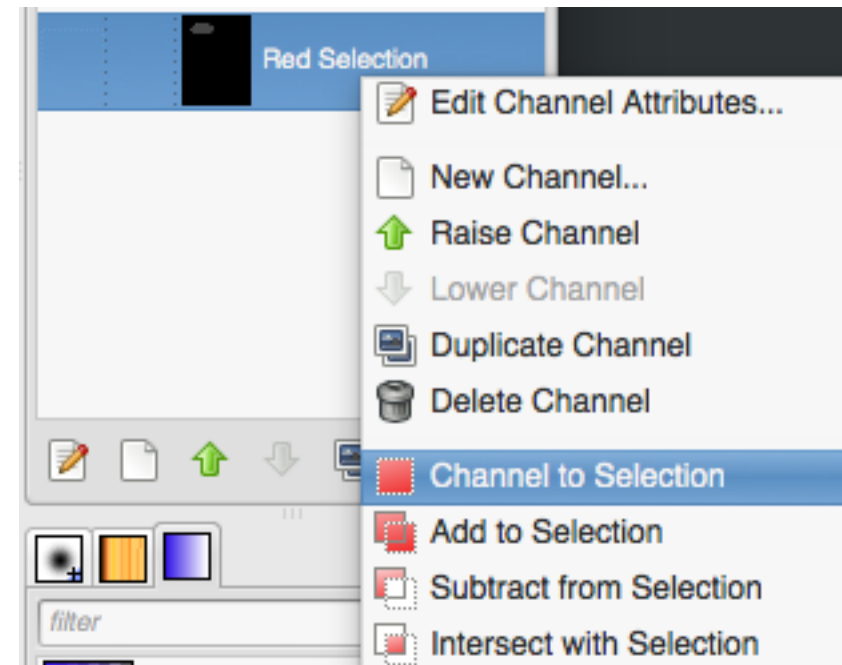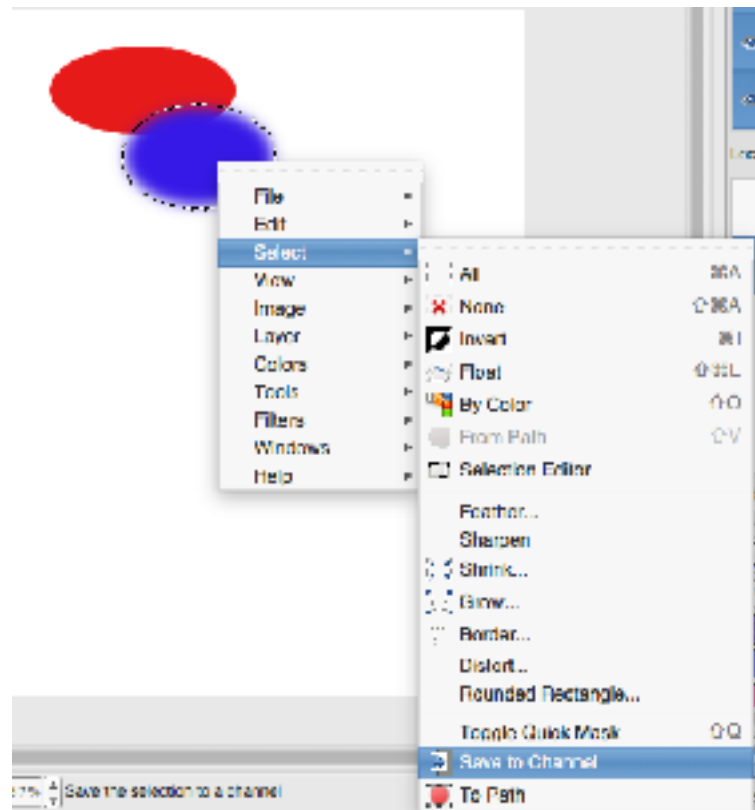
and you can select and manipulate such an alpha channel just as if it were a "normal" image.

There are many ways of creating / editing / manipulating a selection; we will barely scratch the surface.

Selections (2)

The complete image.
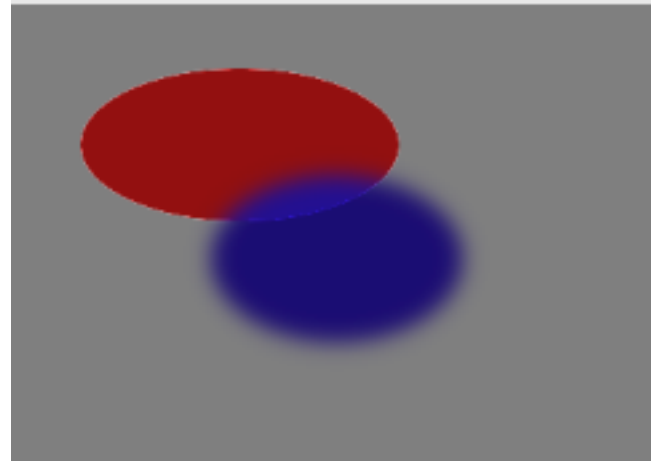
The red selection mask.
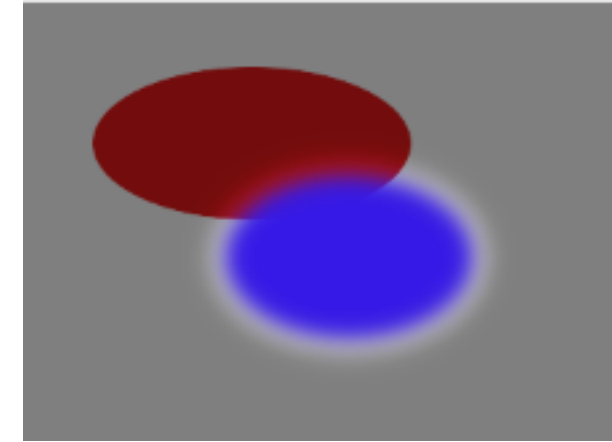
The blue selection mask. Note the gradual transition, which results from feathering.
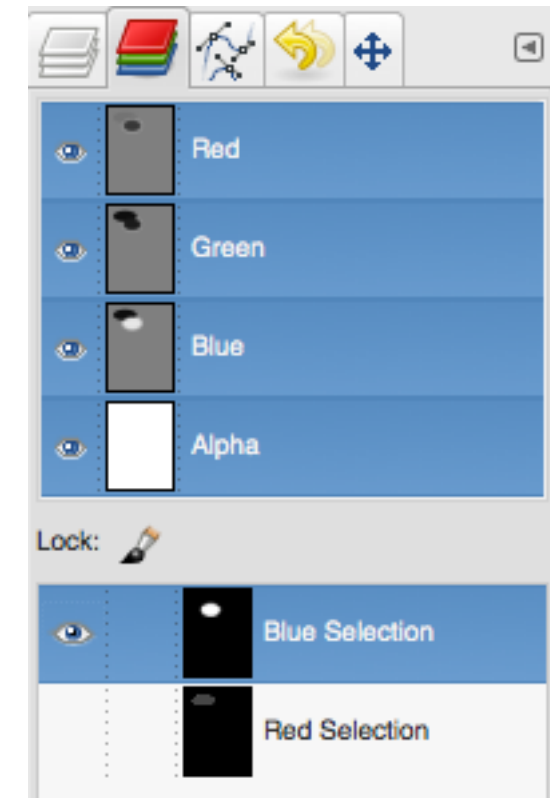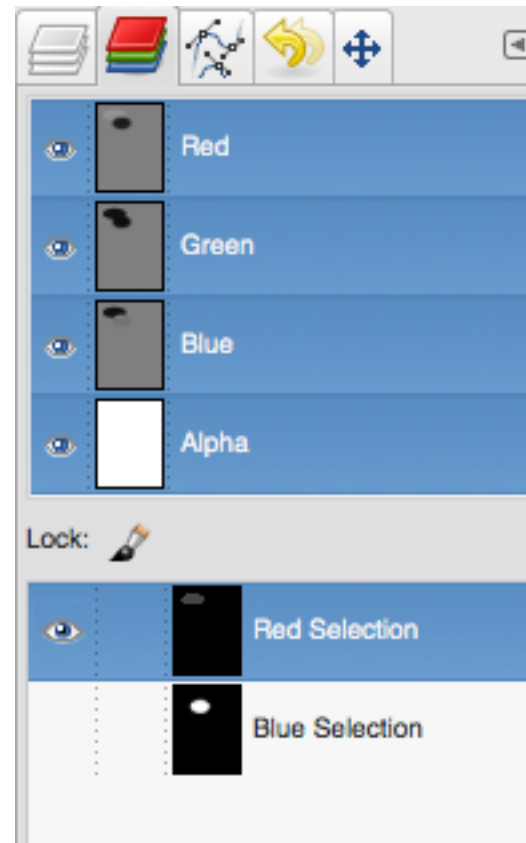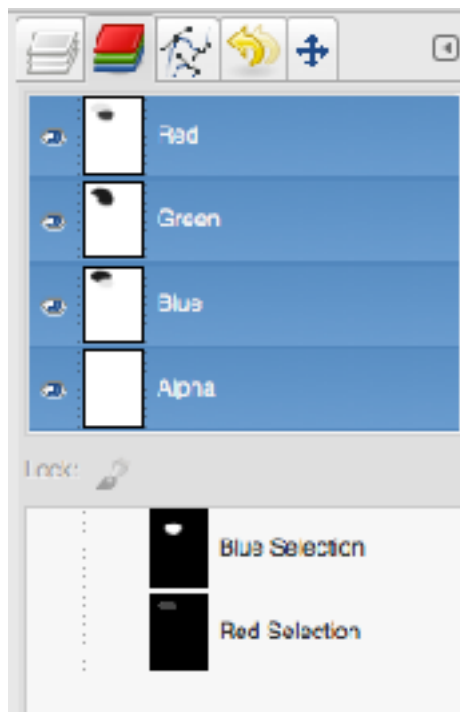
Pixel Histograms

Colors > Levels

The graph plots the number of pixels having each intensity value

How many pixels have that intensity
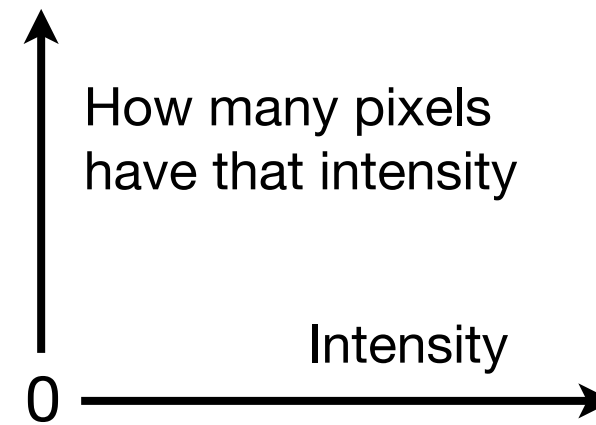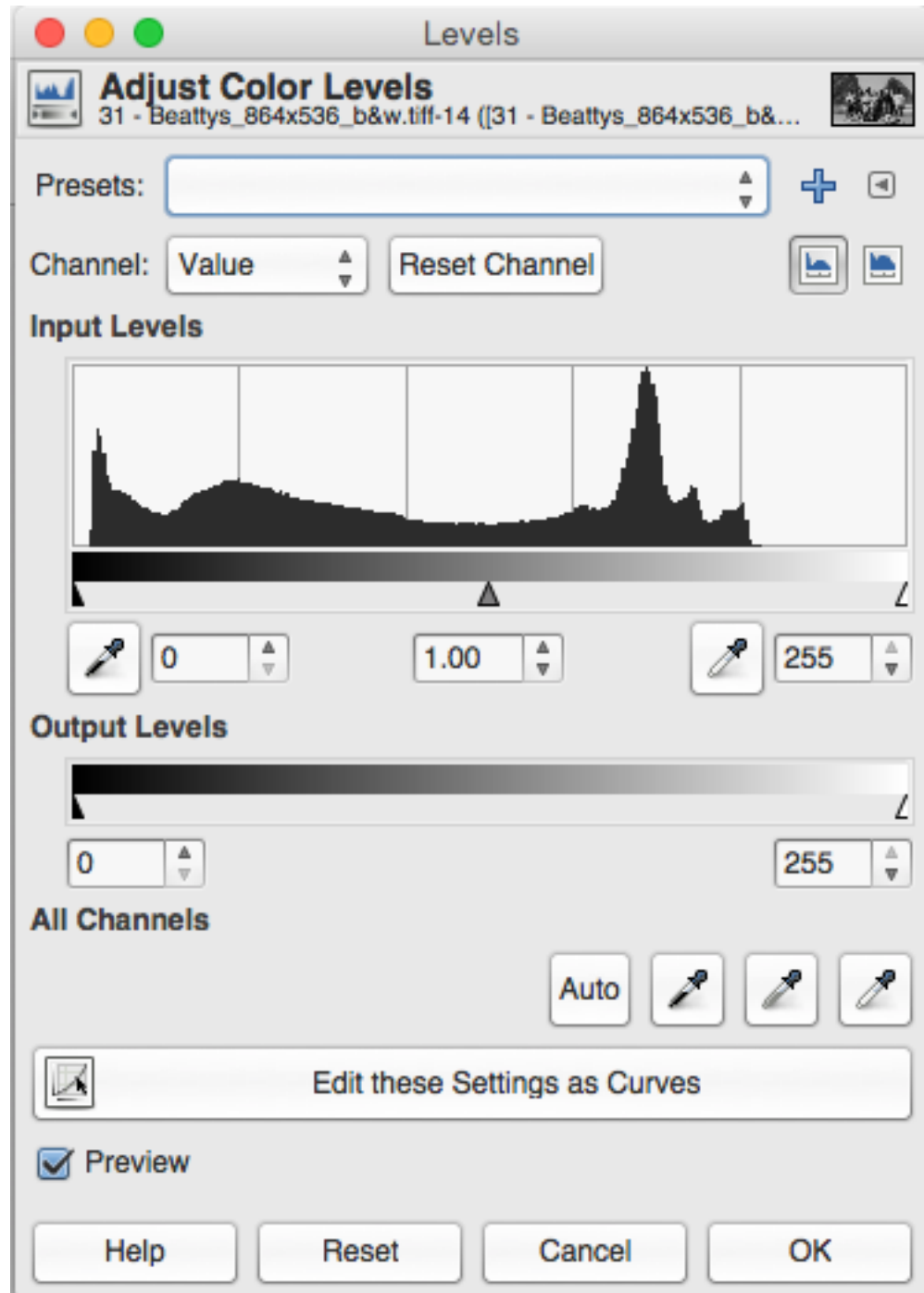
0   Intensity

The Levels Dialog Box (1)

Colors > Levels…

Note the unused values at both ends.

Before
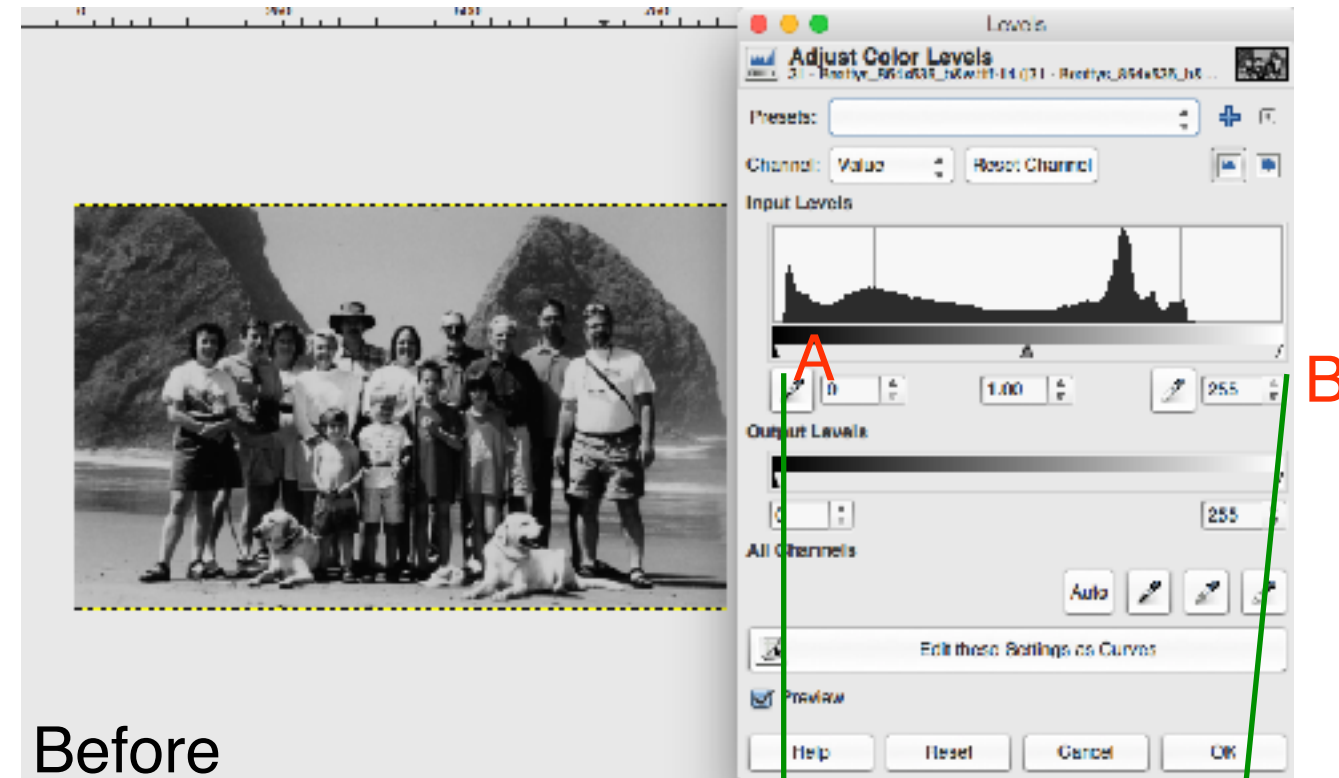
A has been moved right to pixel intensity 7.
B has been moved left to pixel intensity 210.

After
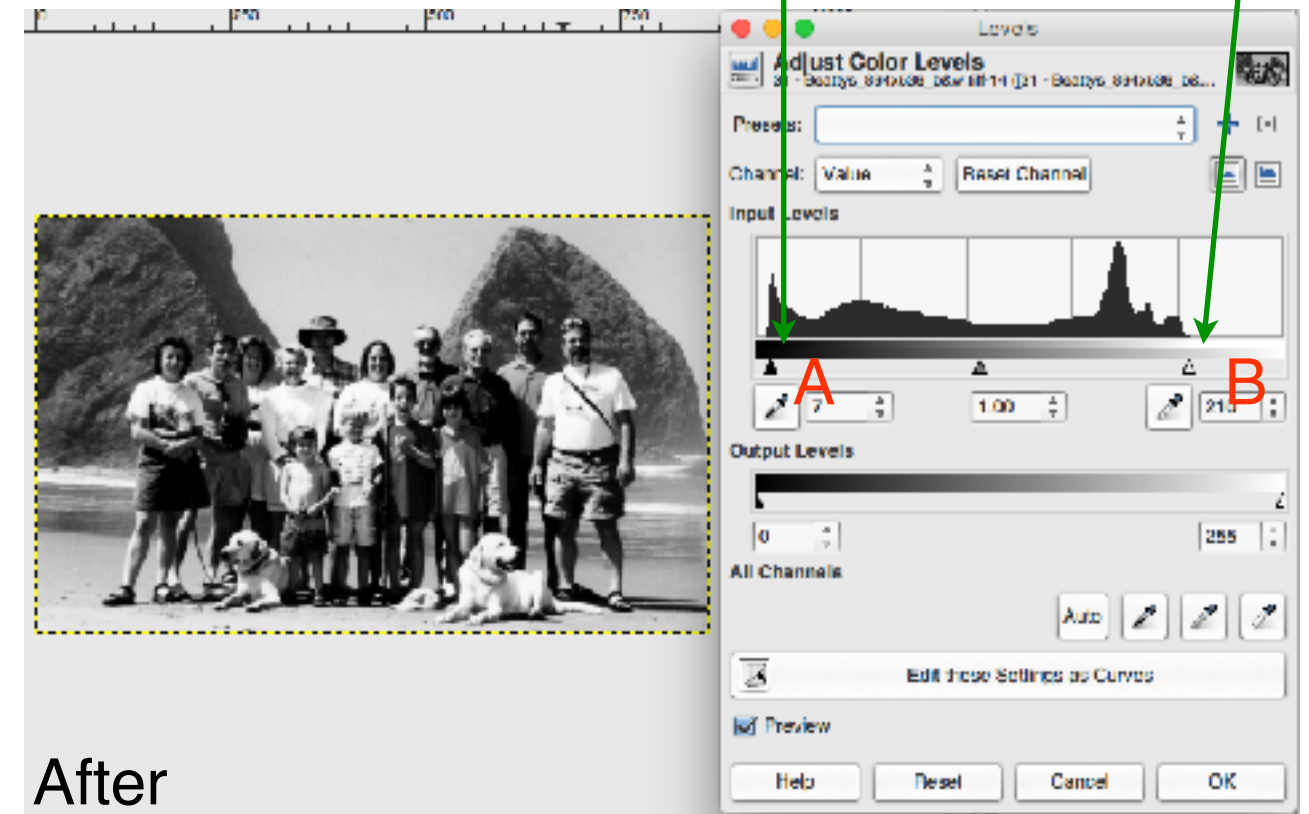
The Levels Dialog Box (2)

The effect of these particular changes to A and B is to use the full range of available intensities

- pixels with intensity 0, 1, ...,7 take on intensity 0
  - blacks become blacker

- pixels with intensity 210, 211, ... 255 take on intensity 255
  - whites become whiter

- pixels with intermediate intensities shift accordingly
  - the graph is "stretched uniformly"
  - In other words, for the image as a whole, there's **more contrast** and **more dynamic range**
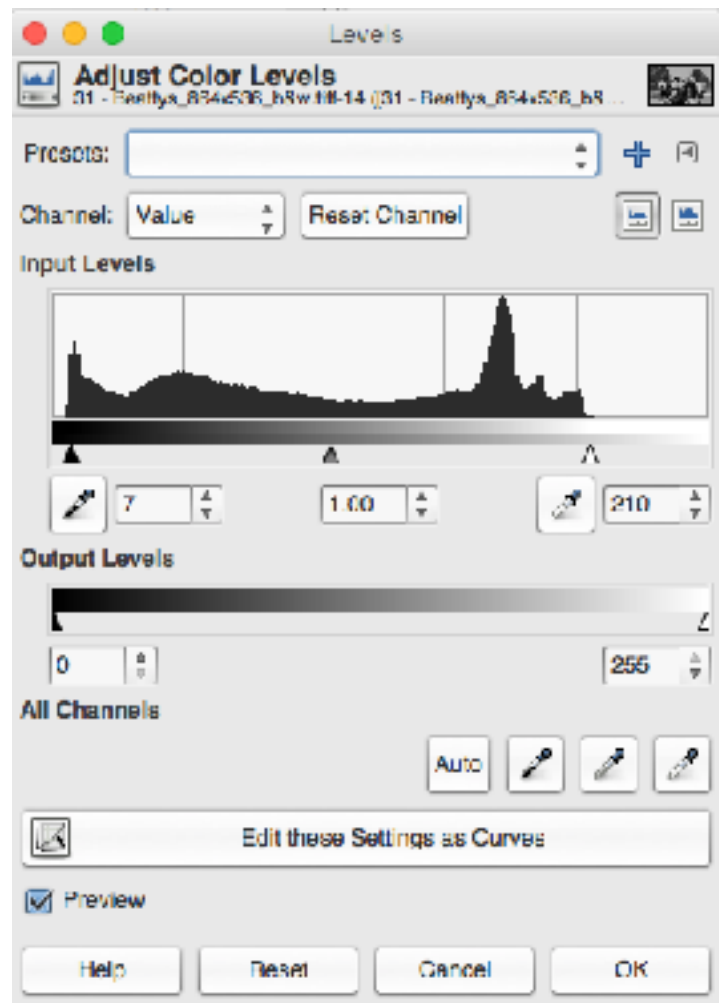
Before

After

Shifting Midtones

Move slider C…

- *left to lighten* intermediate intensities or "midtones"

    "stretch left, compress right"

- *right to darken* intermediate intensities

    "compress left, stretch right"
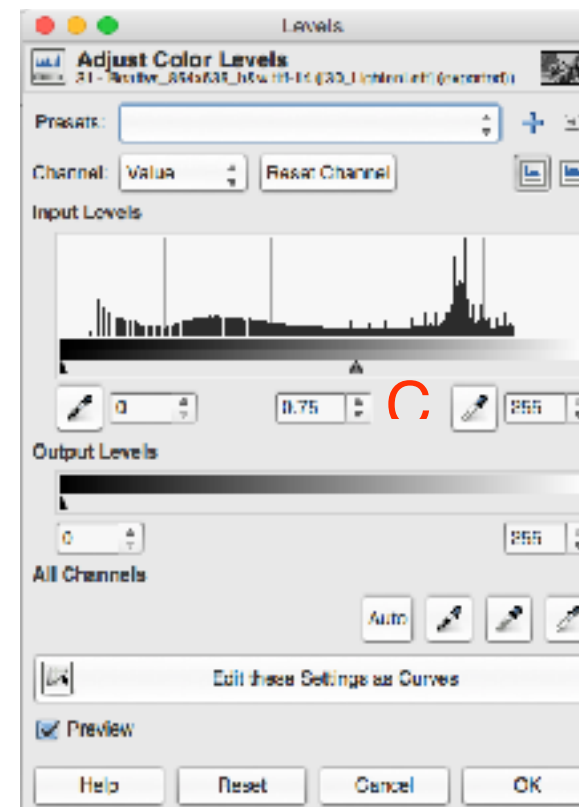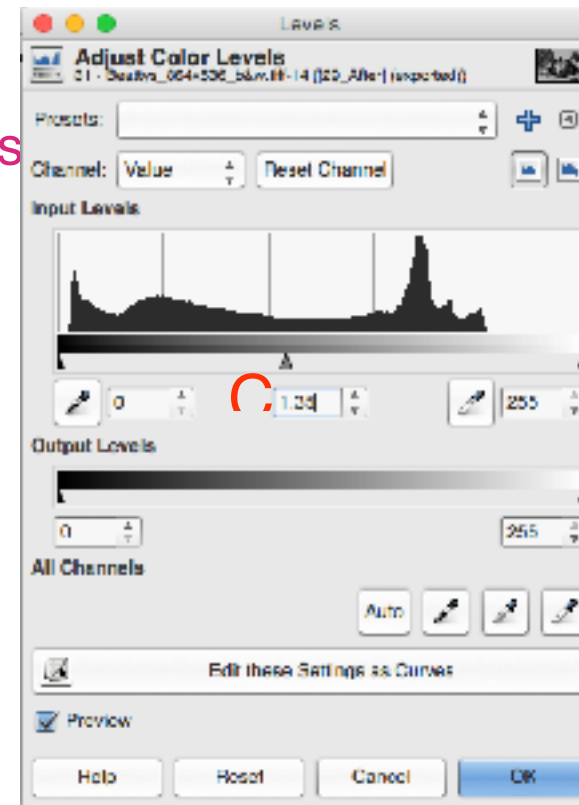
— either results in a NON-uniform change to the histogram

Lightened

Sharpening

Filters > Enhance > Unsharp Mask...

*each pixel value is replaced
by a weighted sum of its neighbours,
in such a way as to
sharpen the appearance of the image
by making edges more visible*

Amount (%)

- how much to sharpen (start with 30%)

Threshold

- by how much adjacent pixels must differ
  before sharpening occurs (start with 4)

- an effort at edge detection

- increase the threshold to focus on "real" edges

Radius

- is the width in pixels of the effect on either side of an edge
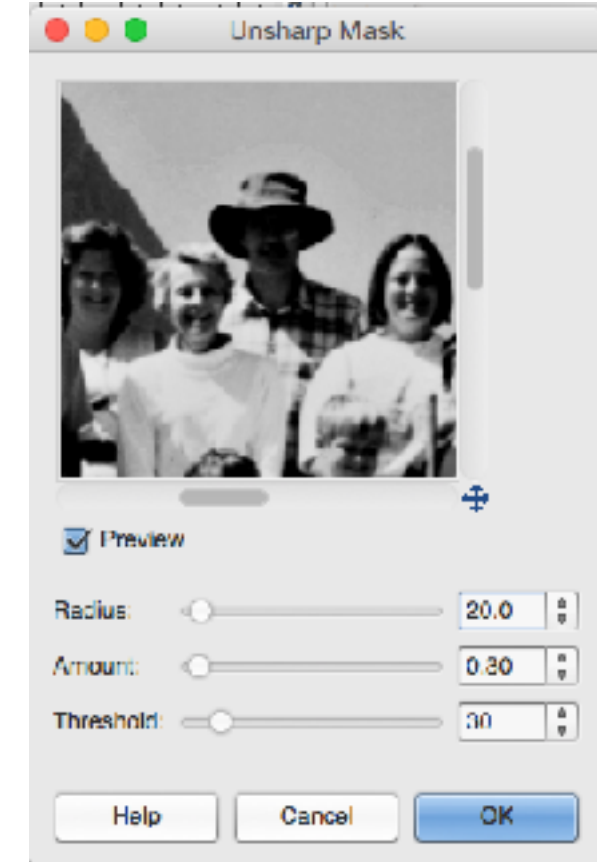
Unsharp Masking—What's Happening

Before: RGB = (100,100,100) on the left & (200,200,200) on the right
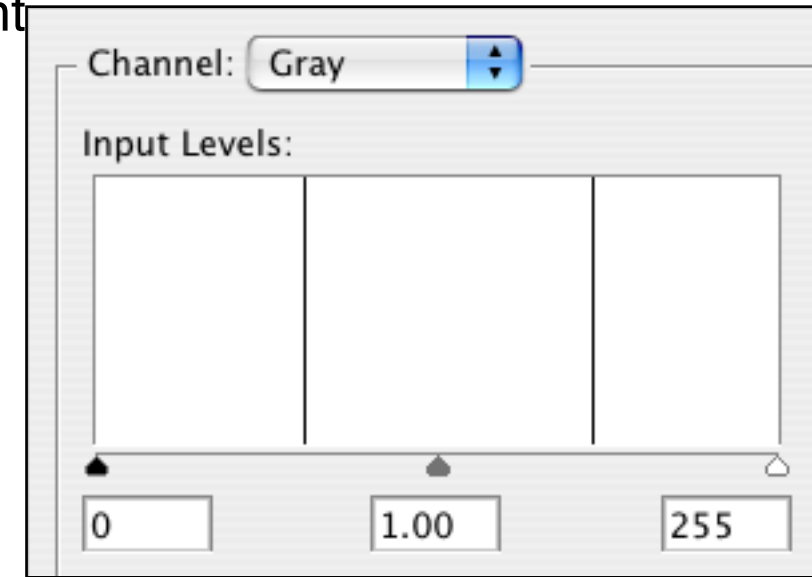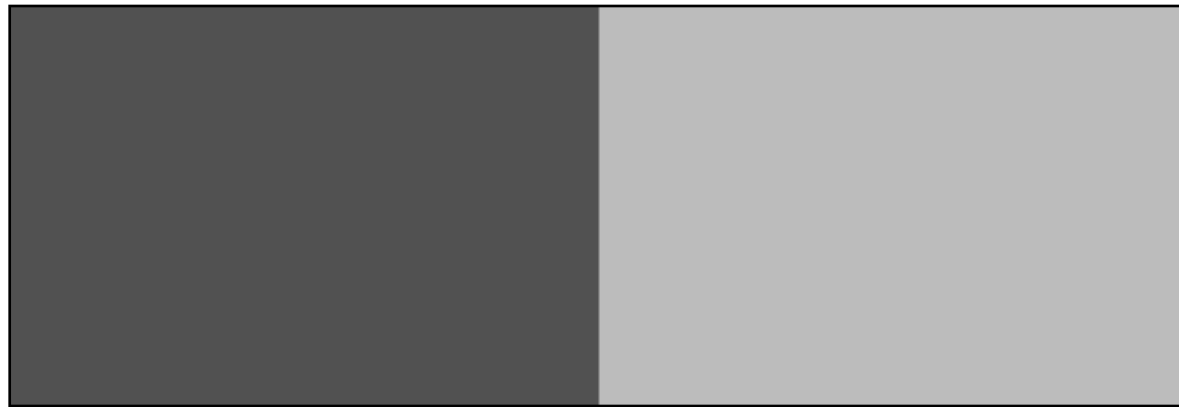
Pixel Histograms

After sharpening with amount = 100, radius = 2.0, threshold = 0
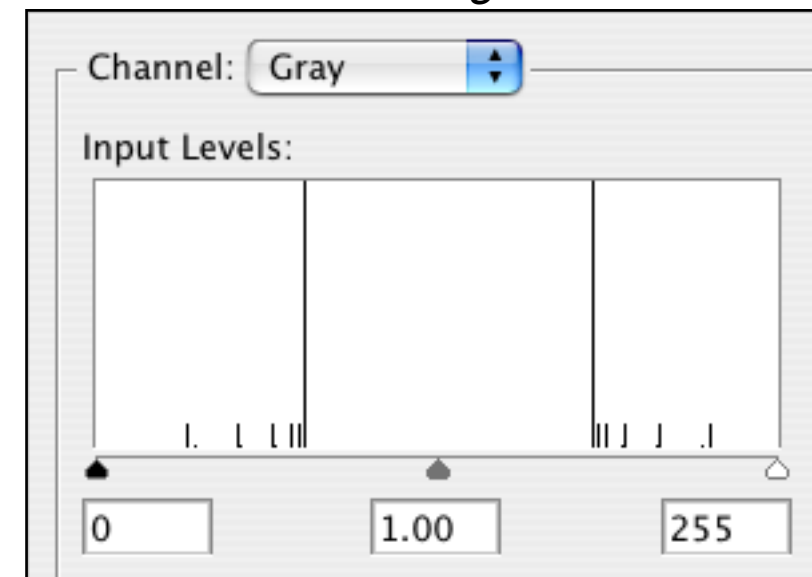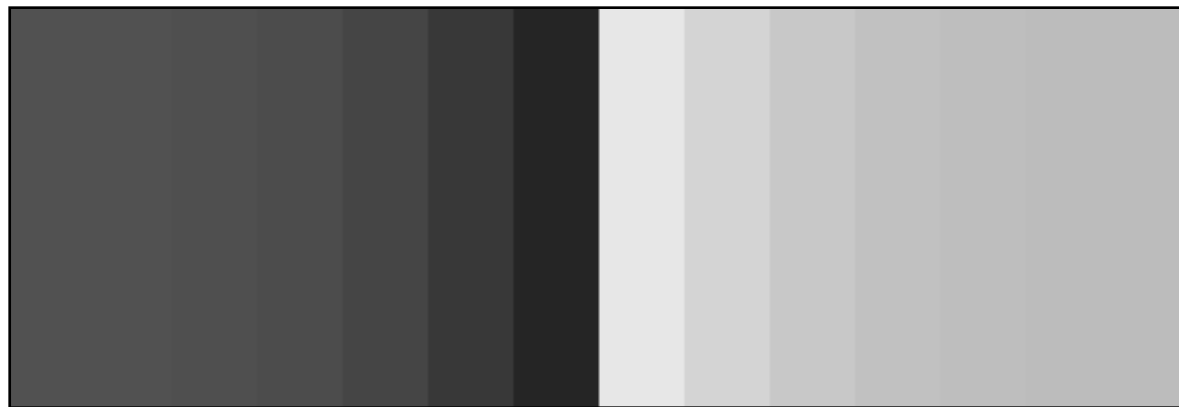
The contrast immediately to left and right of the boundary
has been increased—when not enlarged, the eye sees this as a sharper edge

What About Colour?

Apply Level and Sharpening adjustments

- to the R, G and B channels simultaneously (RGB)

- or individually

The Gimp "Curves" tool provides for very flexible adjustment of

- levels

- colour balance

- contrast

Unfortunately it's use is a bit beyond the scope of CS200. For more, s

http://www.cambridgeincolour.com/tutorials/photoshop-curves.htm
(strongly recommended...)

Transformations specifically for colour:

- Colour Balance

- Hue / Saturation / Lightness

- Brightness / Contrast

Colours > Curves...
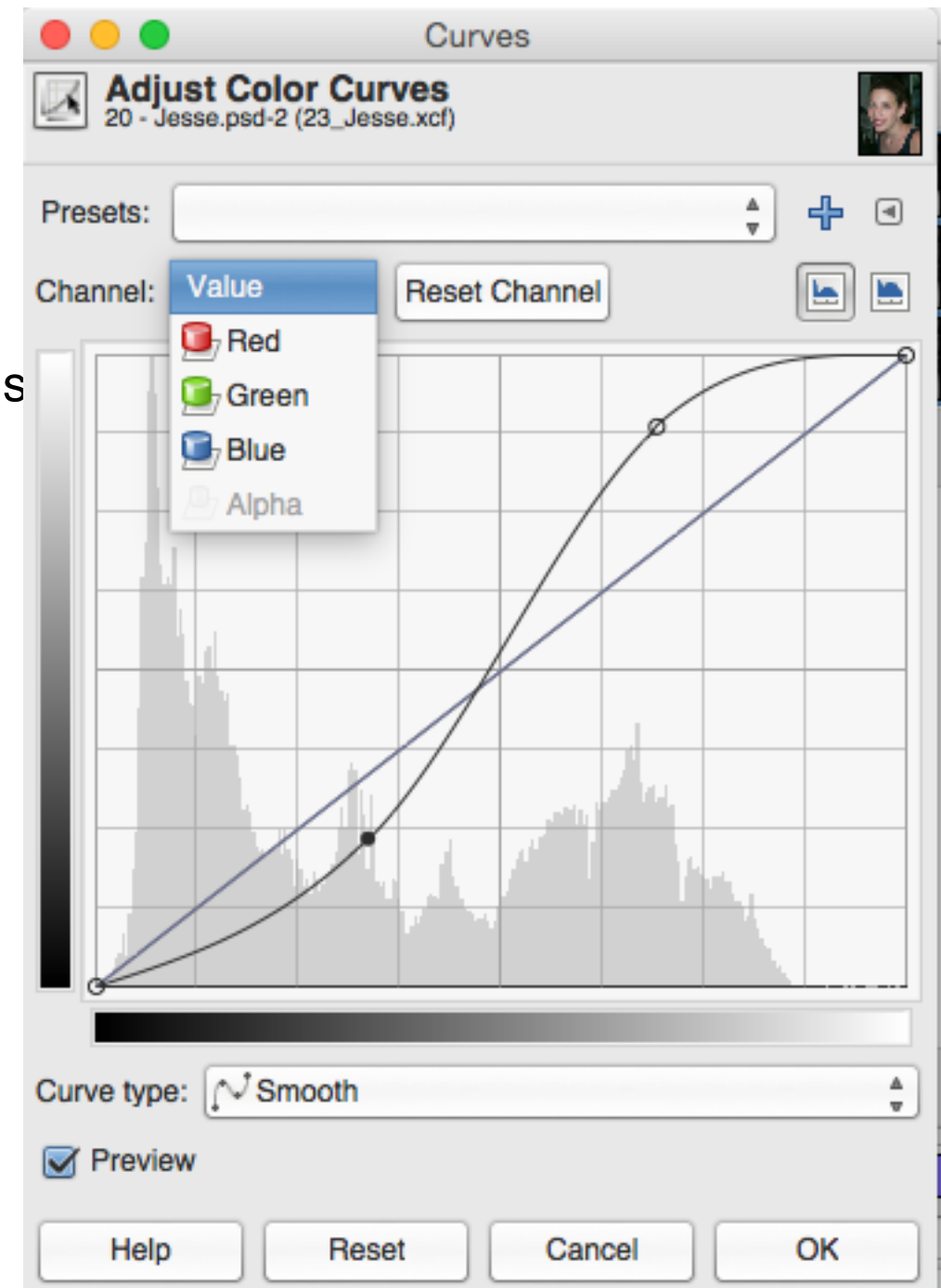
Hue, Saturation and Lightness (aka Brightness, Luminance)

Image > Adjustments > Hue/Saturation...
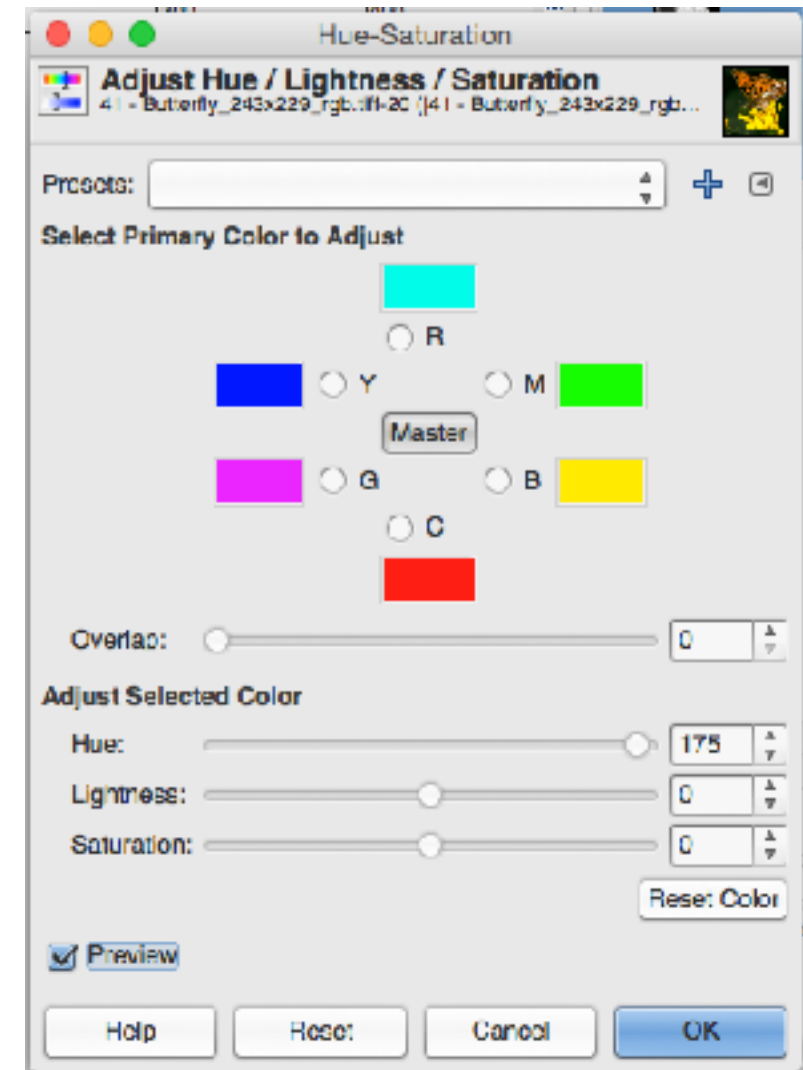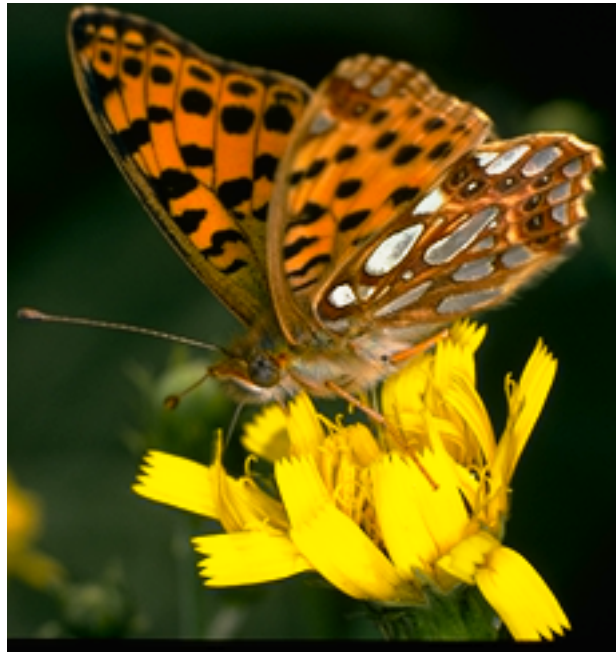
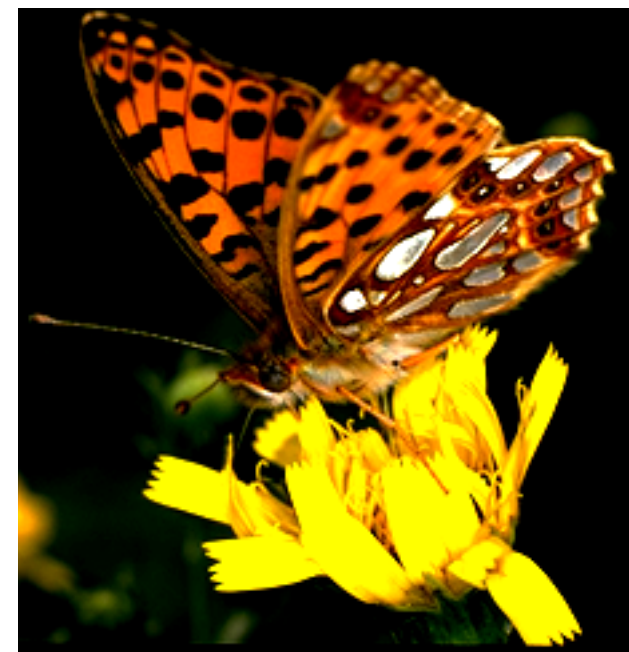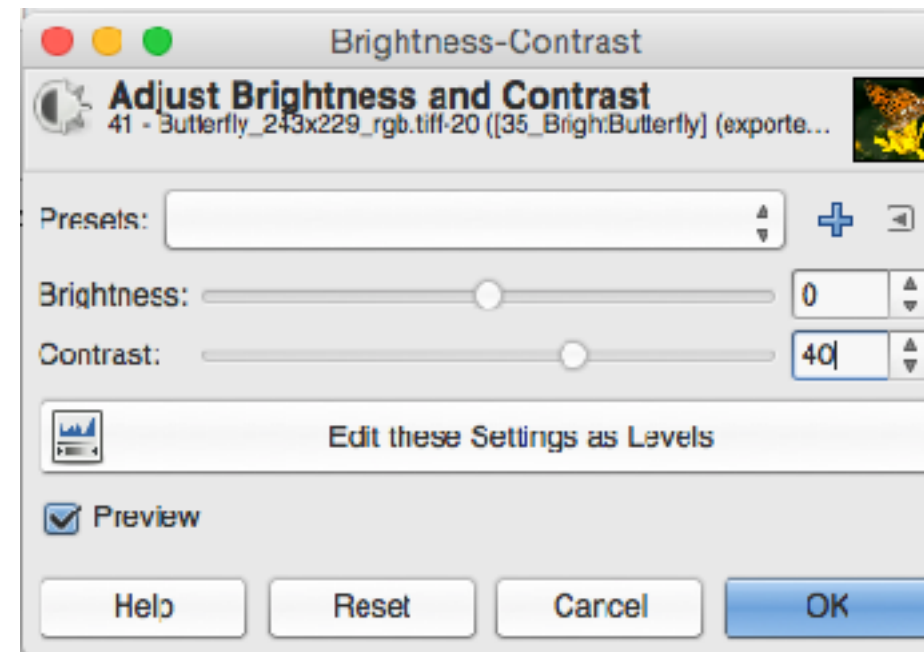The Hue slider rotates colour around the colour wheel
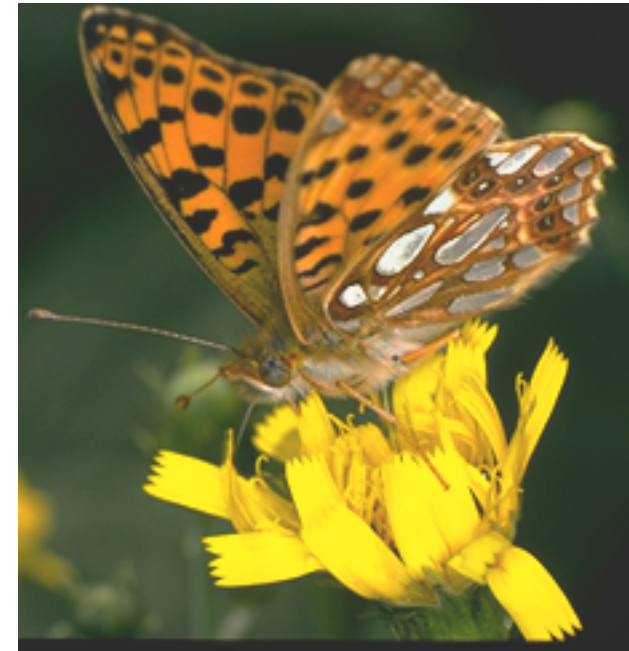
Saturation
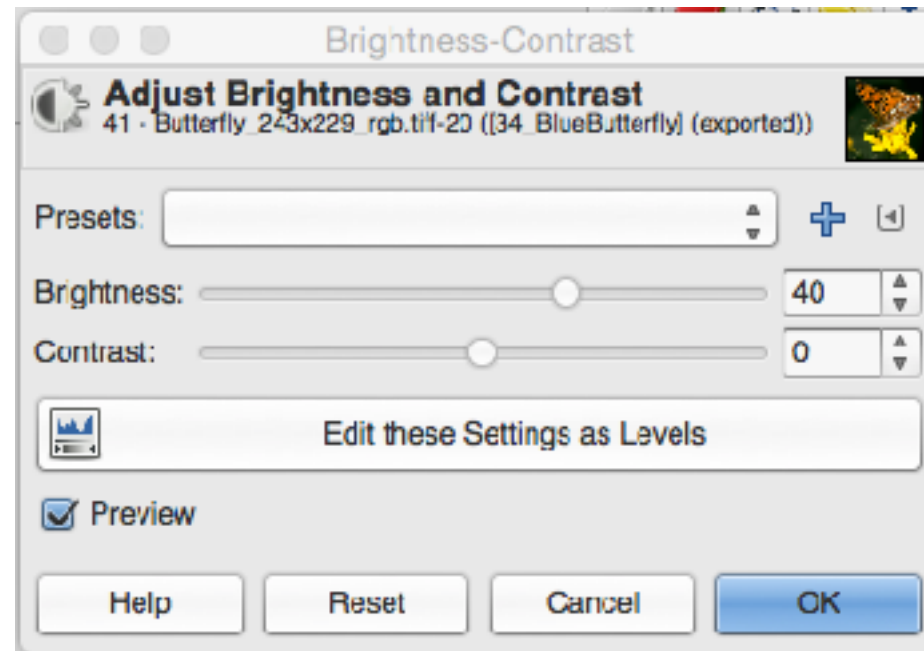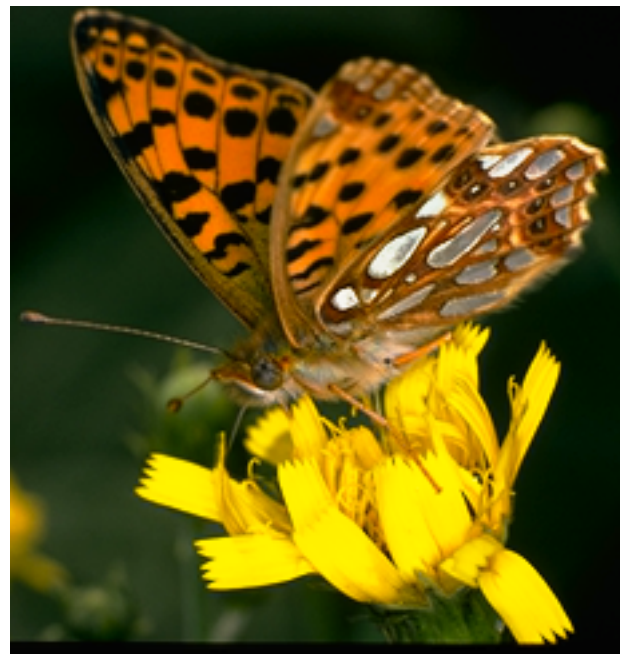
- increasing saturation makes colours more vivid
- fully desaturated colours are gray

Increasing lightness lightens the entire image
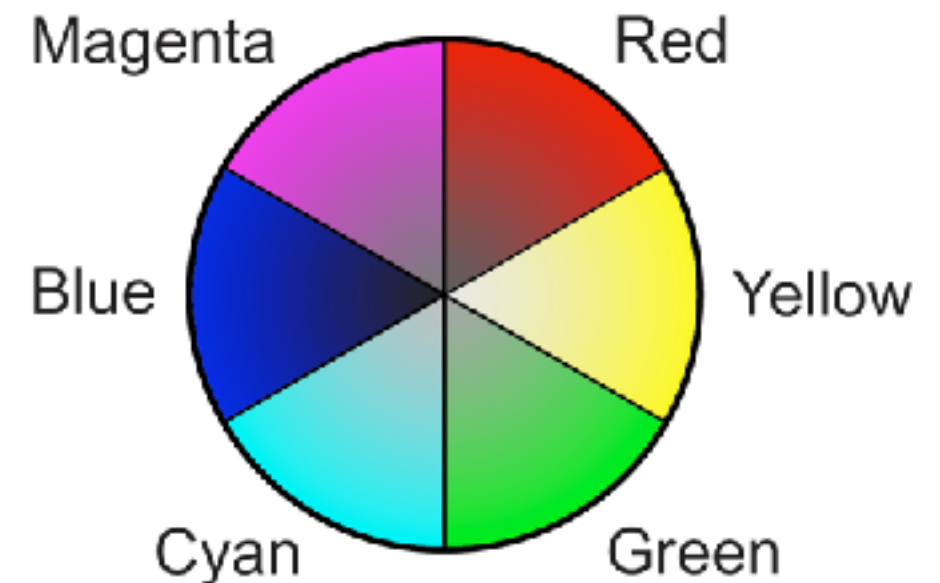
Brightness-Contrast

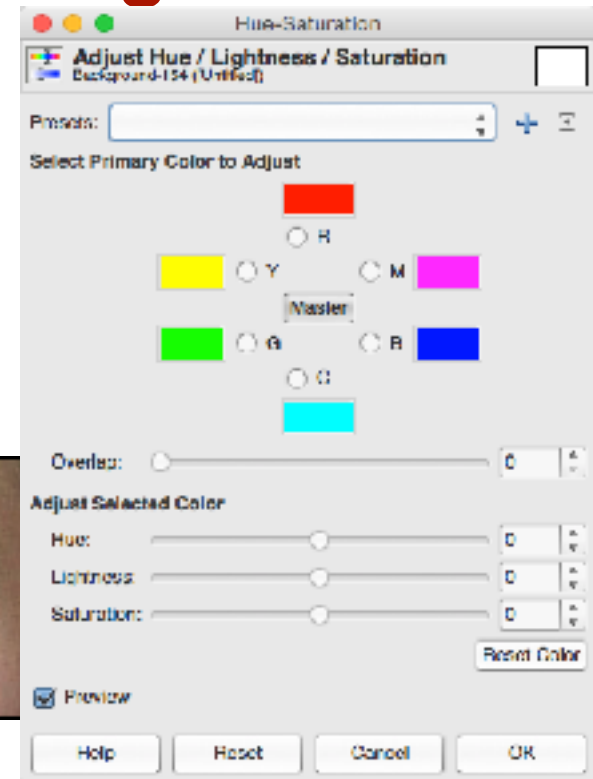Image > Adjustments > Brightness/Contrast...

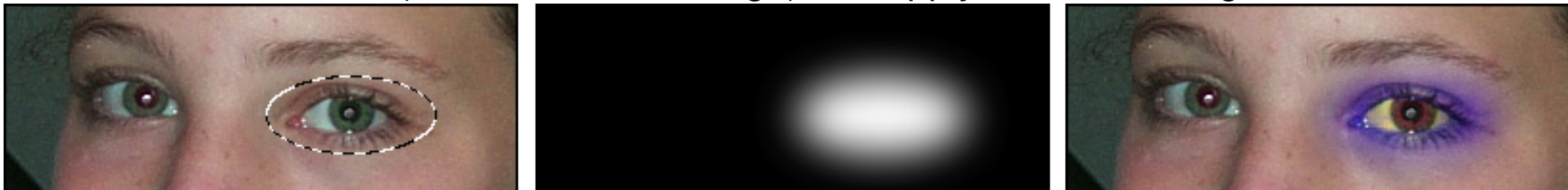# Applying Image Transformations to a Selected Region

Select a Marquee Tool

Use the tool to select a part of the image & apply an image transformation

Feather the selection (remember feathering?) and apply the same image transformation

- pixels inside a selection can be modified
- pixels outside the selection are "masked" (remember masking?)
- "Feathering" results in a gradual transition from full to no effect as you move outwards across the selection boundary

We've seen this before, when filling selections

Hint: Use Select > Feathering... to increase the feathering for an existing selection.

The Layers Palette (Another Data Model)

Each "layer" is a pixel grid (effectively, an individual & distinct painting)

- stacking order determines visibility (painting order)
  — the net effect is built up by painting the layers in order from bottom to top —
  though objects may be partially transparent

- each layer is ONLY a pixel grid (compare with the lecture on Geometric Graphics)

- click-drag in the Layers palette to change a layer's stacking (ie painting) order

- when you draw on the canvas, ink goes into (onto?) the selected layer

- you can control whether a layer is visible

- you can "lock" a layer so that it cannot be modified

- click-drag the ink in an object to move the object in x and y

    Gimp identifies the object to be moved by whose ink is frontmost
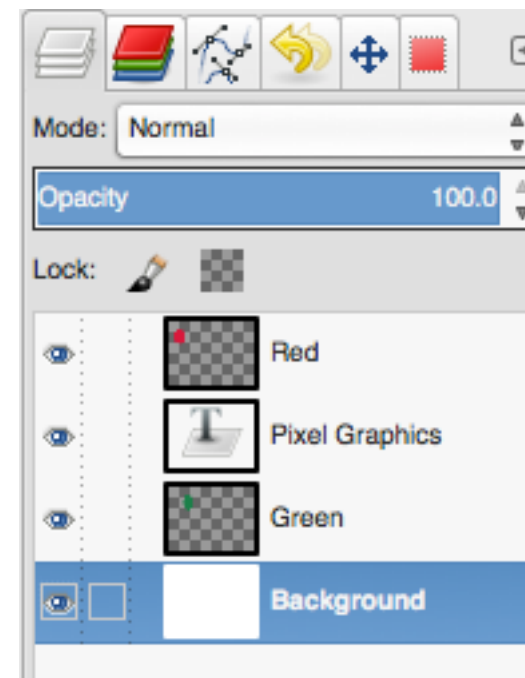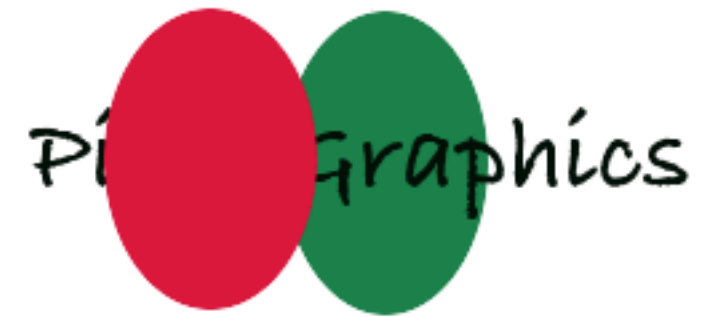
Using Layers to Control the Stacking Order (aka "Z-Depth")
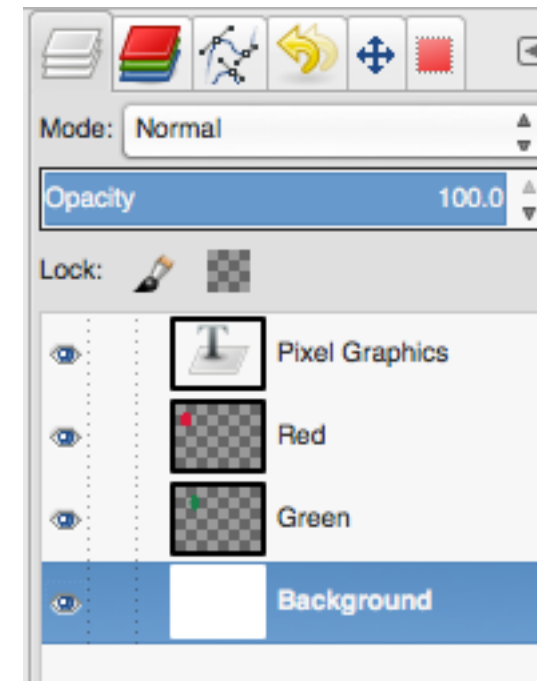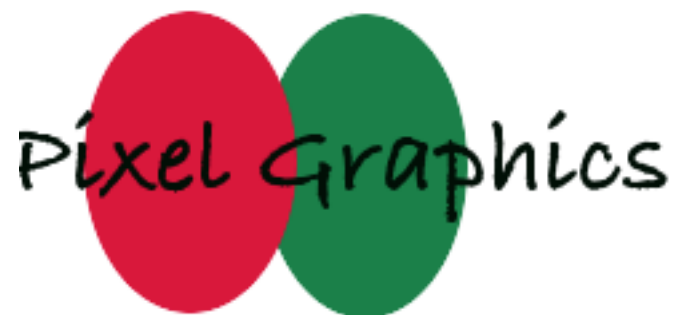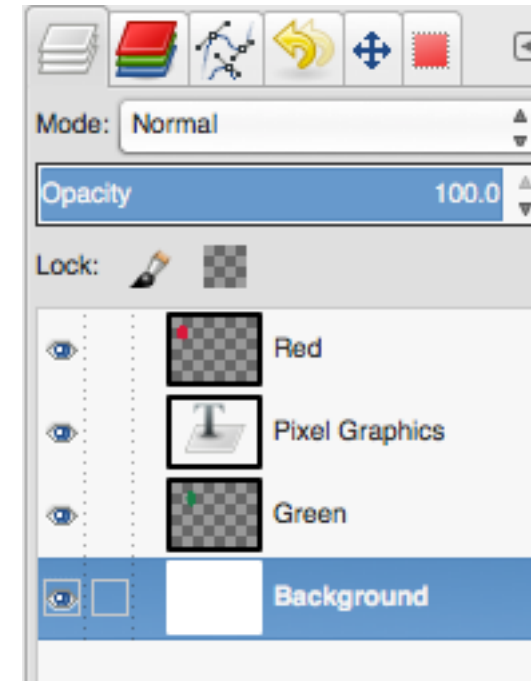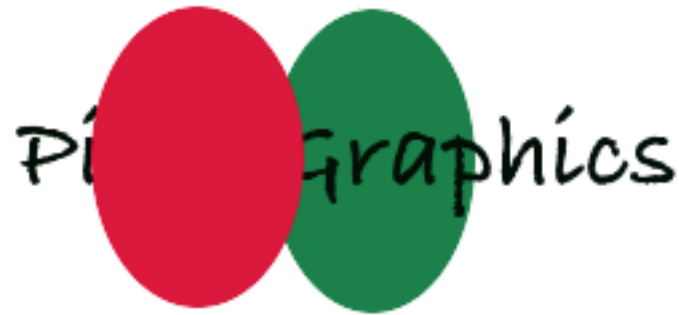
Adjustment Layers

Layer > New Adjustment Layer > ...

An "adjustment layer" is a "layer" with an attached image transformation

the adjustment may affect the entire image, or only a selected ("masked") portion

you can alter the transformation later

- Layer > Change Layer Content

  *to change transformation parameters
 or apply a different transformation*

Warning

- You can apply image manipulations directly to an image via the Image > Adjustments submenu.

- It's nearly always better to create an adjustment layer.

- Directly adjusting an image alters the image pixels themselves,
  whereas altering an adjustment layer changes only what's displayed on the screen.
  (The adjustment layer is stored separately, and the transformation applied to the image whenever it is rendered.)

Adjustment Layers Example 1

You can (also) alter the transformation's settings by double-clicking on the "adjustment layer icon" in the relevant row of the Layers palette
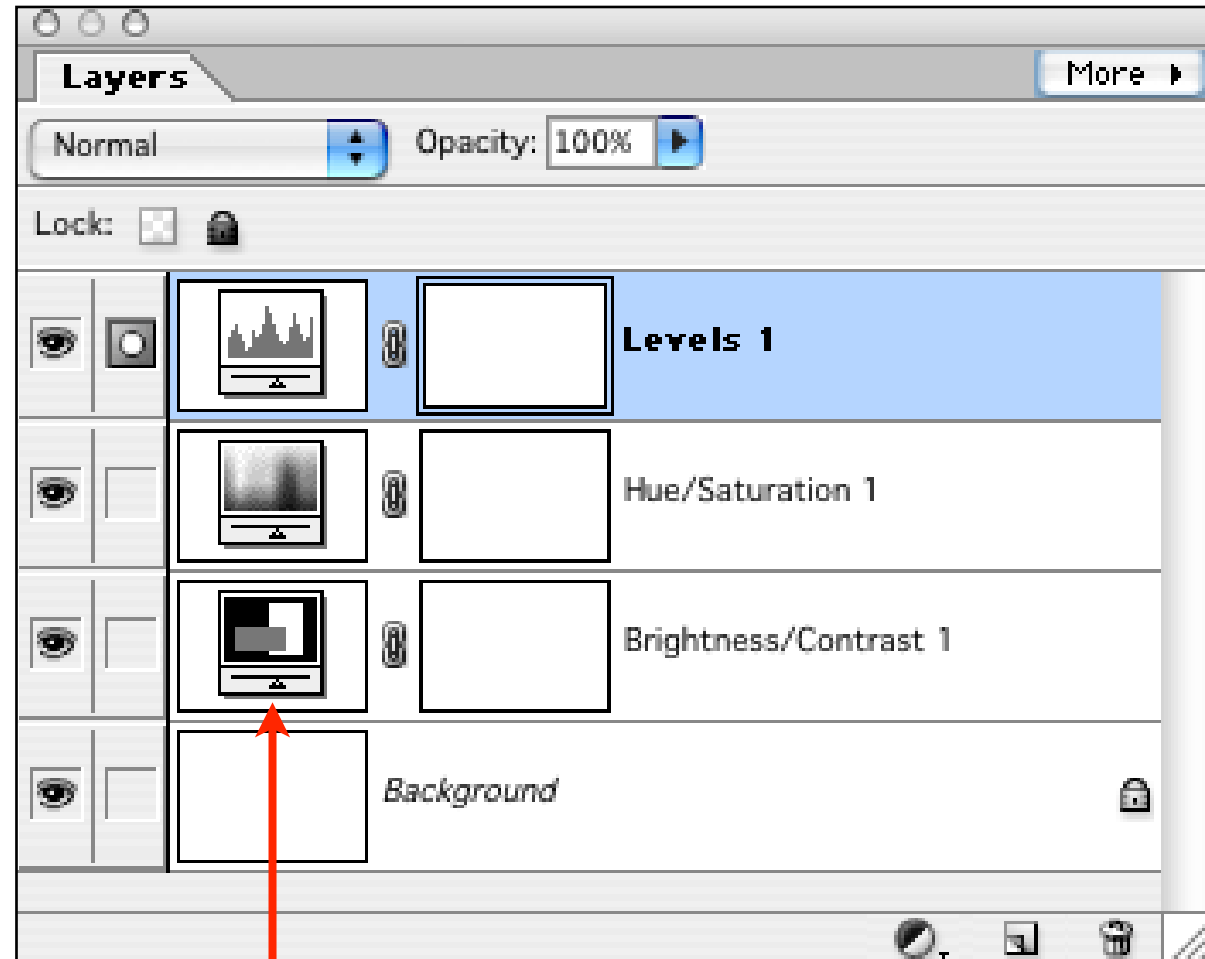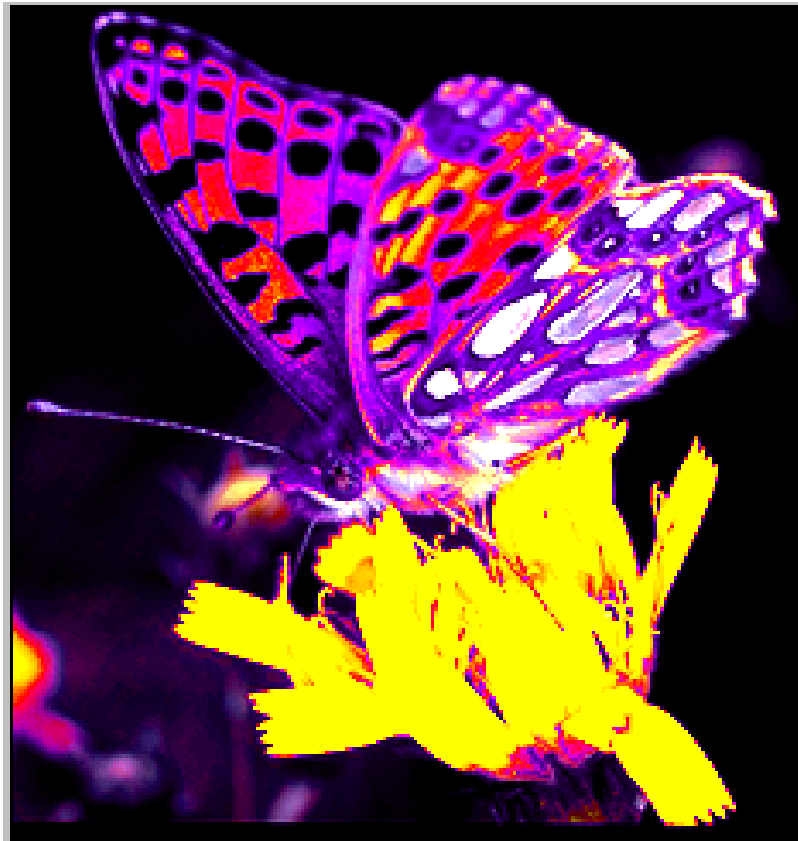
The "adjustment layer icons"

If adjustments are made via multiple layers you can alter them at any time and in any order; *you can't do that if you directly adjust the image*.

Layers, Layer Masks, and Selections

Selections can be converted to "layer masks"

- create a new adjustment layer while something's selected
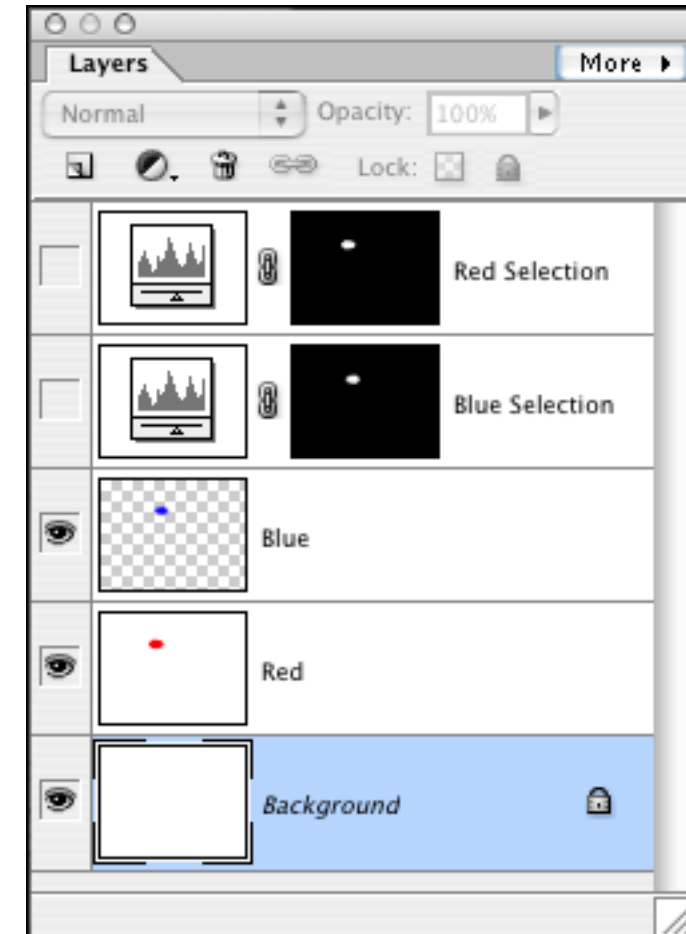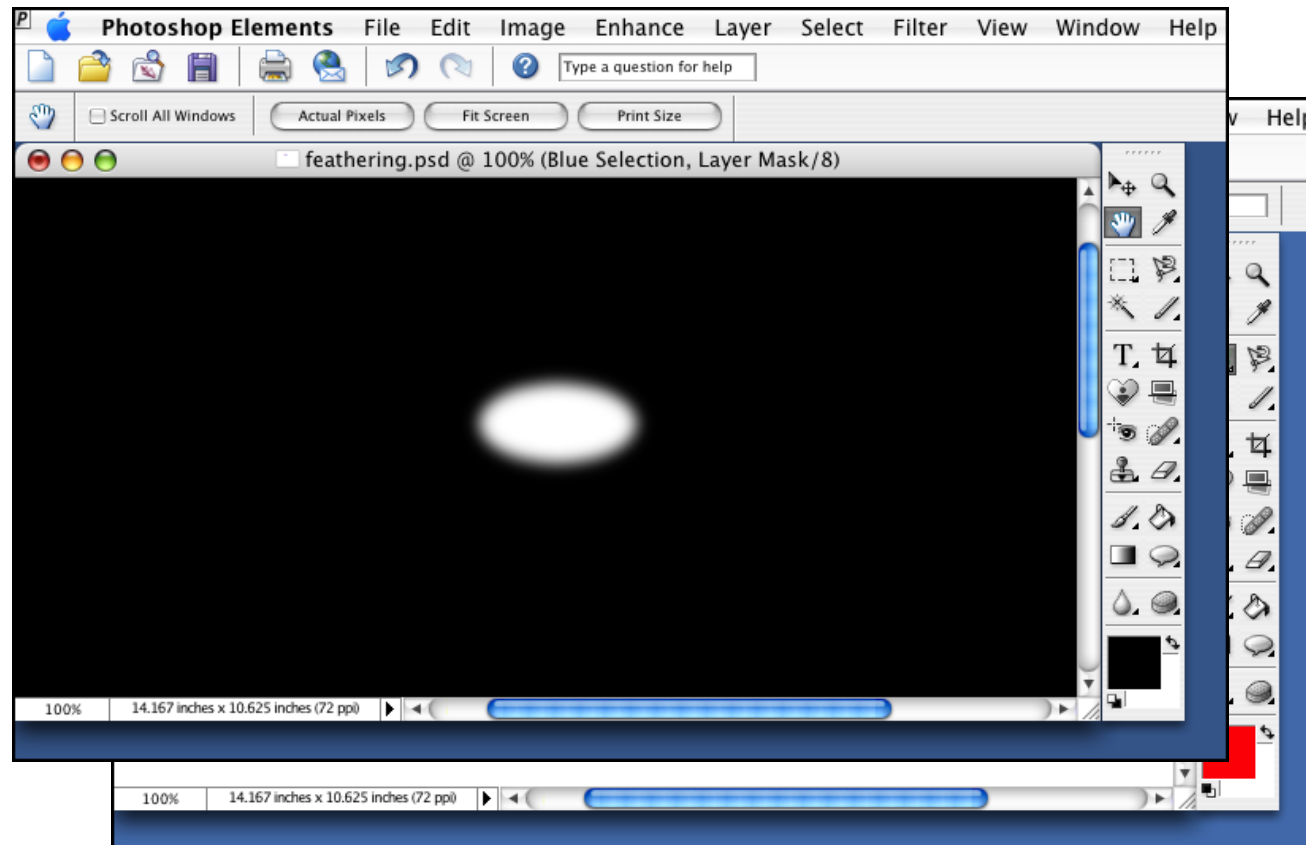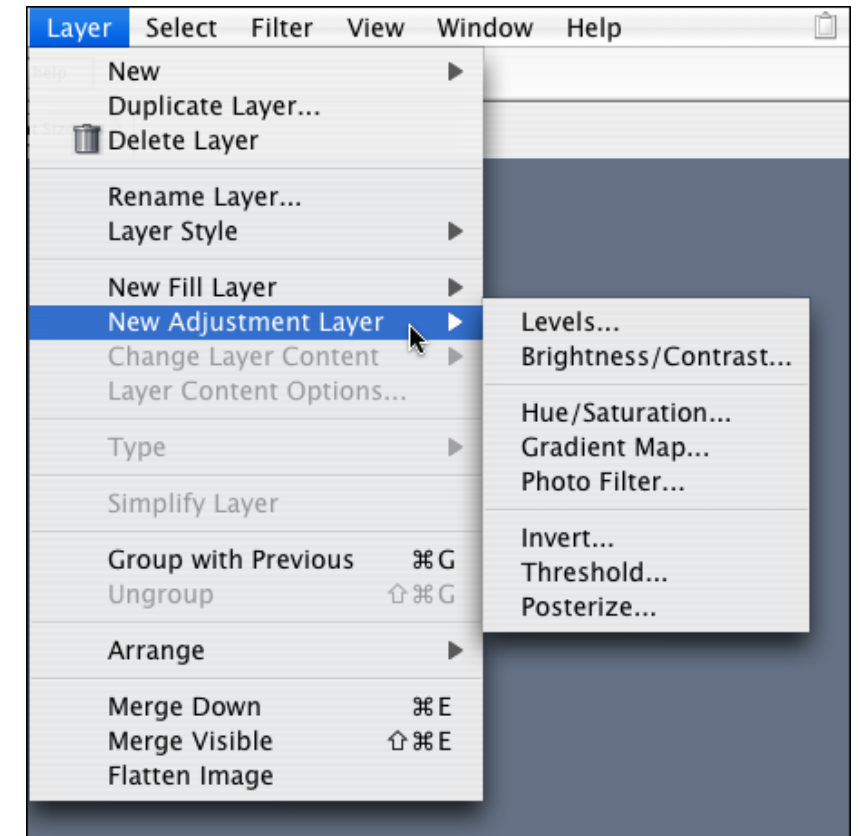
A layer mask can be converted to a selection

- click on the layer in which you want the selection, then command-click on the layer mask

You can edit a layer mask with all of Photoshop's tools, just as you edit an image
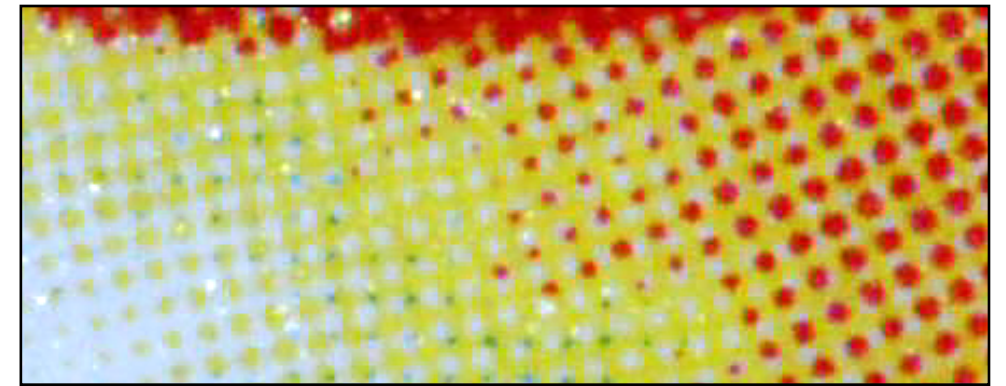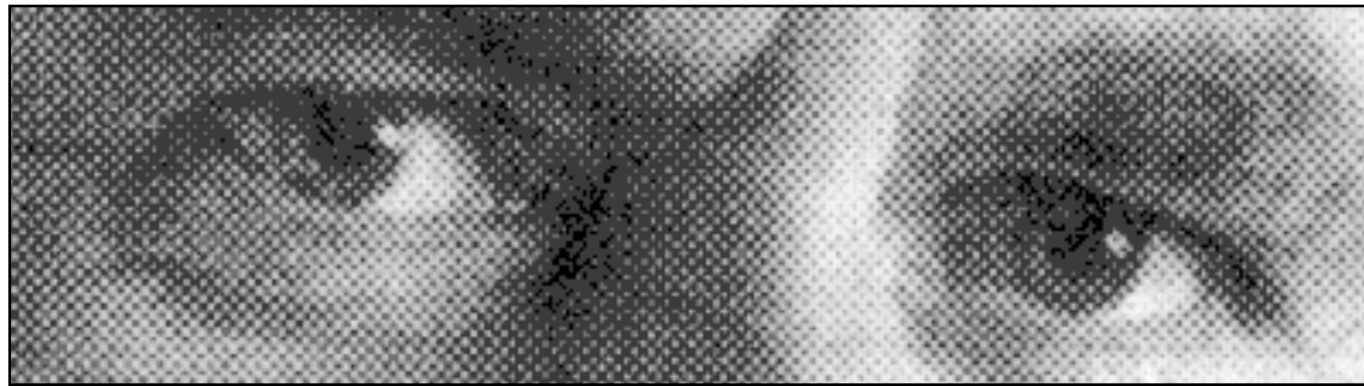
- option-click on the layer mask

You can disable (turn off) a layer mask

- shift-click on the layer mask
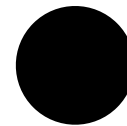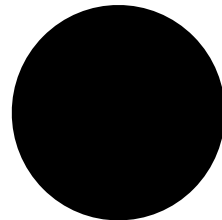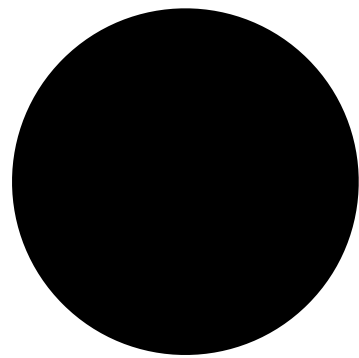
T

Half-Tone Dots—"Traditional" Printing

(A) Traditional print media print solid black dots of varying size to imitate gray
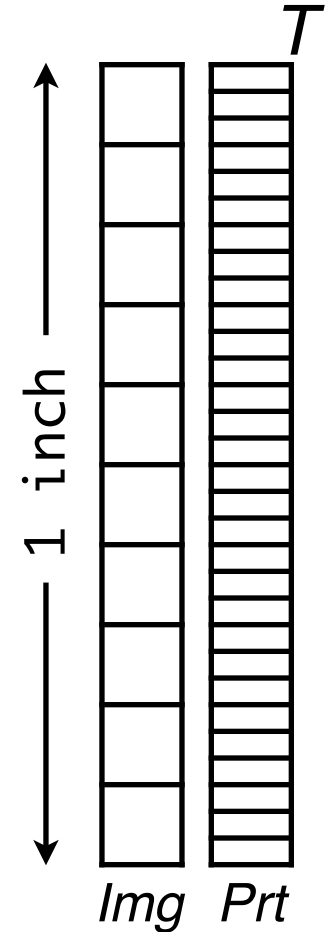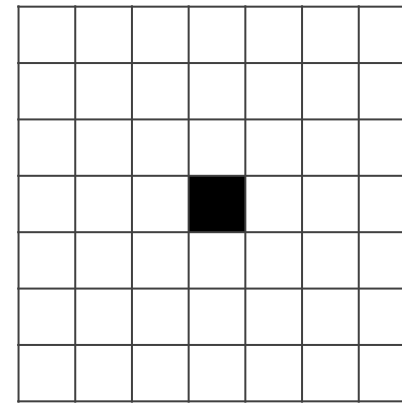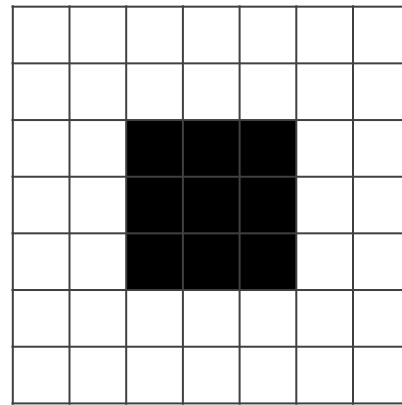

Darker ... Lighter

and of solid Y/C/M/K dots of varying size to obtain colour, again when viewed from a sufficient distance

(B) Compared to a monitor — "true" intensity variation (ie no half-toning)

Faking Half-Tone Dots on a Bi-Level Printer

(C) Digital half-toning for bi-level printers, solid black or white dots (most, but not all printers)
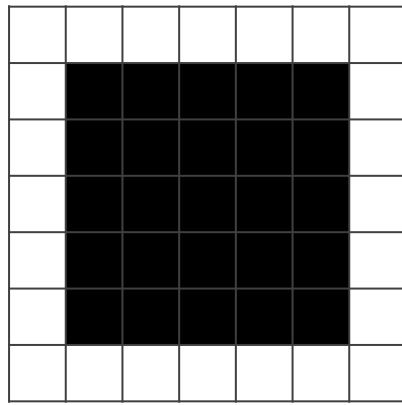
"Lines Per Inch" = # of rows / pixel

An NxN square yields $1+N^2$ grey levels

• (eg 2x2 squares can have 0, 1, 2, 3, or 4 black pixels, & thus be   0 %,   25 %,   50 %,   75 %,   100 % black
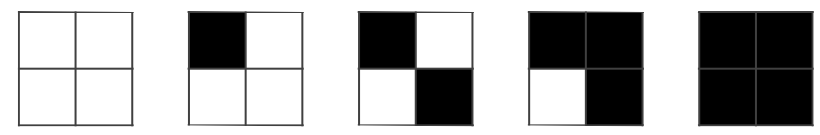
So to print an image the same size as the original ...

if your scanned photo has 72 pixels per inch (dpi) with 8 bits per pixel (256 intensities)

and your bi-level printer has 1200 dots per inch (dpi) (eg the HP 2300 in my office)

you'll have about 1200 / 72 ≈ 16.7 rows of printer pixels / image pixel

• & 16 x 16 squares are available to mimic half-tone dots on the printer (257 intensity levels—just right!)

T

1 inch

Img   Prt

Rule of 16

See Chapter 21 of "Scanning & Halftones,"3/e, by Blatner, ..., for more detail.

There's no point in scanning your image at higher spatial resolution (eg 100 dpi)

because then you'd only have 1200/100 = 12x12 squares & 145 intensity levels, & you need 256

Because most digital images have 256 intensity levels, & therefore need 16x16 printer pixels / image pixel, we have

"the rule of 16:"   for a given printer,   more than   (printer resolution / 16)   image pixels/inch is wasteful

or   for a given image,   more than   (image resolution * 16)   printer pixels/inch is wasteful

Digital Printing—Variations on a Theme

"Regular-pattern halftones"

what's important is actually that the right fraction of the dots be inked in,
not whether they're clustered in the middle as a dot

"Stochastic screening" ≈ "dithering"

WikiPedia — "dither"

randomly select which pixels to ink in,
in such a way that the right *percentage* of pixels are inked in

eg 33% gray could be presented by many different patterns
— in every 3x3 squares, there are 9*8*7 possible patterns with 0.33*9 = 3 dots inked:

    ...

Notes

ink jet and laser printers are bi-level => "fake" half-toning or dithering (as discussed)
though many now now have *some* ability to vary dot size (4-16 shades/ink?) => combine techniques

dye-sublimation printers heat transparent dyes and diffuse the resulting vapour onto paper;
the dyes mix, resulting in "photo-quality" images (256 shades/ink) as on an LCD or film-based-photo

•See http://en.wikipedia.org/wiki/Dye_sublimation for more

colour printers can't print the entire range of colours you can see on a CRT or LCD;
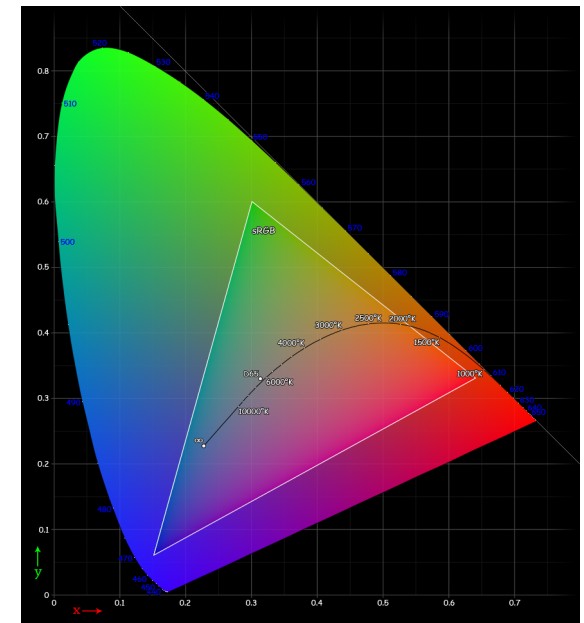in particular, you lose highly saturated colours

the particular "gamut" of printable colours various from device to device;
even if what you see on an LCD is within the printer's gamut,
getting EXACTLY those colours printed is HARD

There's a LOT more to be said about printing ... but not by us ...

Final Words

Gimp is an *extremely* rich application

- rich both in features

- and in the variety of useful ways in which you can combine features

we've only scratched the surface / given you a skeleton to flesh out on your own

- esp wrt making selections and masking

Places to go for more information

Real World Adobe Photoshop CS3 (© 2005)

by David Blatner, Conrad Chavez and Bruce Fraser
PeachPit Press, www.peachpit.com, ISBN 0-321-51868-3

Real World Scanning & Halftones, 3/e (© 2004)

by David Blatner, Conrad Chavez, Glenn Fleishman and Steve Roth
PeachPit Press, www.peachpit.com, ISBN 0-321-24132-0

The Non-Designer's Scan and Print Book (© 1999)

by Sandee Cohen and Robin Williams
Peachpit Press, www.peachpit.com, ISBN 0-201-35394-6

resources > Drop Shadows & Masks on the cws

(Like O'Reilly, Peachpit is a quality publisher whose books are generally recommended.)