To Ponder
Color and Images

Lecture 18
Colors in CSS

- Use: fonts, borders, backgrounds
- Provides semantic signal:
  - **Green** – go, success, complete, solution
  - **Red** – stop, failure, incomplete, problem
  - **Yellow** – yield, warning, attention
- Helps to set mood/emotion/tone:
  - **Bright** – cheerful, playful, positive
  - **Dark** – somber, serious, negative
  - **Warm** – energetic, alert, active
  - **Cool** – calm, tranquil, peaceful
Elementary Color Theory

- Combination of
  - Physics: wavelengths in nm
  - Biology: perception of “red” vs “yellow” vs...

- Visible spectrum: 390-700nm
  - Spectral colors: rainbow, single wavelength
  - Nonspectral colors (pink, brown, white...) result from presence of *multiple* wavelengths
Power Spectrum = Color

The rose (genus Rosa)
Color Perception

- Human eyes have 3 types of cones
  - Respond to different wavelengths (LMS)
- Perceived color = eye's cone response
Metamerism

- Different (continuous) spectra that stimulate our eyes in identical ways
  - Consequence: Different spectra with indistinguishable (to humans) color

- Example: white
  - Spectrum 1: all wavelengths equally present
  - Spectrum 2: a few wavelengths present, stimulating LMS cones equally

- Consequence: Any continuous spectrum can be projected down to 3 components (as far as human eyes are concerned)
  - XYZ “tristimulus values”
  - Not truly independent (overlap of response), so any 2 give the 3\textsuperscript{rd}; ie a 2D space...
CIE 1931 xy Chromaticity

Max luminance (100%)

Perceivable colors

Spectral (pure) colors
Color Mixing

- There are two ways to combine colors
  1. Subtractive: Color is a *filter*
     - Mixing = filter out both
     - Used for printing (& dyes, paints, gels)
  2. Additive: Color is a *light source*
     - Mixing = sum
     - Used for monitors
Subtractive Color Mixing: CMYK

- Filters transmit different *spectra*
  - Mixture transmits the *product* of both
  - Mix all three primaries = black

- Primary colors: cyan, magenta, yellow
  - Black (K) added for quality and cost
  - Traditional set (RYB) popular for painting

Primary yellow (transmits R & G) (absorb B)
Colors as Filters

Yellow: Filters out (only) blue

Rosi et al., Euro. J. of Physics, 37(6), 2016
Additive Color Mixing: RGB Cube

primary

secondary

magenta

cyan

red

green

yellow

#fff /* white */
#000 /* black */

http://www.flickr.com/photos/ethanhein/3103830956/
Color Mixing: sRGB Gamut
Gamuts for Monitors

And Many More Gamuts...
HSL Color Wheel (50% Lightness)

HSL Color Space: 3D Cylinder
HSL Color Space: 3D Cylinder
HSL Grid for Red (ie 0, S, L)

- (0, 75%, 88%)
- (0, 100%, 50%)
- (0, 0%, 25%)
CSS Color Values

- Keywords: case-insensitive identifiers
  - red, navy, firebrick, chocolate

- RGB as decimal (0-255), percentage, or hex
  - `rgb (255, 0, 0) /* pure red */`
  - `rgb (100%, 0%, 0%)`
  - `#ff0000`
  - `#f00 /* expand by doubling each digit */`

- HSL (Hue, Saturation, Light)
  - Hue (0-360) is angle on color wheel: 0 is red, 120 green, 240 blue
  - Saturation & light are both %'s
    - `hsl (0, 100%, 50%) /* full bright red */`

- Alpha channel (transparency): 1 is opaque!
  - `rgba (255, 0, 0, 0.5)`
  - `hsla (0, 100%, 50%, 1)`
## Color Keywords

<table>
<thead>
<tr>
<th>Color</th>
<th>Color</th>
<th>Color</th>
<th>Color</th>
<th>Color</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>aliceblue</td>
<td>antiquewhite</td>
<td>aqua</td>
<td>aquamarine</td>
<td>azure</td>
<td>beige</td>
</tr>
<tr>
<td>bisque</td>
<td>blanchedalmond</td>
<td>chartreuse</td>
<td>chocolate</td>
<td>coral</td>
<td>cornflowerblue</td>
</tr>
<tr>
<td>burlywood</td>
<td>cadetblue</td>
<td>chartreuse</td>
<td>darkblue</td>
<td>darkcyan</td>
<td>darkgoldenrod</td>
</tr>
<tr>
<td>cornsilk</td>
<td>crimson</td>
<td>cyan</td>
<td>darkmagenta</td>
<td>darkolivegreen</td>
<td>darkorange</td>
</tr>
<tr>
<td>darkgray</td>
<td>darkgreen</td>
<td>darkkhaki</td>
<td>darkmagenta</td>
<td>darkolivegreen</td>
<td>darkorange</td>
</tr>
<tr>
<td>darkorchid</td>
<td>darkred</td>
<td>darksalmon</td>
<td>darkseagreen</td>
<td>darkslateblue</td>
<td>darkslategray</td>
</tr>
<tr>
<td>darkturquoise</td>
<td>darkviolet</td>
<td>deepink</td>
<td>deepskyblue</td>
<td>dimgray</td>
<td>dodgerblue</td>
</tr>
<tr>
<td>firebrick</td>
<td>floralwhite</td>
<td>forestgreen</td>
<td>fuchsia</td>
<td>gainsboro</td>
<td>ghostwhite</td>
</tr>
<tr>
<td>gold</td>
<td>goldenrod</td>
<td>gray</td>
<td>green</td>
<td>greenyellow</td>
<td>honeydew</td>
</tr>
<tr>
<td>hotpink</td>
<td>indianred</td>
<td>indigo</td>
<td>ivory</td>
<td>khaki</td>
<td>lavender</td>
</tr>
<tr>
<td>lavenderblush</td>
<td>lawngreen</td>
<td>lemonchiffon</td>
<td>lightblue</td>
<td>lightcoral</td>
<td>lightcyan</td>
</tr>
<tr>
<td>lightgoldenrodyellow</td>
<td>lightgray</td>
<td>lightgreen</td>
<td>lightpink</td>
<td>lightsalmon</td>
<td>lightseagreen</td>
</tr>
<tr>
<td>lightskyblue</td>
<td>lightslategray</td>
<td>lightsteelblue</td>
<td>lightyellow</td>
<td>lime</td>
<td>limegreen</td>
</tr>
<tr>
<td>linen</td>
<td>magenta</td>
<td>maroon</td>
<td>mediumaquamarine</td>
<td>mediumblue</td>
<td>mediummorchid</td>
</tr>
<tr>
<td>mediumpurple</td>
<td>mediumseagreen</td>
<td>mediumslateblue</td>
<td>mediumspringgreen</td>
<td>mediumturquoise</td>
<td>mediumvioletred</td>
</tr>
<tr>
<td>midnightblue</td>
<td>mintcream</td>
<td>mistyrose</td>
<td>moccasin</td>
<td>navajowhite</td>
<td>navy</td>
</tr>
<tr>
<td>oldlace</td>
<td>olive</td>
<td>olivedrab</td>
<td>orange</td>
<td>orangered</td>
<td>orchid</td>
</tr>
<tr>
<td>palegoldenrod</td>
<td>palegreen</td>
<td>paleturquoise</td>
<td>palevioletred</td>
<td>papayawhip</td>
<td>peachpuff</td>
</tr>
<tr>
<td>peru</td>
<td>pink</td>
<td>plum</td>
<td>powderblue</td>
<td>powderblue</td>
<td>purple</td>
</tr>
<tr>
<td>red</td>
<td>rosybrown</td>
<td>royalblue</td>
<td>saddlebrown</td>
<td>salmon</td>
<td>sandybrown</td>
</tr>
<tr>
<td>seagreen</td>
<td>seashell</td>
<td>sienna</td>
<td>silver</td>
<td>skyblue</td>
<td>slateblue</td>
</tr>
<tr>
<td>slategray</td>
<td>snow</td>
<td>springgreen</td>
<td>steelblue</td>
<td>tan</td>
<td>teal</td>
</tr>
<tr>
<td>thistle</td>
<td>tomato</td>
<td>turquoise</td>
<td>violet</td>
<td>wheat</td>
<td>white</td>
</tr>
<tr>
<td>whitesmoke</td>
<td>yellow</td>
<td>yellowgreen</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Color Depth

- "Depth" = # of bits in representation
  - 8 bits → 256 different colors
  - 24 bits → 16,777,216 different colors (eg 8 bits each for r, g, b)

- Alpha may be (incorrectly) included
  - rgba is a point in 4-dimensional space

- Problem: image color depth > display color depth
  - Quantization: each pixel gets closest available color (leads to banding)
  - Dithering: add noise, which looks better!
Quantization of Continuous Func
Quantization vs Dithering

original  quantized  dithered
Quantization vs Dithering

Original Image  
GIF without dithering  
GIF with dithering

HTML `<img>` Tag Attributes

- **src**: location of image file
- **width, height**:  
  - Area in *window* to reserve for image  
  - Image is *scaled* to those dimensions  
  - These attributes affect browser flow, regardless of when/if image is displayed
- **alt**: text to show if graphic can not be displayed or seen (i.e., alternative)  
- **title**: text to *augment* displayed graphic (e.g., tooltip)
Image Representation

- Raster vs vector graphics
  - Raster: stored pixel-by-pixel
  - Vector: mathematical description

- Compression of raster images
  - Lossy: better compression, lower quality image
  - Lossless: largest file size, best quality
Major Formats

- **GIF**
  - Raster graphics, lossy compression (oldest)
  - 8 bit, basic transparency (on/off)
  - Frame-based animation (groan)
  - Good for small file size, crisp lines, logos

- **JPEG**
  - Raster, lossy compression
  - 24 bit, no transparency
  - Good for photos, gradual gradients

- **PNG**
  - Raster, lossless (but still often good) compression
  - Variable depth, full alpha transparency
  - Good replacement for GIF (but no animation)

- **SVG**
  - Vector graphics (newest)
  - Good for crisp lines, simple logos, graphs
Scaling Images

- Vector graphics scale perfectly
- Raster images should be *pre-scaled*
  - Width (height) attributes of image tag should match actual width (height) of image
  - Why?
Alternative: CSS

.button {
  display: inline-block;
  padding: 0.3em 1.2em;
  margin: 0 0.3em 0.3em 0;
  border-radius: 2em;
  box-sizing: border-box;
  text-decoration: none;
  font-weight: 300;
  color: #FFFFFF;
  background-color: #4eb5f1;
  text-align: center;
  transition: all 0.2s;
}

Button
Summary

- **Color theory**
  - Perception, metamerism
  - Mixing: subtractive, additive
  - RGB, HSL, keywords

- **Images**
  - Quantization and dithering
  - Raster graphics vs vector graphics
  - Formats jpeg, png, gif, svg
  - Tradeoffs of size, quality, features