COLOUR, COLOUR MODELS AND IMAGES

2011 Introduction to Graphics, Lecture 2

Overview

- Colour
  - Properties of the eye
- Colour models
  - RGB, HSV
- Dithering
- The story in Java2D

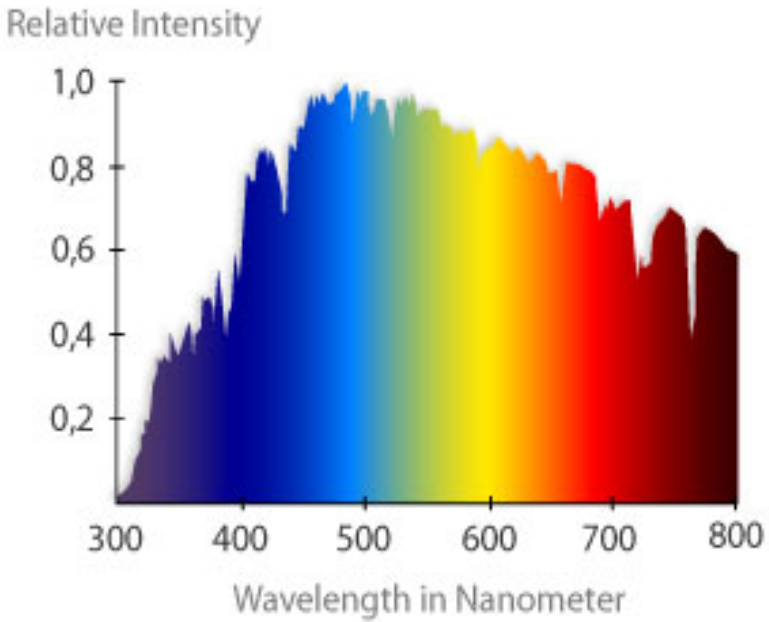
Light

- Radio
- Infrared
- Visible

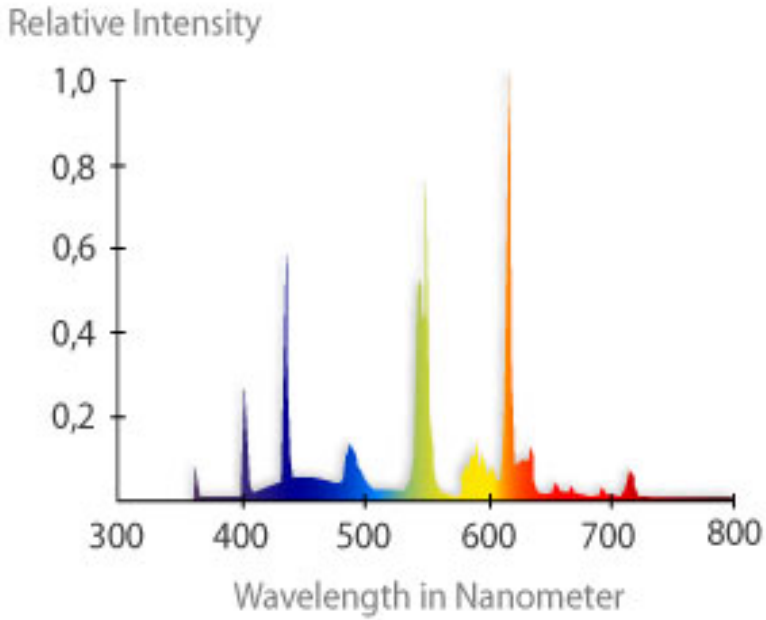
  red (wavelength 700 nm),
  orange, yellow, green,
  blue, indigo,
  violet (400 nm)

- Ultraviolet
- X-Ray …

Light Spectra

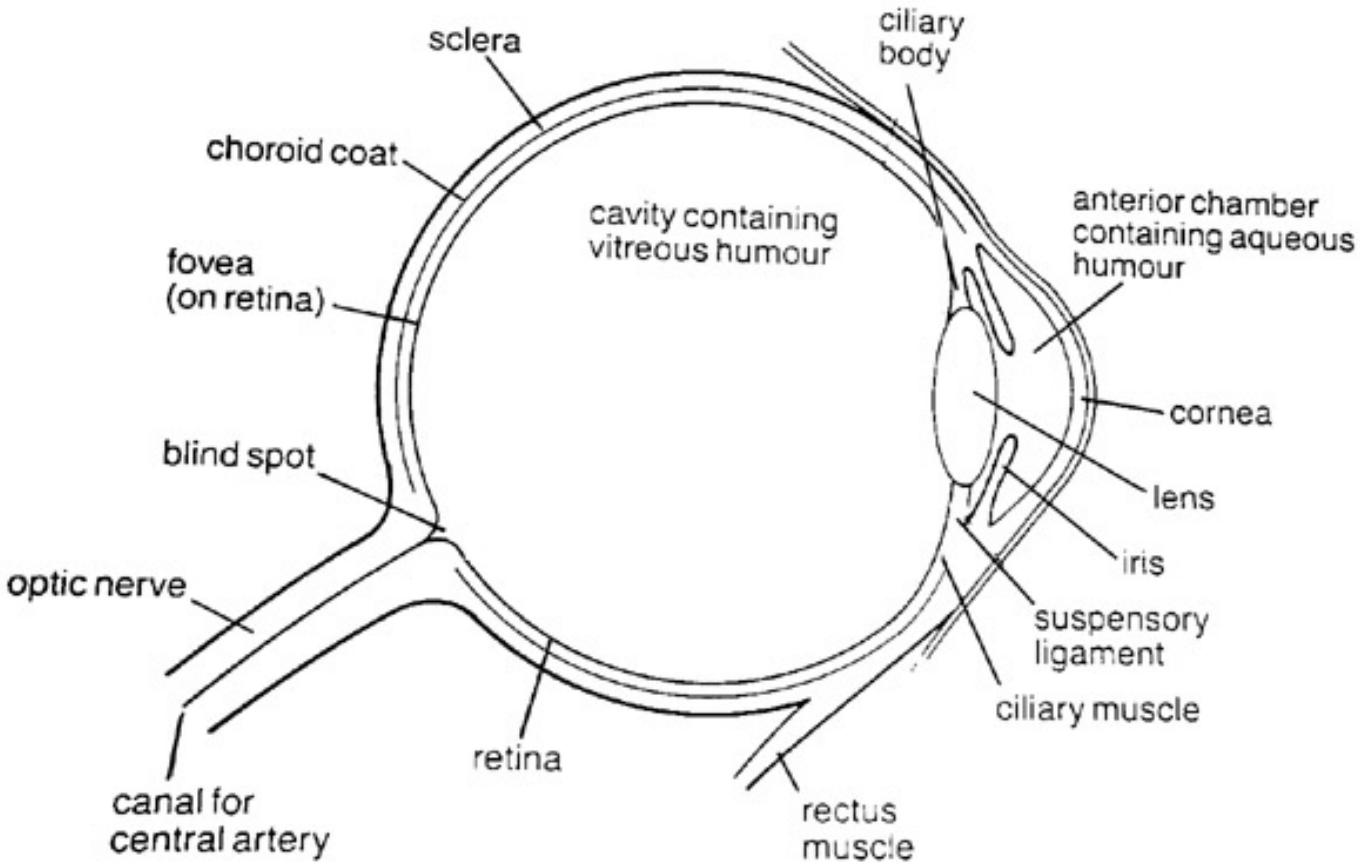


sunlight over Germany – July 2005
5850° Kelvin – CRI 99



ordinary energy saving lamps
4200° Kelvin – CRI 83

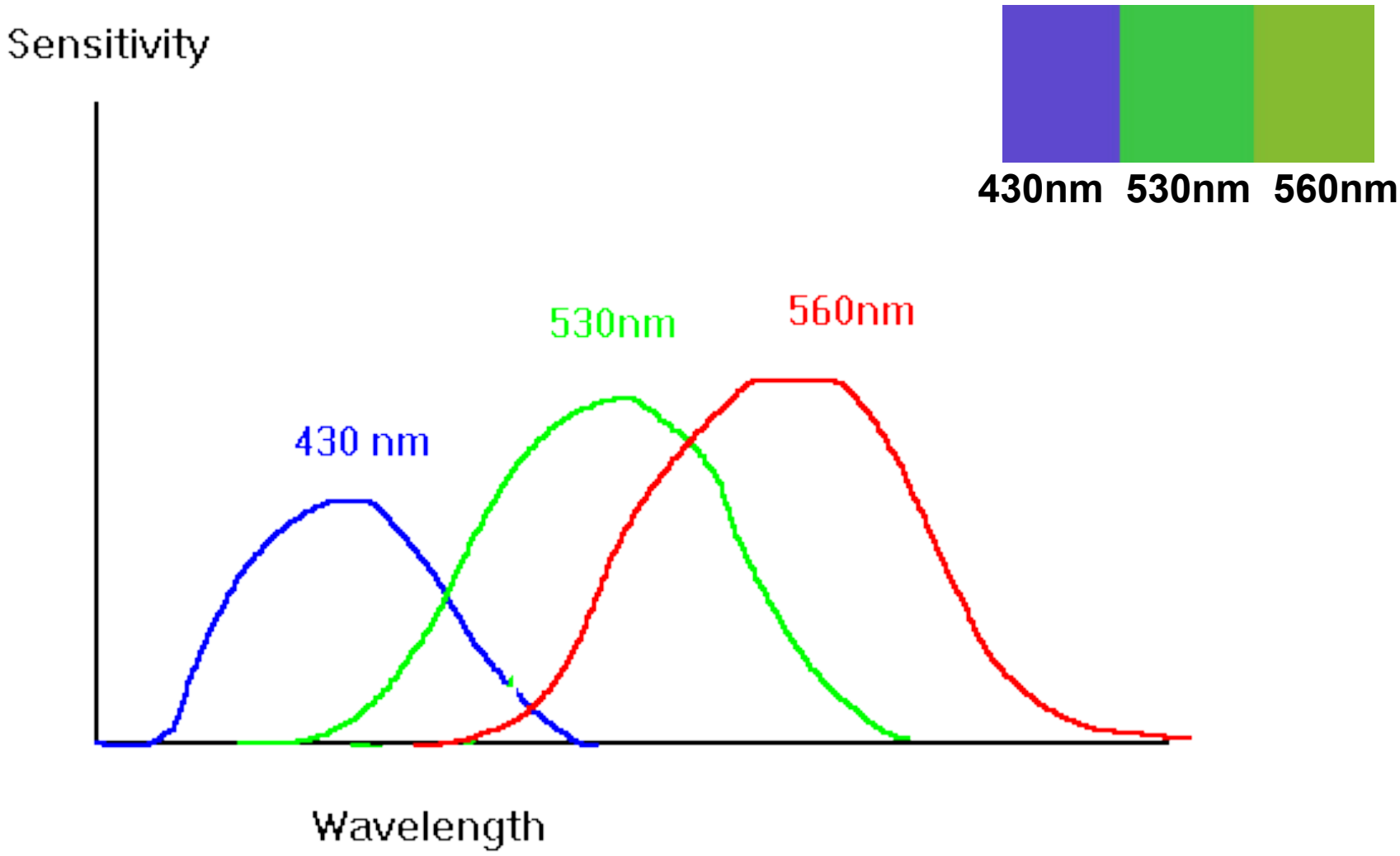
Eye


sclera
ciliary body
choroid coat
cavity containing vitreous humour
anterior chamber containing aqueous humour
fovea (on retina)
cornea
blind spot
lens
iris
optic nerve
suspensory ligament
ciliary muscle
retina
canal for central artery
rectus muscle

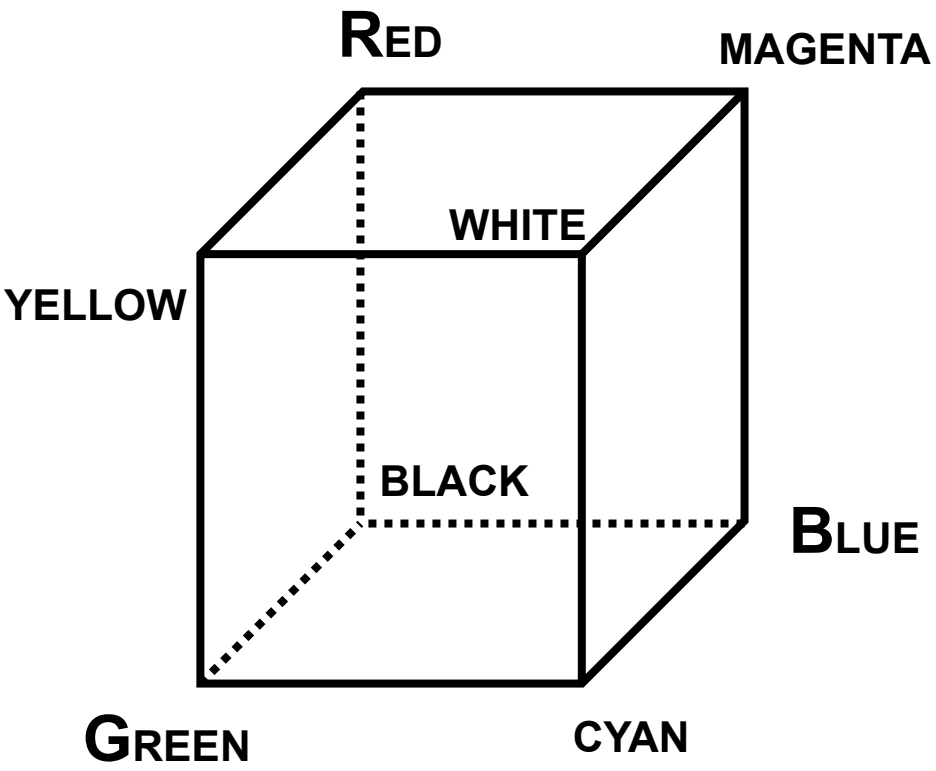
Physiology of Eye Response

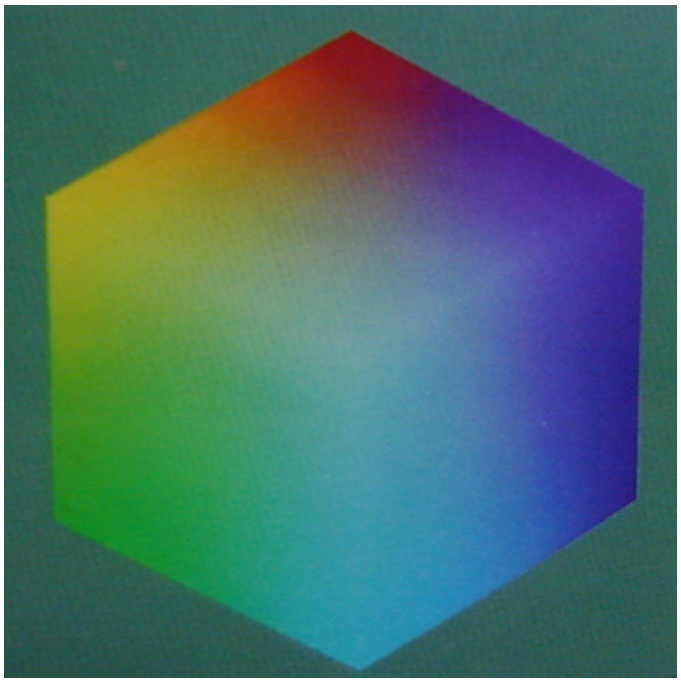
- 6 million cones in the fovea
  - cones sense red, green or blue light
  - colour perception region is very small
- 120 million rods over the whole eye
  - peripheral vision
  - motion sensitive

Eye Response



RGB Colour Model





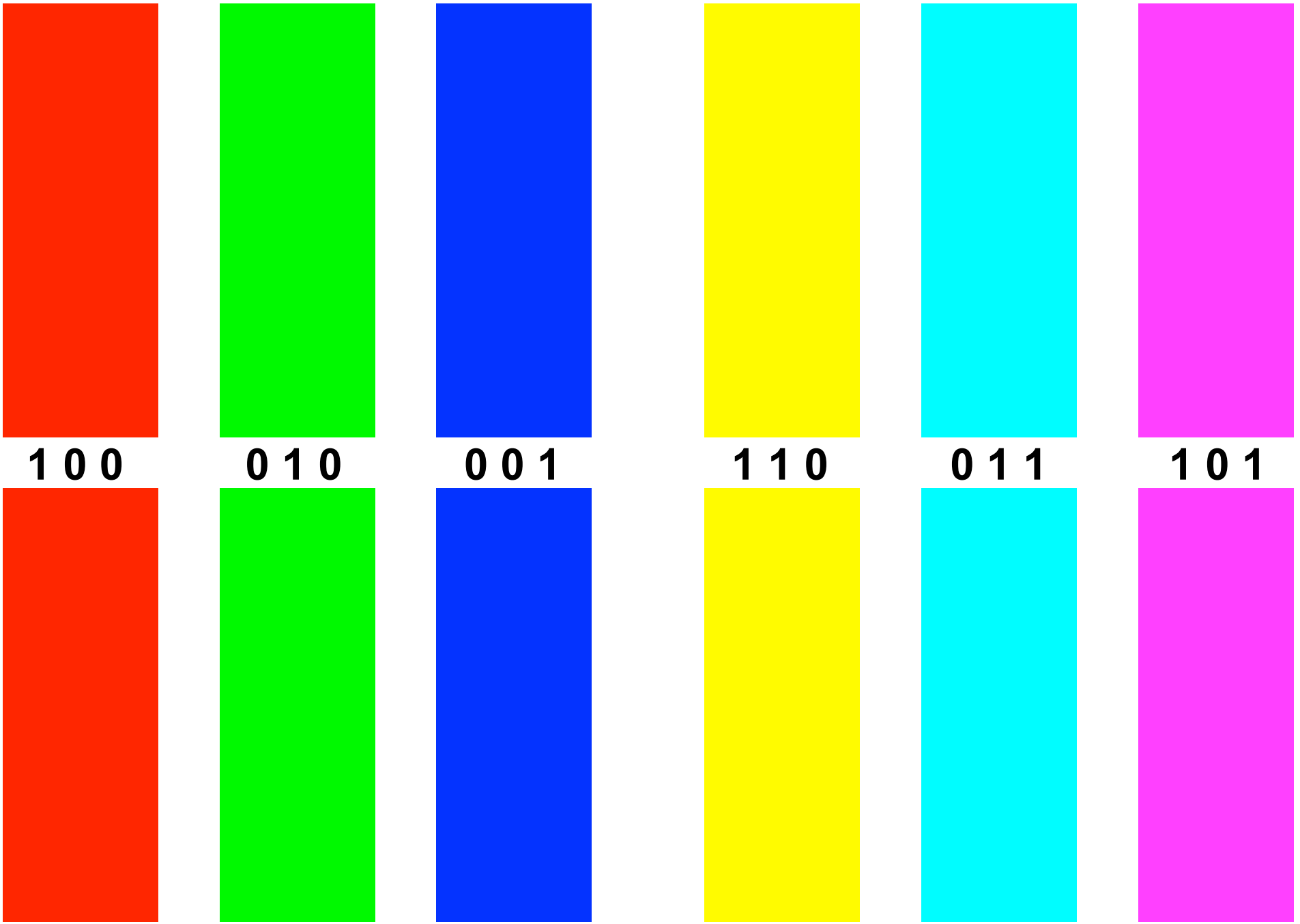
Colours

- Additive Colour
  - Superimposing light frequencies
  - Superimposing all frequencies = white
  - Red + green = yellow
- Subtractive Colours
  - Like mixing paint
  - Subtracting light frequencies from white
  - E.g., red colour subtracts everything **but** red

Additive vs. Subtractive Colours

- Additive

- Subtractive


1 0 0
0 1 0
0 0 1
1 1 0
0 1 1
1 0 1

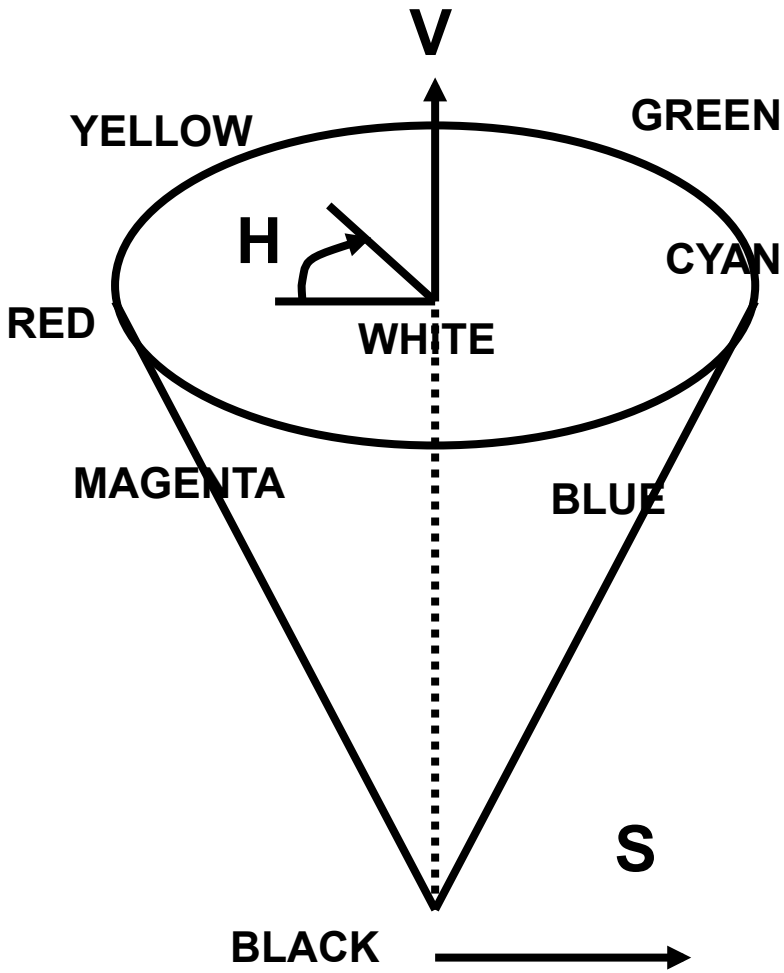
Printing vs. Displays

- What about printers?
  - Which base colours should they use?

Metamers

- Fundamental assumption of graphics displays is that because eye only generates three signals, many colours give the same response
- Two spectral distributions that generate the same perceptual response are **metamers**
- RGB generates reasonable metamers for a large, but **NOT** complete, range of possible spectral distributions

HSV Colour Model



Hue, Saturation, Value

- Hue (0 to 2PI)
  - the colour (dominant wavelength)
- Saturation (0 to 1)
  - the purity of the colour
  - impure -> white mix (spread)
- Value (0 to 1)
  - the intensity of the light (energy)

Why Use HSV?

- Better match to how people think of colour in terms of primary colour and then shades
- Better properties when interpolating between two colours

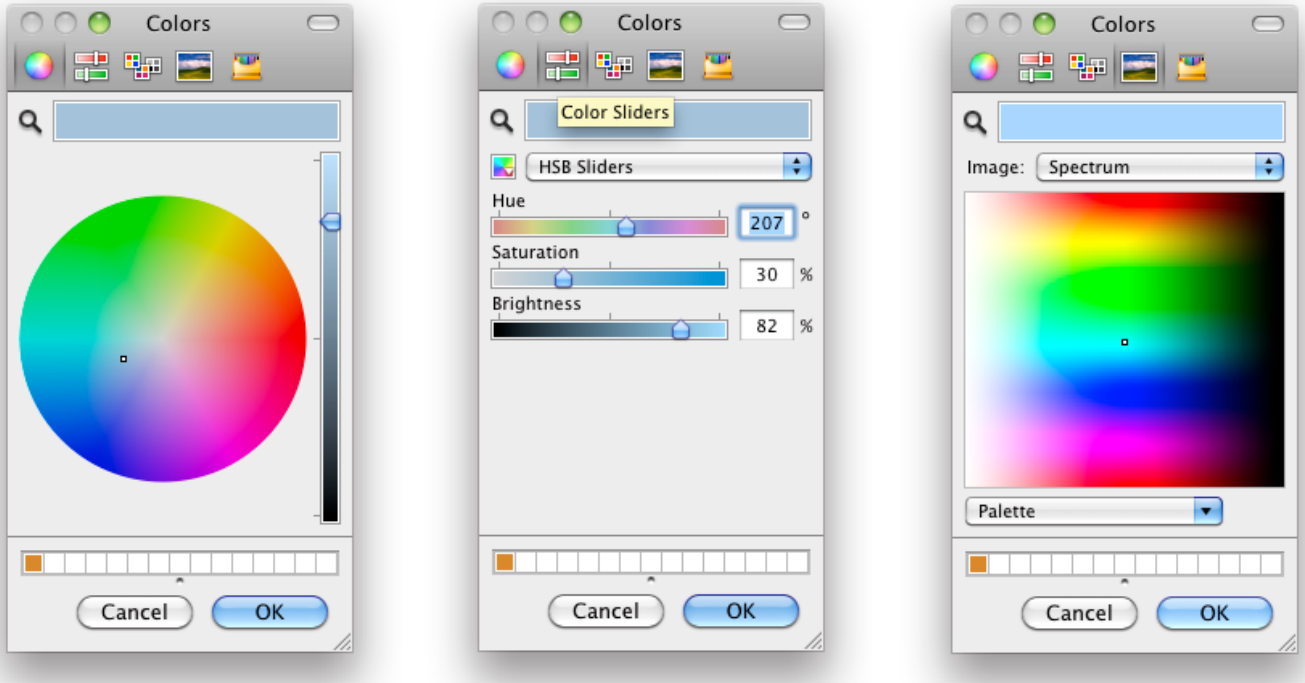
Other Common Color Spaces

- **Lab**
  - "Perceptual" colour space
  - Separate L luminance from chroma (a,b)

- XYZ
  - CIE "standard" colour space
  - Encompasses all colours visible to average person
  - Does *not* correspond to R,G,B nicely

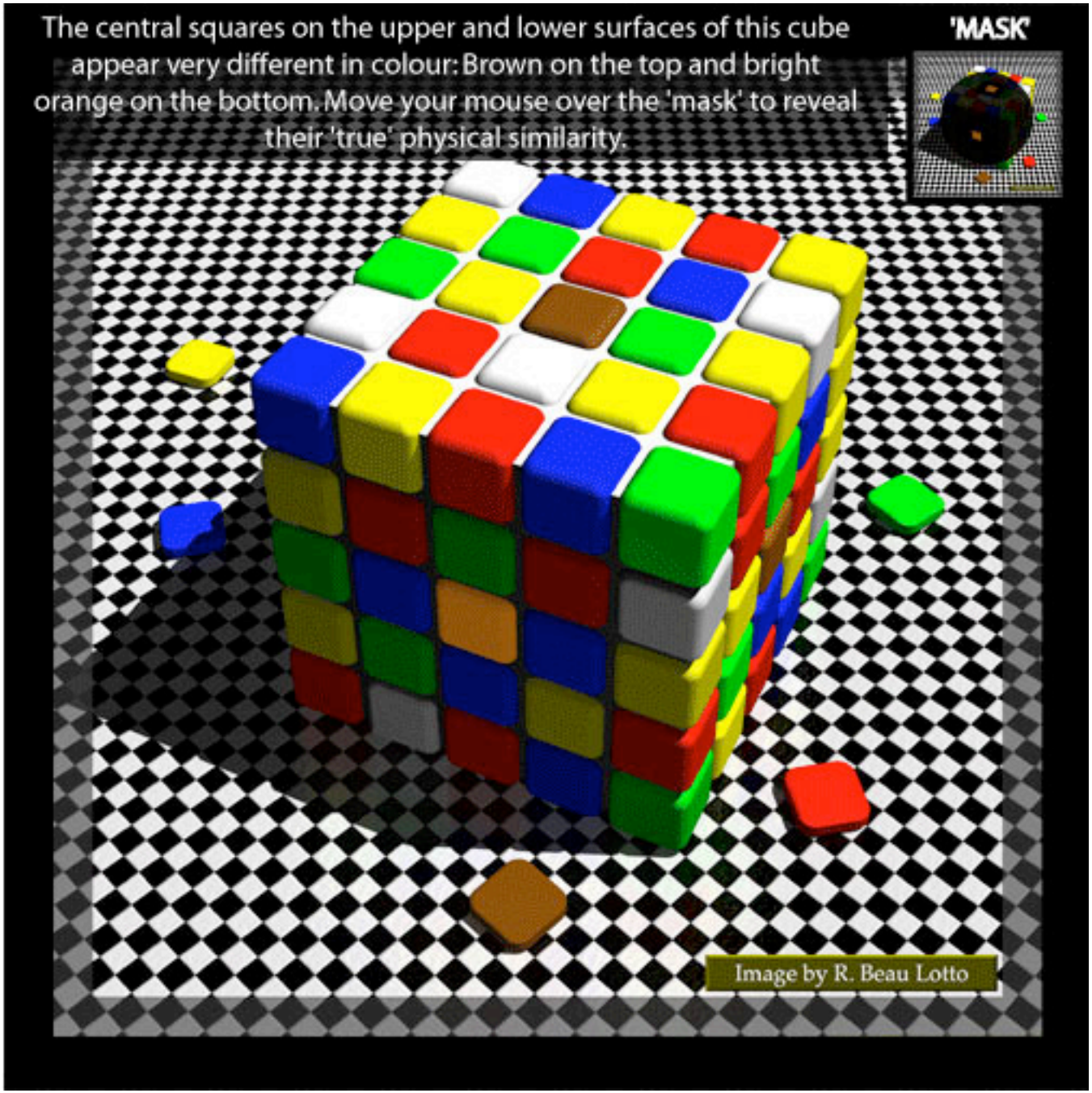
Common Interface

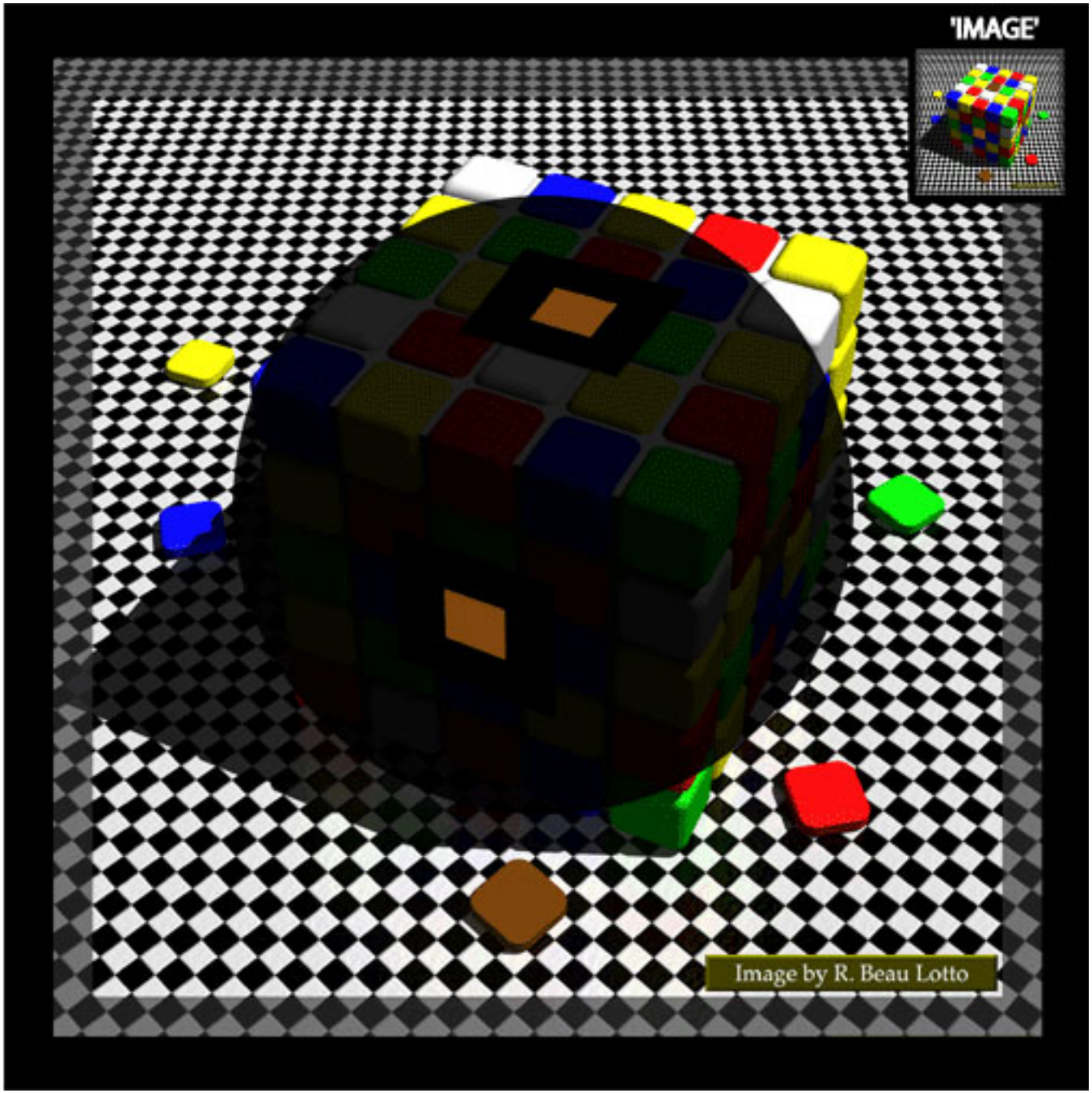
- Powerpoint:

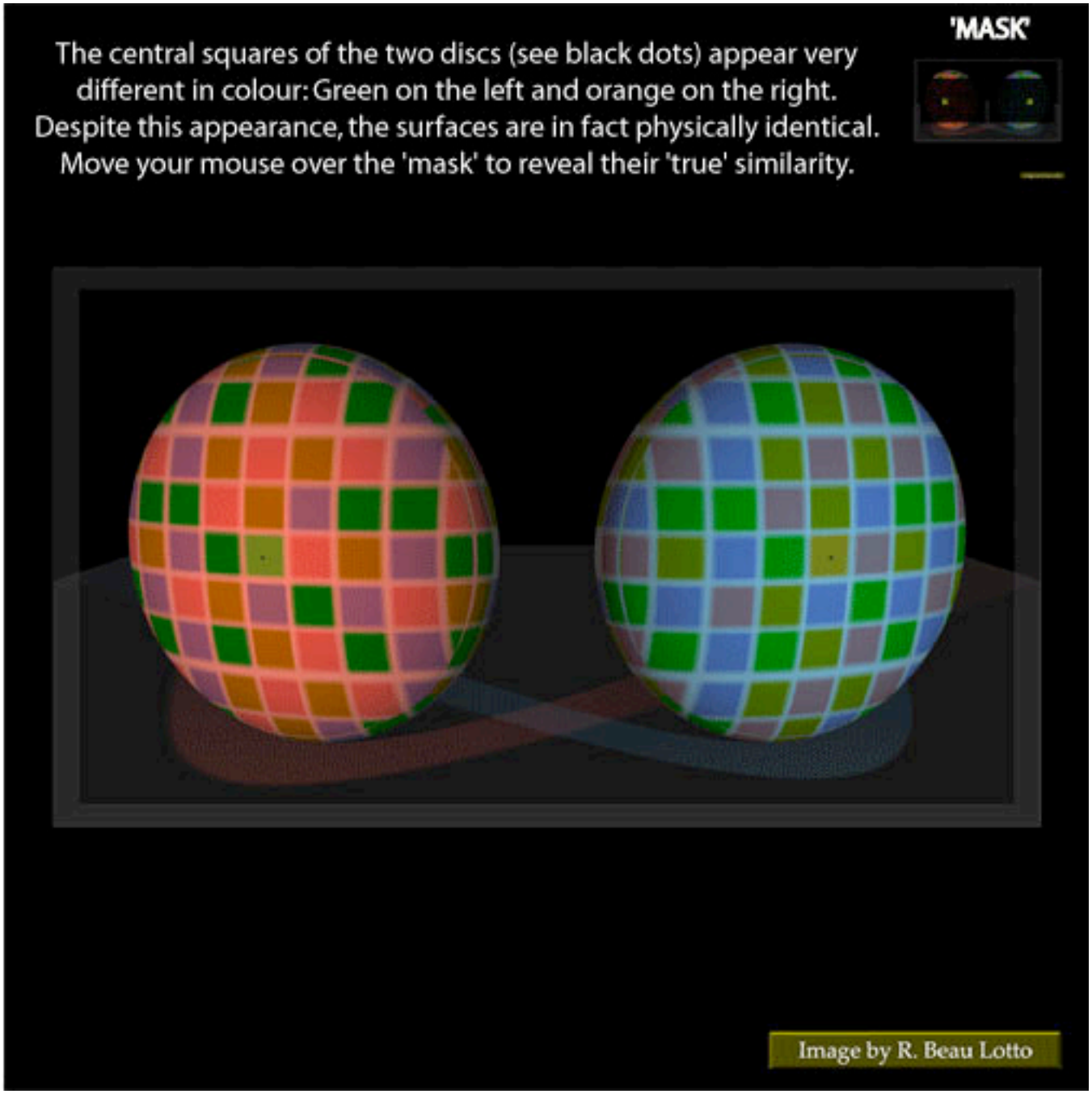


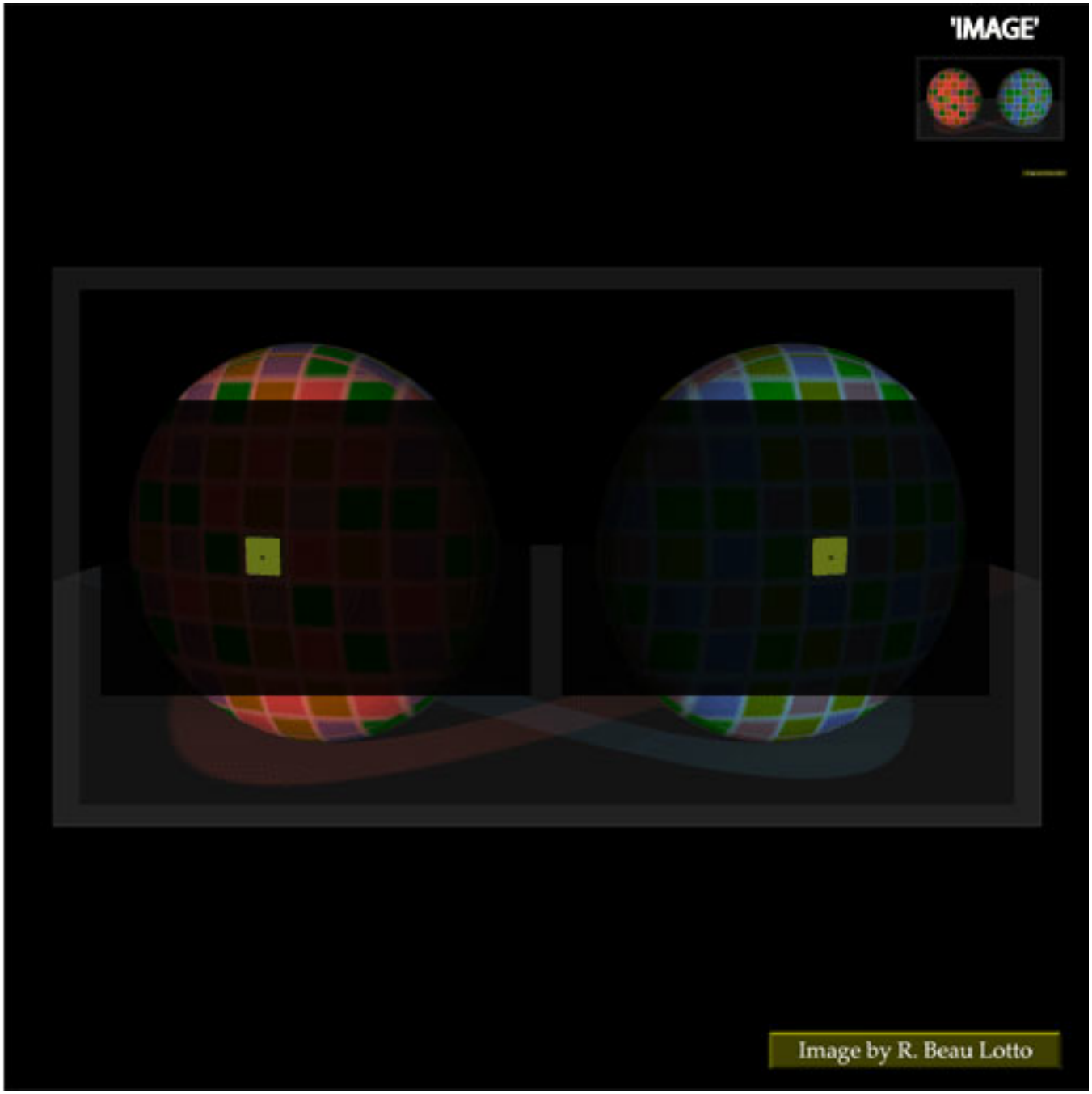
OPTICAL ILLUSIONS

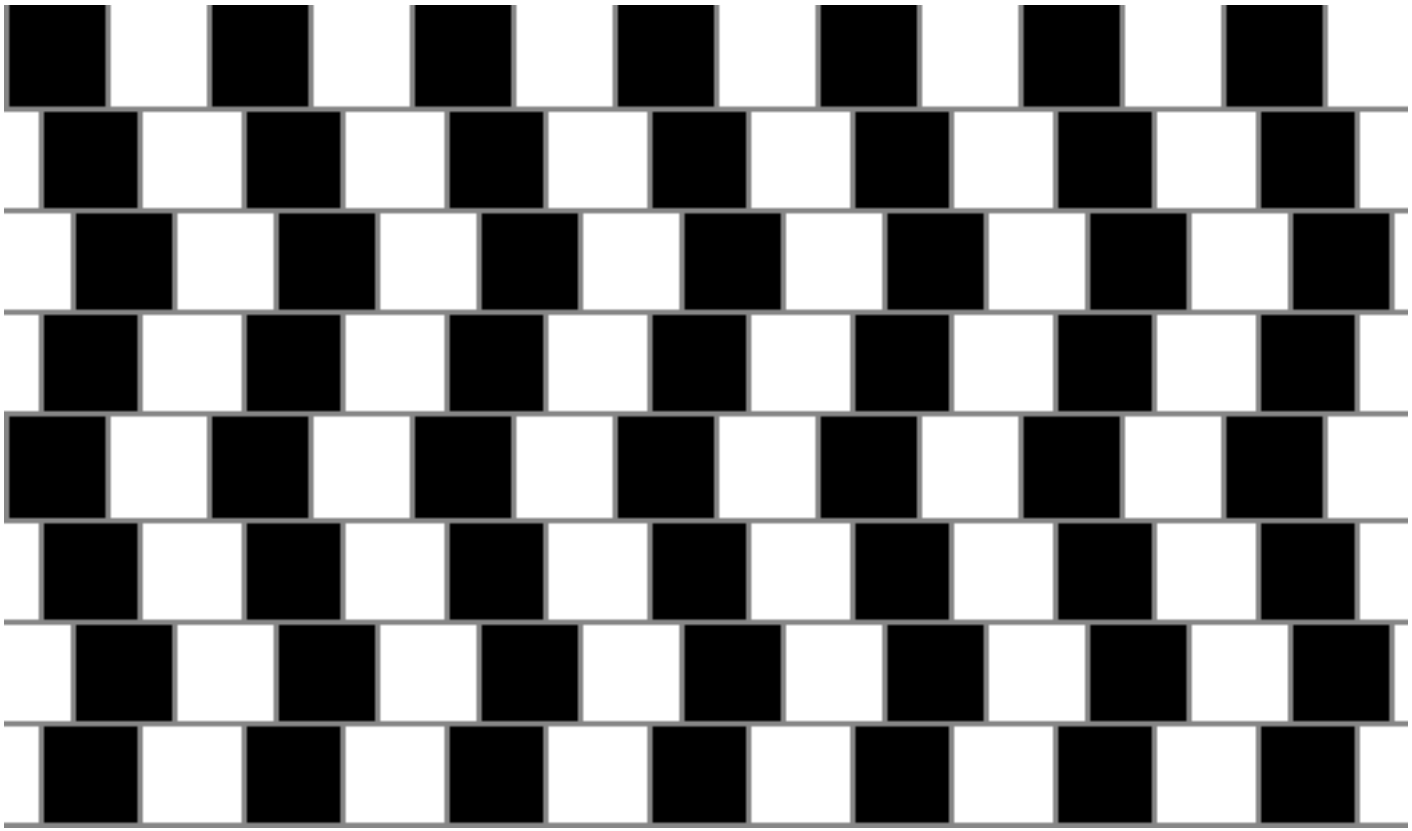
Interlude

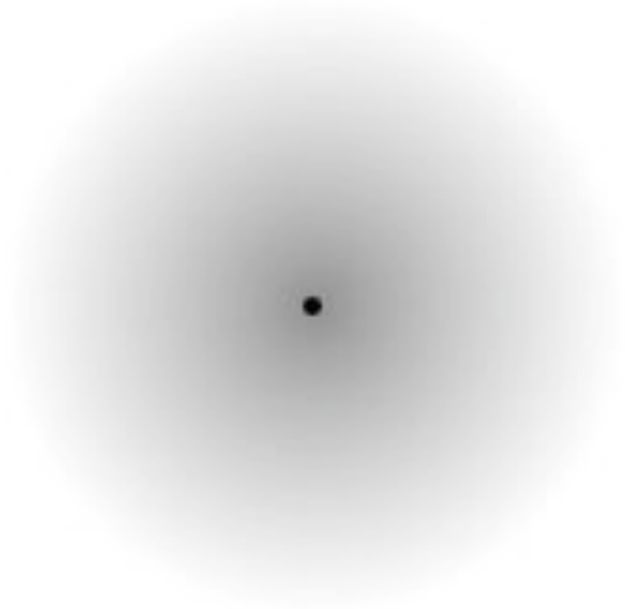

The central squares on the upper and lower surfaces of this cube appear very different in colour: Brown on the top and bright orange on the bottom. Move your mouse over the 'mask' to reveal their 'true' physical similarity.
'MASK'
Image by R. Beau Lotto


'IMAGE'
Image by R. Beau Lotto


'MASK'
The central squares of the two discs (see black dots) appear very different in colour: Green on the left and orange on the right.
Despite this appearance, the surfaces are in fact physically identical.
Move your mouse over the 'mask' to reveal their 'true' similarity.
Image by R. Beau Lotto


'IMAGE'
Image by R. Beau Lotto





IMAGES

Images

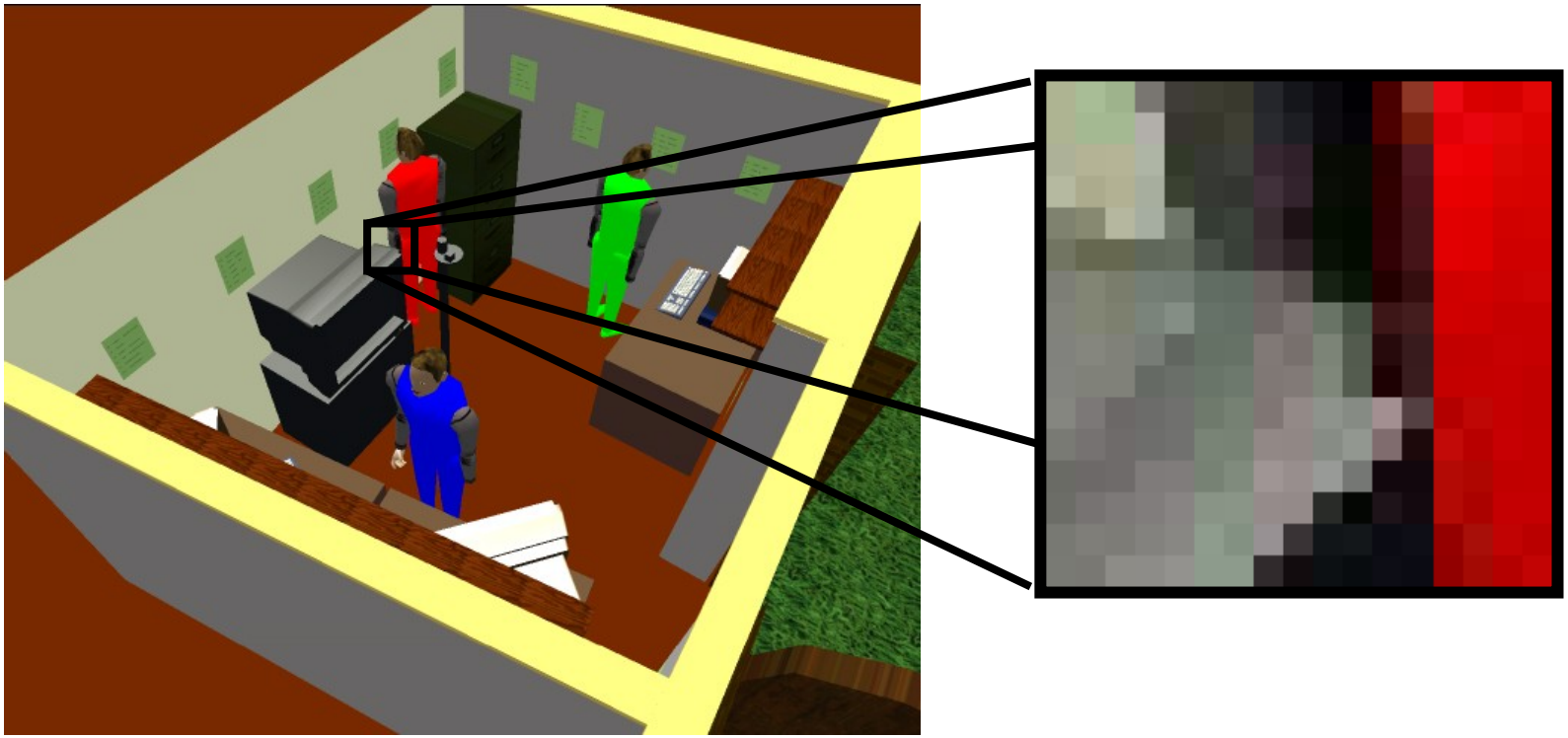


Image Formats

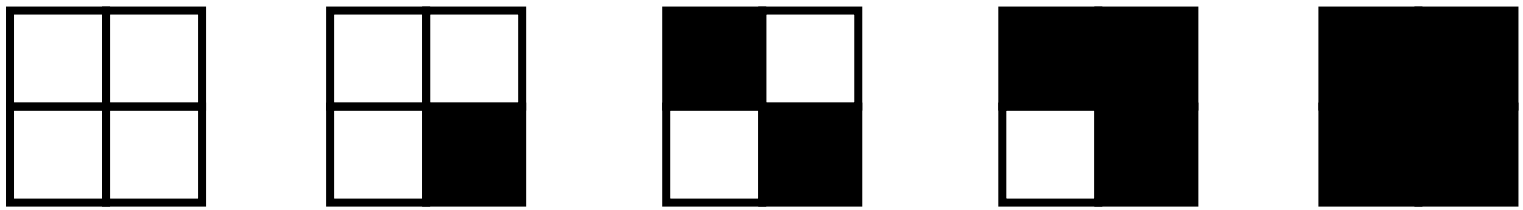
- Represent colour values in an array
- Standard format is RGB triples
  - R,G,B are bands or channels
- 24 bit (1 byte per colour)
  - R:0-255, G:0-255, B:0-255
  - 24 bits = ~16 million colours
  - interleaved or non-interleaved arrays
- 24bit sometimes called TrueColour

Compact Colour Modes

- RGB 16 bit
  - R: 5 bits, G: 6 bits, B: 5 bits
- RGB 10 bit
  - R:3 bits, G:4 bits, B:3 bits
- Note more bits for green since eye is more sensitive to colours in the green band of the visible light spectrum

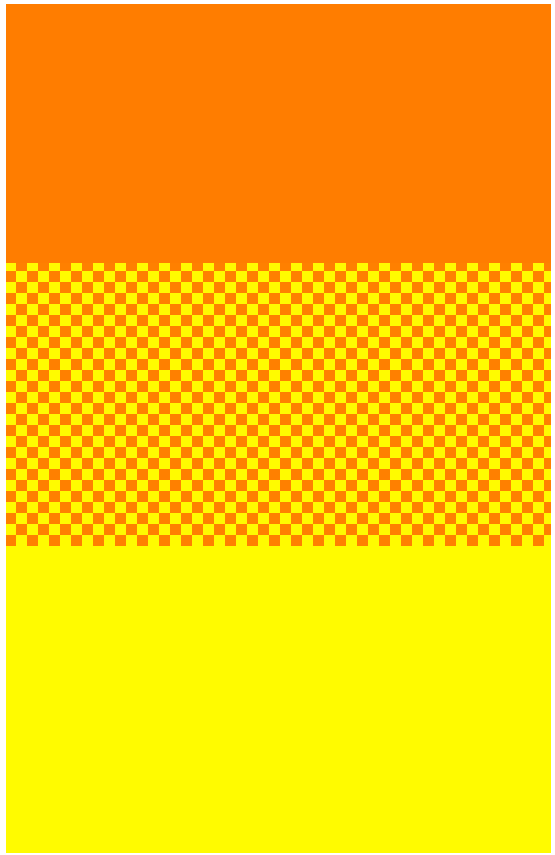
Dithering

- Can always trade spatial resolution for colour resolution
- Group blocks of pixels together to create new shades based on average colour
- E.G. 5 gray shades with 2x2 B&W



Dithering

- Works well with "nearby" colours
- E.G. combinging
  - 50% red
    - (255,0,0)
  - 50% orange
    - (255, 127, 0)



Dithering

- Examples 

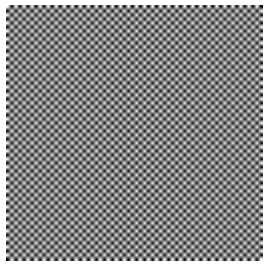
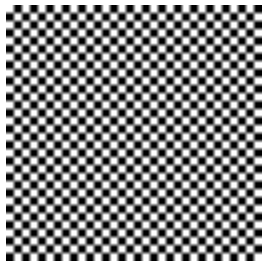
Original

2x2

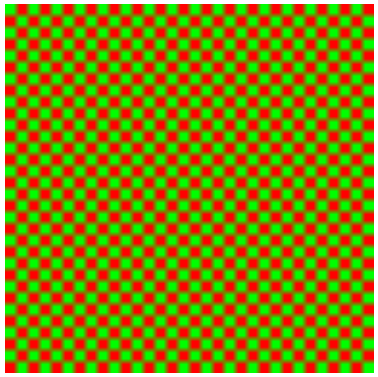
Floyd-Steinberg

Dithering

- High magnification ruins effect


- High colour contrast also ruins effect
  - 50% red and green v. solid (127,127, 0)




Summary

- Colour and properties of the eye
- Colour models
  - RGB, HSV
- Dithering – trading spatial resolution for colour resolution