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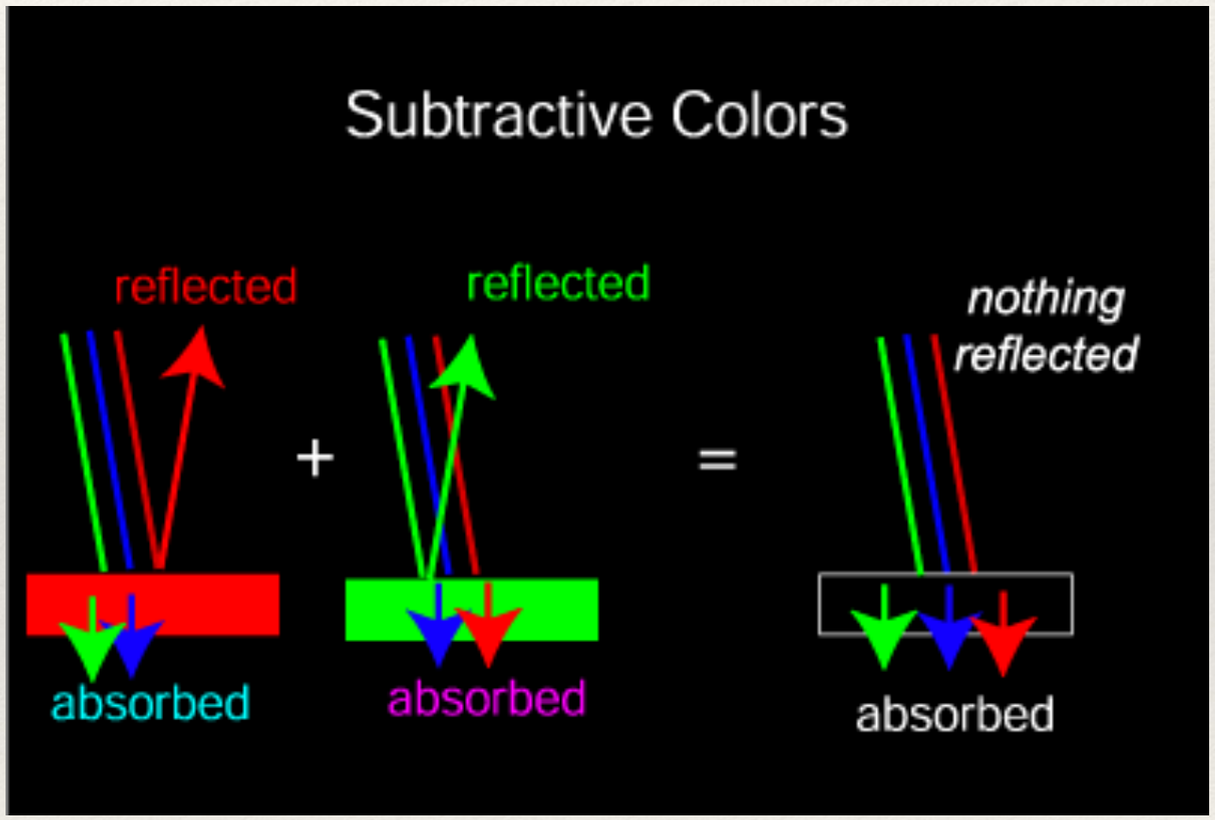
Color

Elements of Graphics
CS324e

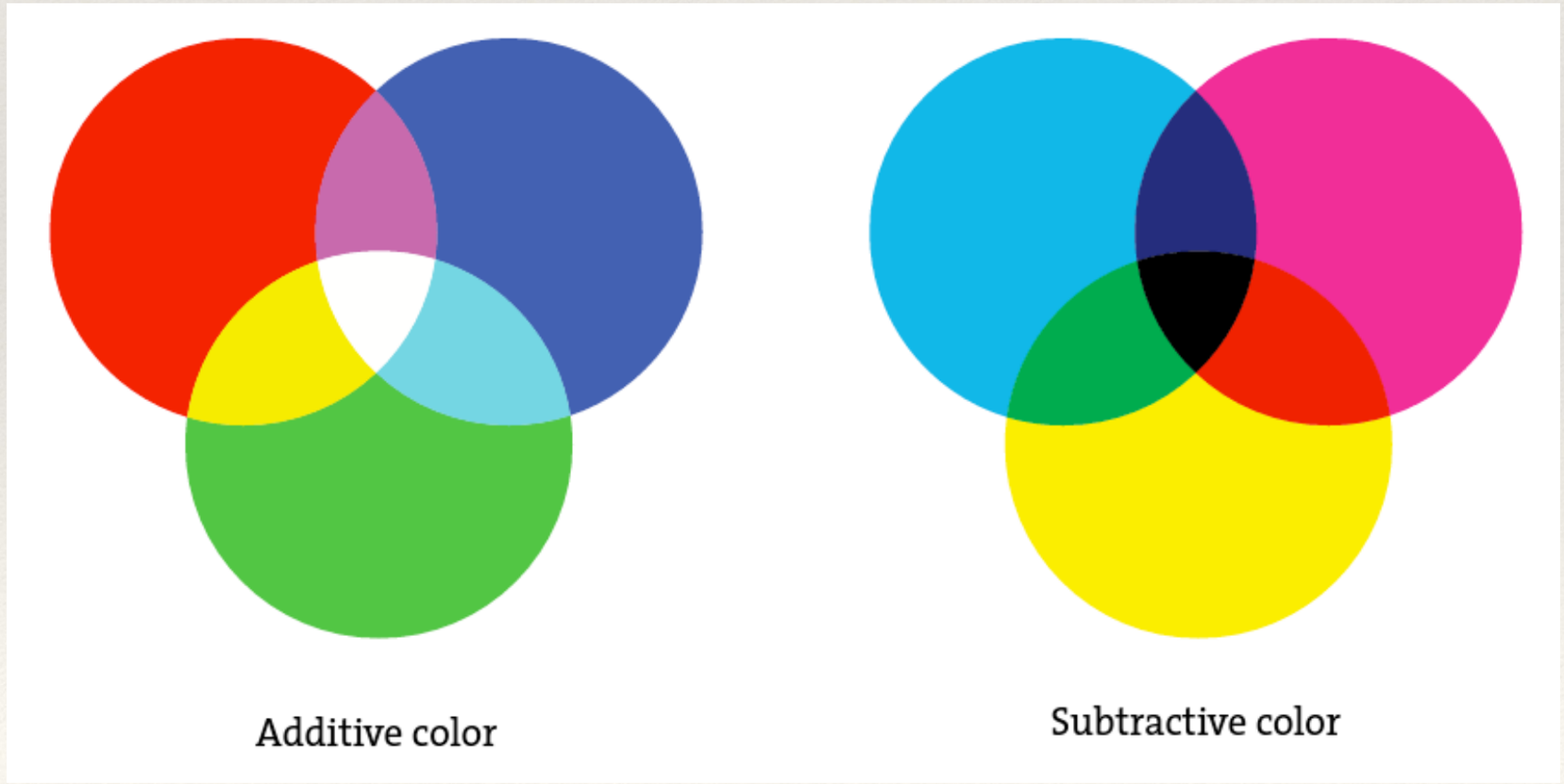
Color Models

- Final color derived from combination of light sources
- Additive color models add light sources
- Subtractive color models subtract light sources



Additive vs Subtractive

- Painting is subtractive (white surface)
- Computer monitors are additive (black surface)



Digital Color

- Each pixel has three light elements:
  - Red
  - Green
  - Blue
- Light element intensity range from 0 to 255
  - 0 means color has least intensity
  - 255 means color has highest intensity

RGB

- Red: (255, 0, 0)
- Green: (0, 255, 0)
- Blue: (0, 0, 255)

- Colors at full opacity tend to be a little garish!
- Processing includes a color selector for more intuitive color selection if you don't have access to digital paint program

Hexadecimal

- Color notation useful for HTML and CSS
- RGB color (0 - 255) encoded as a two-digit base 16 value
- Examples:
  - #000000 <==> (0, 0, 0)
  - #FFFFFF <==> (255, 255, 255)
  - #6699CC <==> (102, 153, 204)

Color Depth

- 1 bit can represent 2 values (2^1)
- 2 bits can represent 4 values (2^2)
- 4 bits can represent 16 values (2^4)

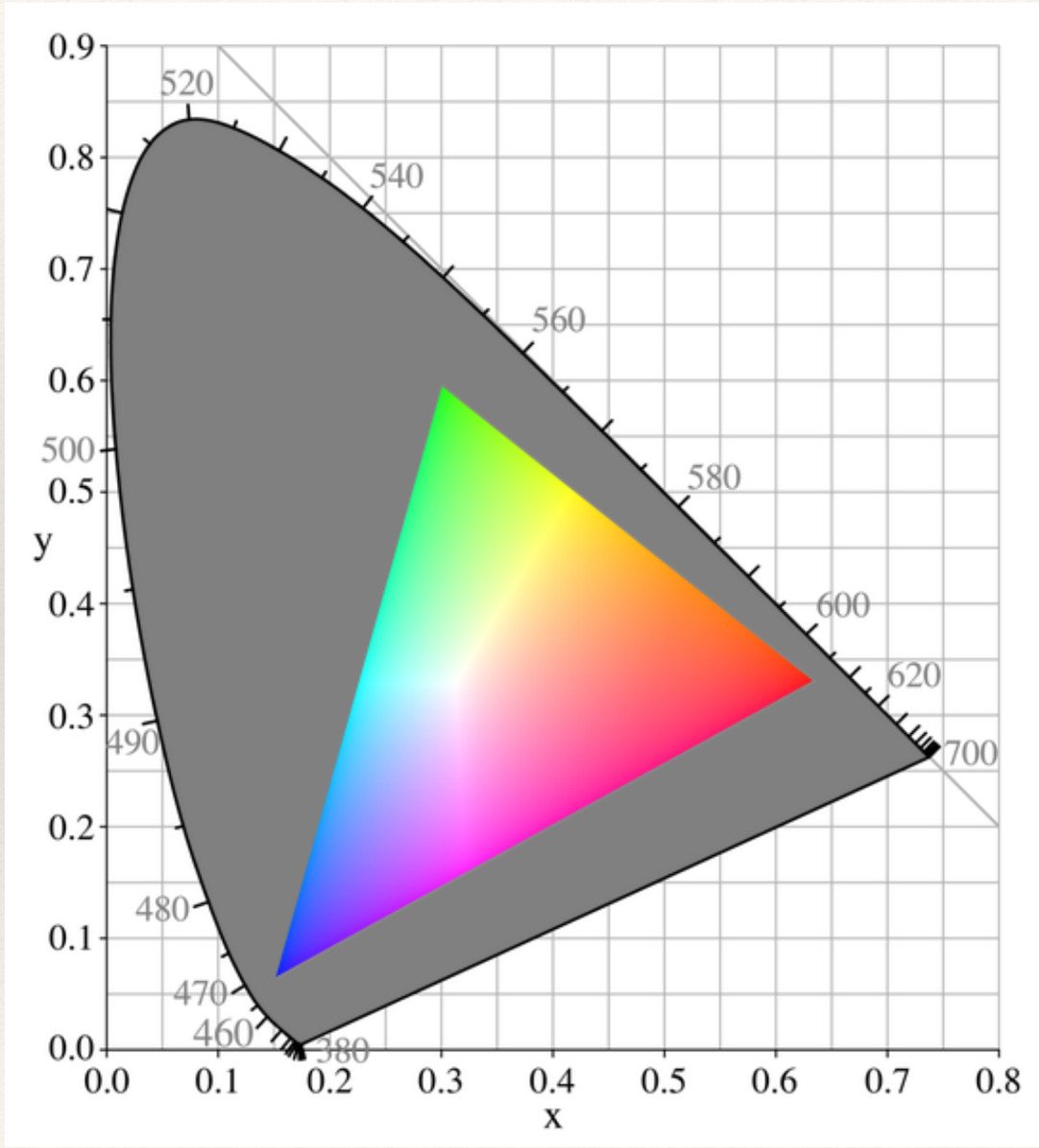
Question

- How many color values can 8-bits represent?
- Answer: 256 (2^8)

True Color

- Supports three 8-bit channels (RGB)
  - RGBA adds a fourth channel for alpha (transparency)
- RGB supports 24-bits total or 16,777,216 values (2^{24})
- The human eye can discriminate around 10M colors

- Note that any RGB model is limited to colors within the RGB gamut — such models cannot represent all human-visible colors!



RGB colors within the CIE colorspace

Image Formats

- GIF
  - Color depth: 1-bit to 8-bit
  - Transparency: 1-bit
- JPEG
  - Color depth: 24-bit
  - Transparency: None
- PNG
  - Color depth: 1-bit to 24-bit
  - Transparency: 8-bit

Setting Color in Processing

- `background(int red, int green, int blue)` sets the color of the window in terms of RGB
- `fill(int red, int green, int blue)` sets the color for any subsequent shape primitives
- `fill(int red, int green, int blue, int alpha)` includes a transparency channel to modify opacity

Using the color Primitive

- Processing has a special primitive for color:
  - `color(float red, float green, float blue);`
  - Can be used in `fill`, `stroke`, `background` functions

Consider…

```
color c = color(255.0, 255.0, 0.0);

fill(c);

rect(0, 0, 200, 200);
```

Transparency and Blending

- Transparency (alpha channel) also ranges from 0 to 255
- Transparency allows for on-screen color mixing based on the blend mode
- Default blend mode is BLEND
  - `blendMode(BLEND)`



ADD

Additive blending with maximum value of white:

```
C = min(A*factor + B, 255)
```



SUBTRACT

Subtractive blending with minimum value of black:

```
C = max(B - A*factor, 0)
```



LIGHTEST

The lightest color is used:

```
C = max(A*factor, B)
```



DARKEST

The darkest color is used:

```
C = min(A*factor, B)
```



MULTIPLY

Multiply the colors, result will always be darker:

```
C = A * B
```

A

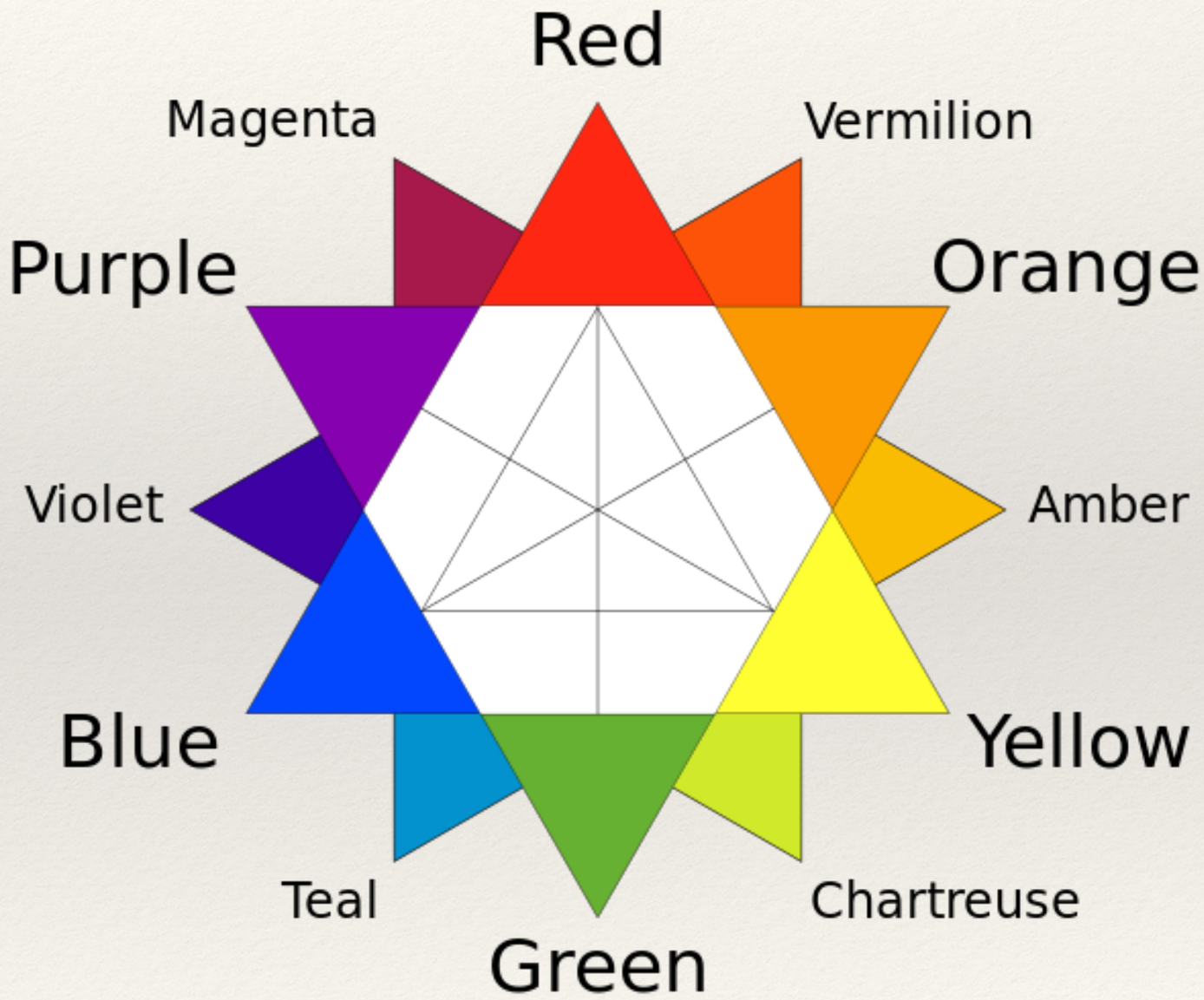
B

C

A is source image
B is destination image
Factor is source alpha

Color Theory

- The study of color interactions
  - Color classification
  - Color mixing
  - Color design
  - Cultural context



RYB color model: primary, secondary, tertiary

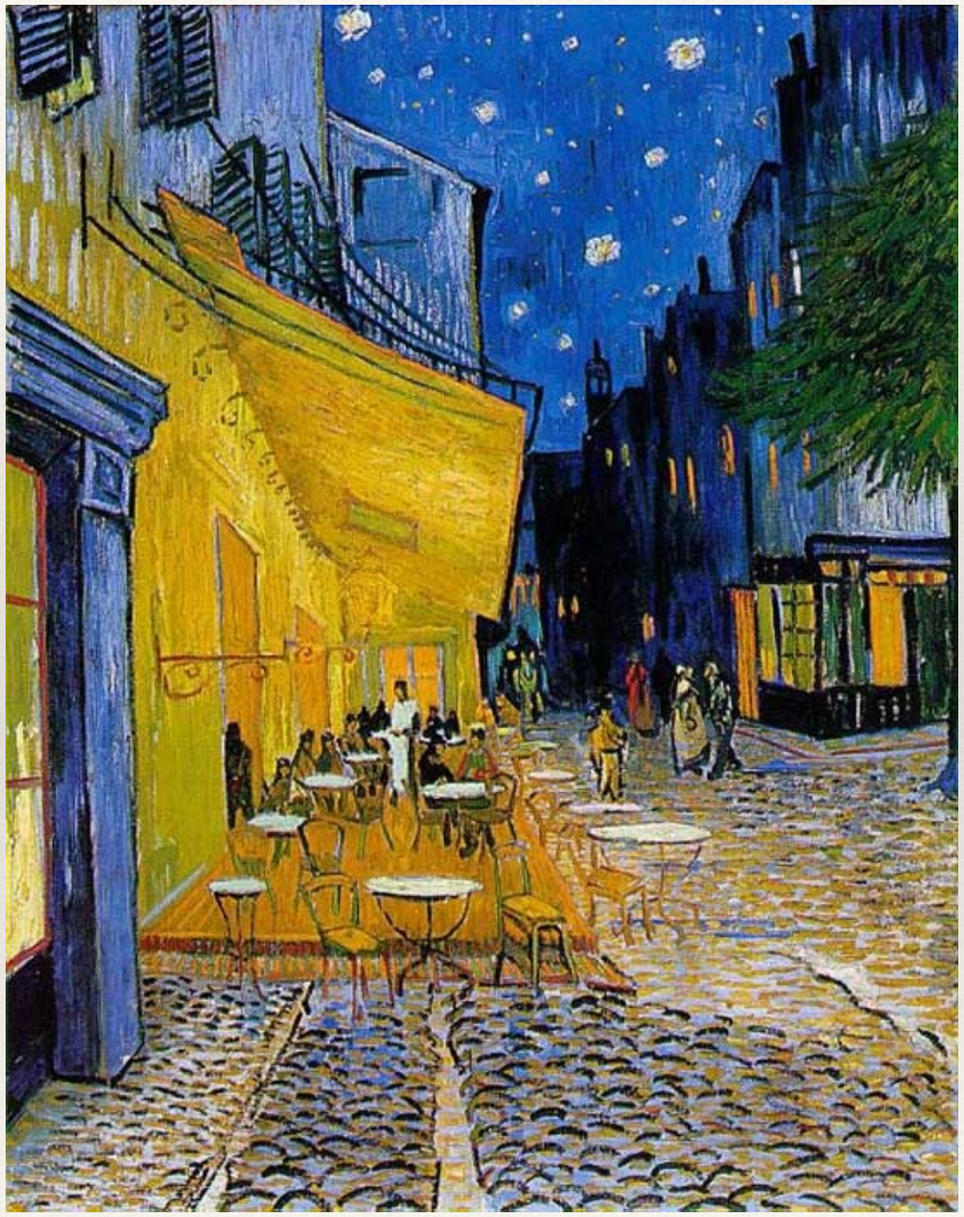
Achromatic and Monochromatic

- Achromatic colors schemes are neutral (white, black, gray)
- Unsaturated colors are near neutral (tans, pastels)
- Monochromatic schemes focus on value using a single hue

Picasso

Complementary

- Complementary schemes use colors on opposite ends of the color wheel
  - High contrast
  - Dramatic
  - Forces eye movement



Van Gogh

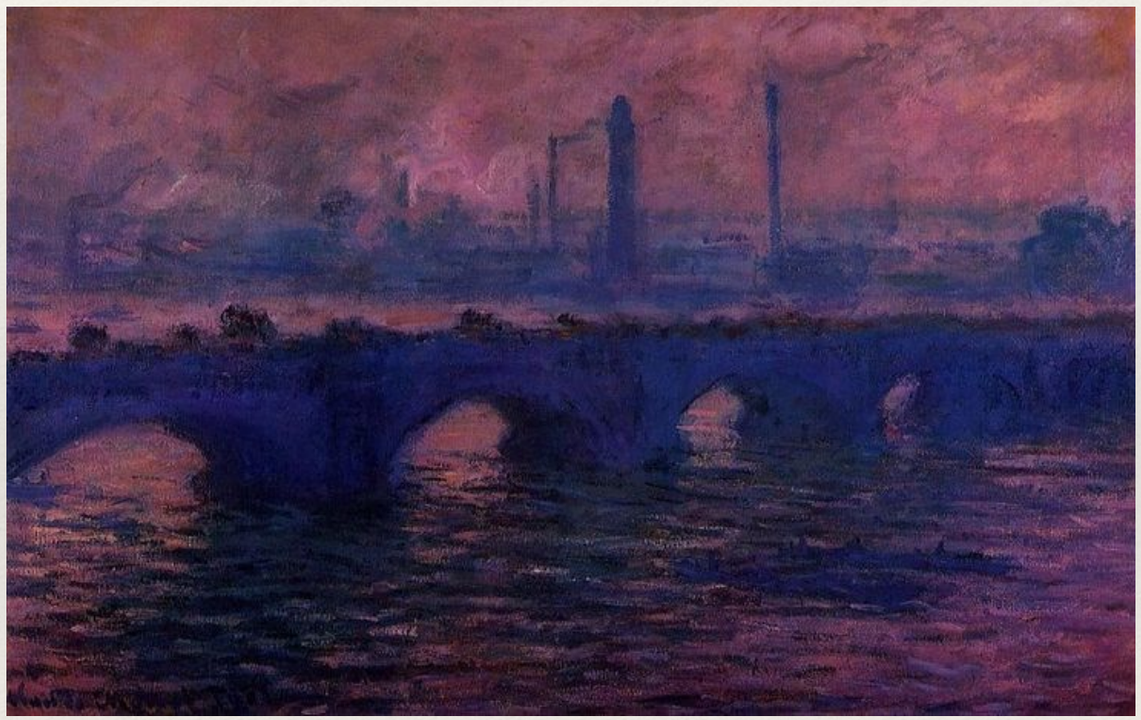
Split Complementary

- Split complementary schemes use a color and the color adjacent to its complement
- Subtle contrast
- Balanced tension

Vermeer

Analogous

- Analogous schemes use adjacent primary, secondary or tertiary colors
- Harmonious
- Moody



Monet

Color Triad

- Triadic schemes use three equidistant colors along the wheel
- Balanced
- Vibrant

Rubens

Hands-on: Using Color

- Today's activities:

  1. Use Processing's color picker to incorporate multiple colors via `fill` and `stroke`
  2. Store `color` primitives in an array for reuse
  3. Use `blendMode` to affect color interactions
  4. Create an image using one of the color theory schemas listed after this slide: achromatic, monochromatic, complementary, split complementary, analogous, color triad, tetrad, or square