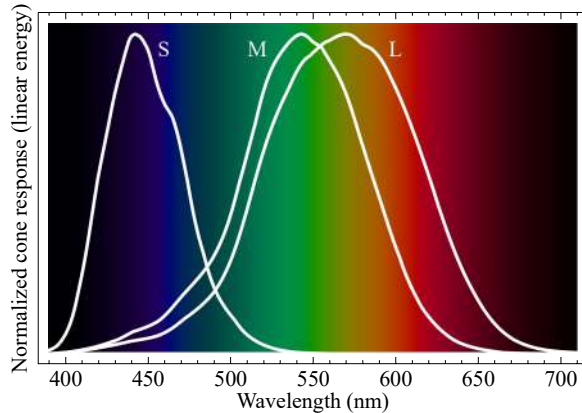


Human Vision

- Humans see through their retina
- ~ 130 m cells:
 - rods (~ 93%), cones (> 4%), ganglions (> 2%)

Physiological Color Perception

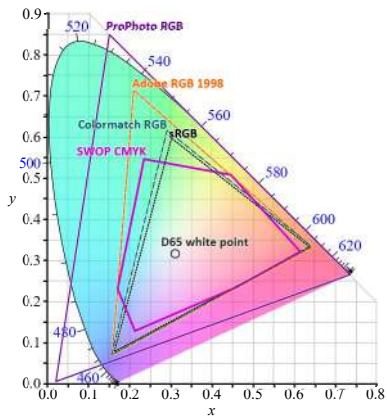


(Image from Wikimedia Commons)

Human Vision Representation

- CIE 1931 color space:
from physical wavelength to physiological vision
- A typical screen has a far narrower gamut

Gamut Comparison



(Image from Wikimedia Commons)

Raster Images

- 2-dimensional representation: grid
- smallest element: *pixel*
- each pixel has a color value
- color depth: number of bits per color
- file size: width x height x depth

Indexed Color

- assign a number to each color
- 1 bit per pixel: 2 colors
- black & white:
 - 0 → black
 - 1 → white

Color Palettes

- 1 byte per pixel: 256 colors
- custom palette:
 - 0 → black
 - 1 → red
 - ...
 - 120 → blue
 - 121 → purple
 - ...
 - 255 → white

Direct Encoding

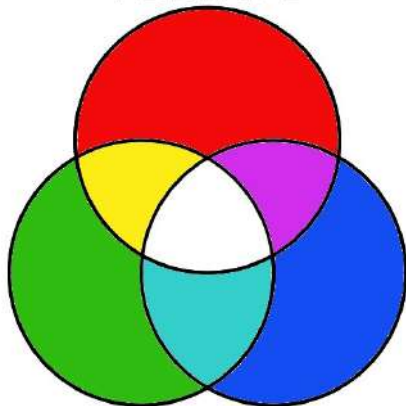
- 1 byte per pixel: 256 colors
- *monochrome*: shades of one color
- *grayscale*:
 - 0 → black
 - 255 → white
 - anything in between → shade of gray

sRGB

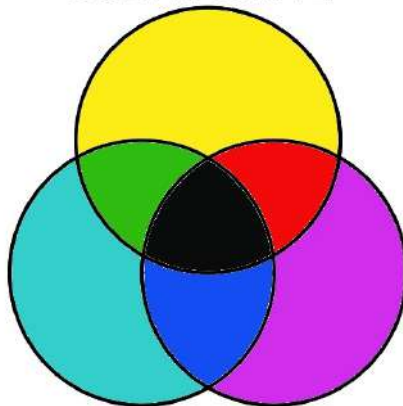
- mixture of 3 components: *RGB*
- Red, Green, Blue
- 1 byte per component: $3 \times 8 = 24$ bits
- 16.7 million colors
- $\sim 30\%$ of perceivable colors

Additive vs Subtractive Color

ADDITIVE



SUBTRACTIVE



Additive Color

- additive color scheme
- based on transmitted light
- how monitors and projectors work

RGB Examples

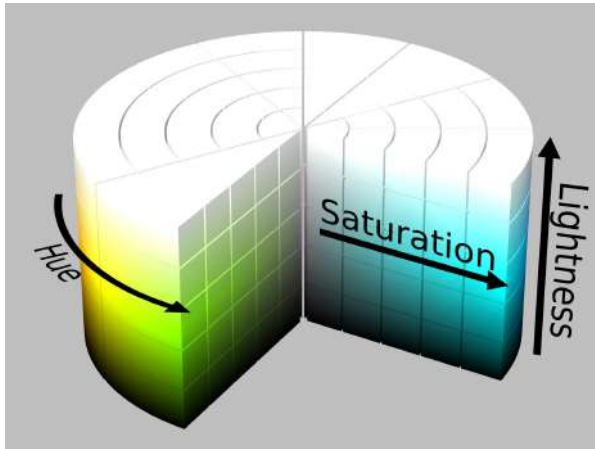
- hex representation: **RRGGBB**

RGB	hex	color
(0, 0, 0)	000000	black
(255, 255, 255)	FFFFFF	white
(255, 0, 0)	FF0000	red
(0, 64, 0)	004000	dark green
(255, 255, 0)	FFFF00	yellow

HSL

- *HSL*: Hue, Saturation, Luminosity
- humanistic additive color scheme
- based on transmitted light
- same range as RGB

HSL Colors

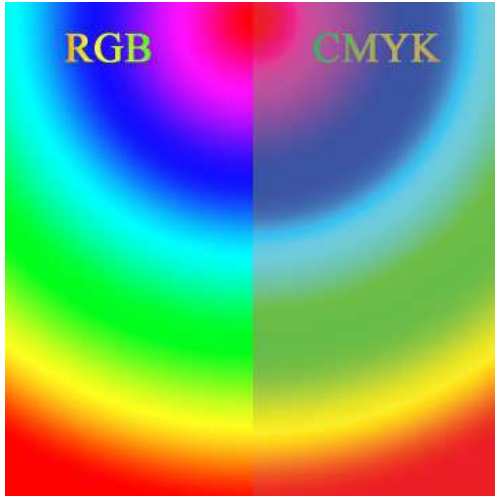


(Image from Wikimedia Commons)

CMYK

- *CMYK*: Cyan, Magenta, Yellow, Key Black
- subtractive color scheme
- based on tints of reflected light
- ~ 20% of perceivable colors
- how printers work

sRGB vs CMYK



(Image from Wikimedia Commons)

Resolution

- what is the size of a pixel?
- *resolution*: number of pixels per unit length
- *ppi*: pixels per inch
- also called *dpi*: dots per inch
- monitors have fixed resolution (~70ppi)
- resolution is important when printing (≥ 300 ppi)

Resolution and Size

- same width and height:
- higher resolution → smaller pixels
- lower resolution → larger pixels

Raster Formats

- *BMP*: header + color values
- grayscale / RGB
- *GIF*: indexed
- 256 colors

Compressed Formats

- use compression to get smaller file size
- e.g. run-length encoding (RLE)
- lossless: possible to get back to original data
- lossy: not possible to get back to original data
- *PNG*: versatile, compressed, lossless
- *JPG*: photolike compression, lossy

Common Raster Operations

- scale
- resize
- flip
- rotate
- crop
- filters: blur/sharpen, edge detect, lens flare, ...


Advanced Raster Operations

- brushes (opacity, size, shape)
- color picking (background & foreground)
- selection (square, all, fuzzy, freehand, grow, shrink)
- layers, transparency

Printers

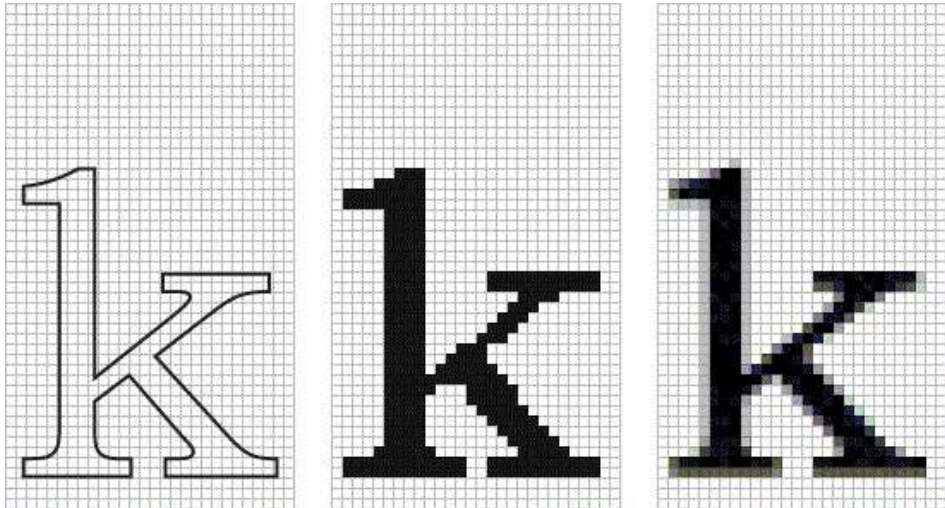
- character printers
- dot-matrix printers
- vector printers

ystem where a
ld allow us to
mercial supplier.



(Image: Fourfour CC BY-SA 2.5)

Aliasing



(Image: Wikimedia Commons)

Raster vs Vector

	raster	vector
primitive element	pixel	path, shape
good for	photorealism	drawings
bad for	scaling	detail
typical format	BMP, PNG, JPG	SVG, PDF
example software	GIMP, PhotoshopInkscape, CorelDraw	

Raster vs. Vector

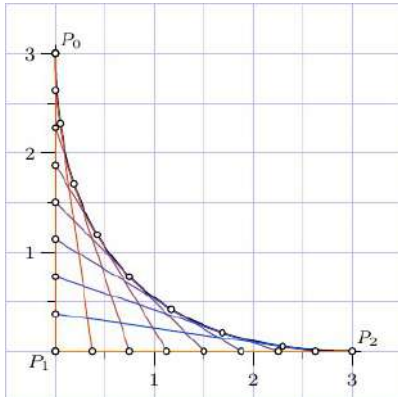
<https://openclipart.org/detail/219677/world-flags-globe>



Vector Image Primitives

- *shapes* (“objects”)
- *paths*
 - dots
 - lines
 - curves

Bezier Curves



(Image: Wikimedia Commons)

Vector Graphic Definition Languages

- *PostScript*: printers
- *TikZ*: typesetting (LaTeX)
- *SVG*: web

PostScript Example

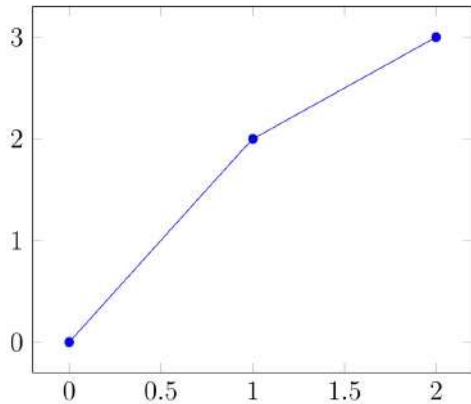
```
%!PS  
/Palatino-Roman 20 selectfont  
300 400 moveto  
(Hello, World!) show  
showpage
```

- *evolution*: ps → eps → pdf

TikZ Example

```
\begin{tikzpicture}  
  \begin{axis}  
    \addplot+[sharp plot] coordinates  
      {(0,0) (1,2) (2,3)};  
  \end{axis}  
\end{tikzpicture}
```

TikZ Example



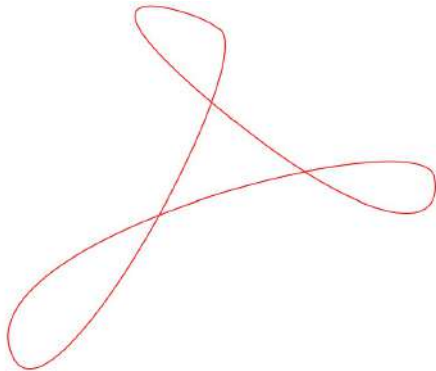
SVG Commands

- *M* : moveto
- *L* : lineto
- *C* : curveto
- ...

SVG Example

```
<!DOCTYPE html>
<html>
  <body>
    <svg height="400" width="400">
      <path stroke="red" fill="none"
        d="M200,20
          C250,30 50,400 20,300
          S380,100 390,150
          S330,200 190,80
          S195,10 200,20"
      />
      Cannot render inline SVG
    </svg>
  </body>
</html>
```

SVG Example



Advanced Vector Operations

- stroke & fill
- transform
- align & distribute
- path set operations
- text on path
- converting: vector \leftrightarrow raster