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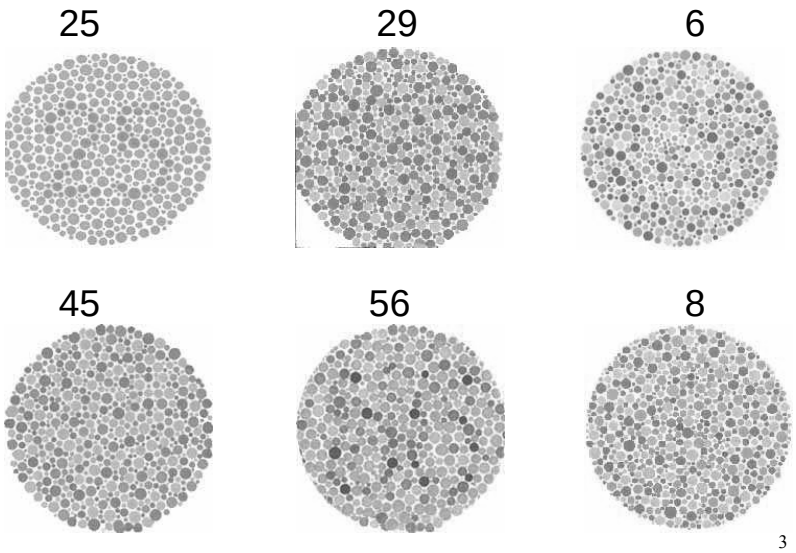
Color Blindness

(ISHIHARA)



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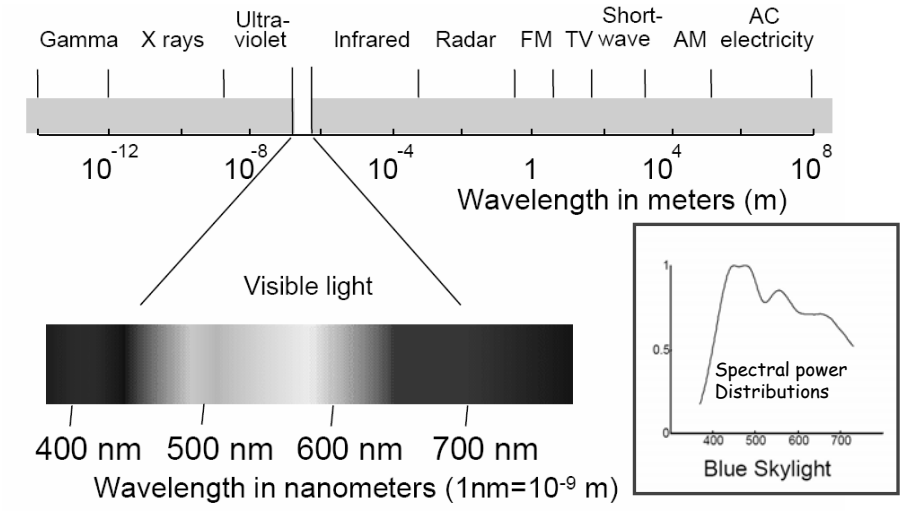
Electromagnetic Radiation - Spectrum



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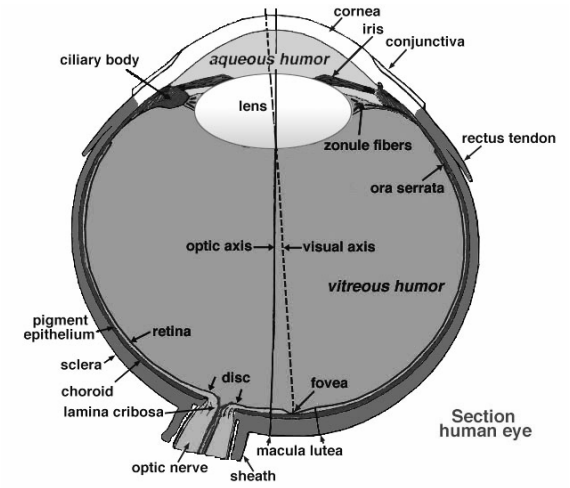
Human Eye Structure



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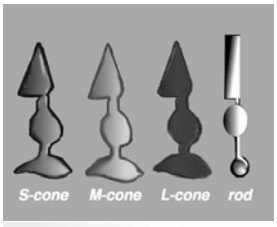
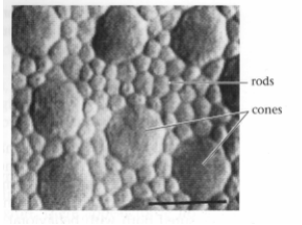
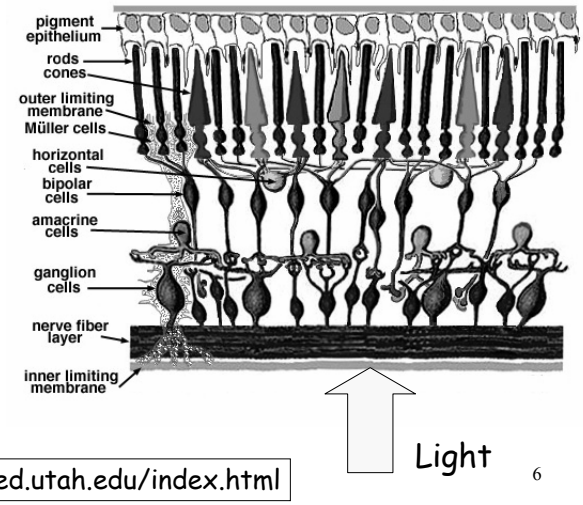
Human Eye Photoreceptors







See: http://webvision.med.utah.edu/index.html

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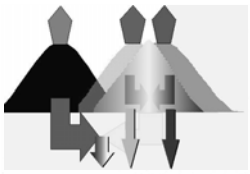
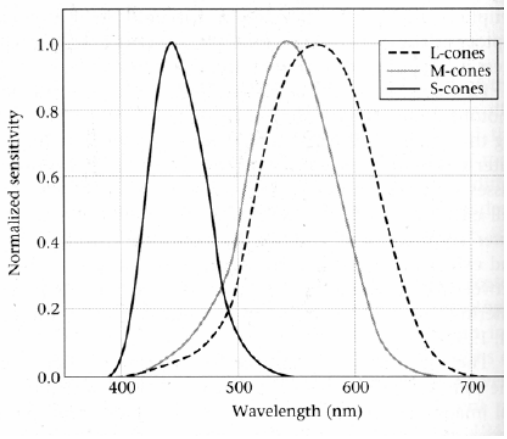
Human Spectral Sensitivities

Most mammals have only 2 different cones





3.3 SPECTRAL SENSITIVITIES OF THE L-, M-, AND S-CONES in the human eye. The measurements are based on a light source at the cornea, so that the wavelength loss due to the cornea, lens, and other inert pigments of the eye plays a role in determining the sensitivity. Source: Stockman and MacLeod, 1993.

The champion of color vision

mantis shrimp has 10-cone vision system

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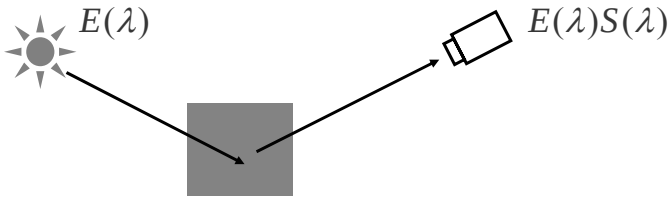
Image Formation



Camera responses depend on 3 factors: light (E), surface (S), and sensor (R, G, B)

$$r = \int R(\lambda)E(\lambda)S(\lambda)d\lambda$$

$$g = \int G(\lambda)E(\lambda)S(\lambda)d\lambda$$

$$b = \int B(\lambda)E(\lambda)S(\lambda)d\lambda$$

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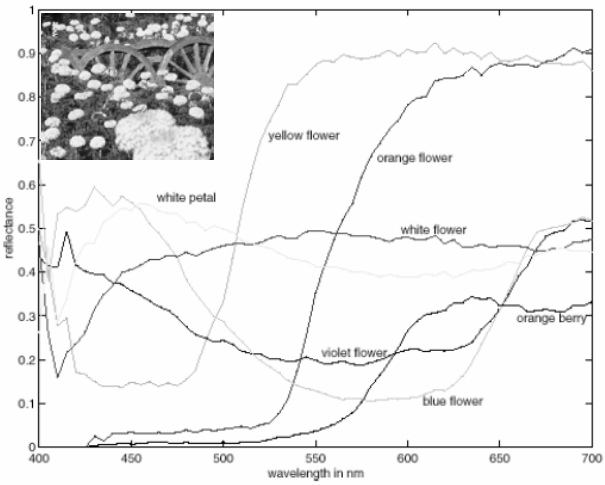
Some reflectance spectra



Spectral albedoes for several different leaves, with color names attached. Notice that different colours typically have different spectral albedo, but that different spectral albedoes may result in the same perceived color (compare the two whites). Spectral albedoes are typically quite smooth functions. Measurements by E.Koivisto.

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Methodology

Up
General Services Administration

Next
Lighting Equipment

3 Definitions and Background

The following terms are used in this report, and may be helpful in understanding the analysis.

3.1 Lighting Units and Quantities

Illuminance is the amount of light coming from a light fixture that lands on a surface. It is measured in Footcandles (Lux in the metric system). A typical office has an illuminance of between 30 to 50 footcandles (300 to 500 lux) on desktops. Horizontal illuminance describes the amount of light landing on a horizontal surface, such a desk, and vertical illuminance describes the illuminance landing on a vertical surface, such as a wall or a face.

Luminance describes the amount of light leaving a surface in a particular direction, and can be thought of as the measured brightness of a surface as seen by the eye. Luminance is expressed in Candelas per square foot, or more commonly, Candelas per square meter (Cd/m²). A typical computer monitor has a Luminance of about 100 Cd/m².

The following two diagrams illustrate the difference between illuminance and luminance.

Figure 1 - Illuminance vs. Luminance

The image on the left shows a light projecting onto a light colored wall, and the image on the right shows the same light projecting onto a dark colored wall. In both cases, the measured *illuminance* on the wall is the same, since the same amount of light is landing on the surface. However, the wall in the image on the left has a higher *luminance* value than the wall in the image on the right since the measured brightness is higher.

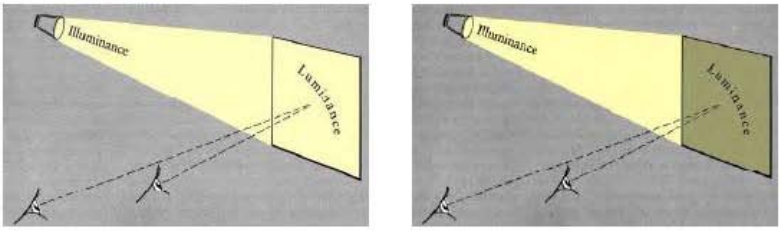
The color rendering index of a light source is a measurement of how well a light source represents color compared to an ideal source. Color rendering index (CRI) is measured on a scale of 0 to 100. As a gauge of measure, sunlight has a CRI of 100, typical fluorescent office lighting has a CRI of 80 to 85, and parking lots vary from 20 to 65.

3.2 Key Ratios in Lighting

By measuring luminance, we can compare the brightnesses of areas in a room, and determine Luminance Ratios. Luminance ratios help quantify the relationship between lit elements in a room, and are also sometimes known as contrast ratios.

The reflectance of a surface is the percentage of light landing on a surface that is reflected outward. A typical white wall has a reflectance of around 70%, while a dark wood surface,

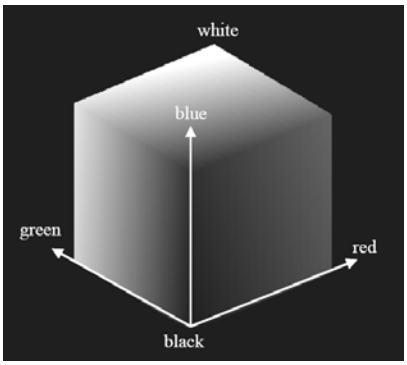
Figure 1 - Illuminance vs. Luminance

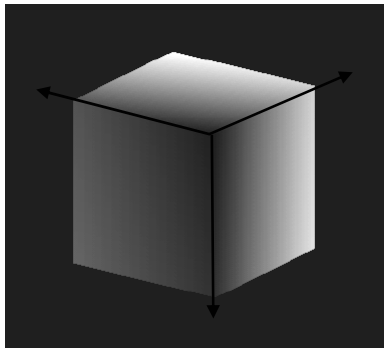


such as cherry, has a reflectance of about 20%. Reflectance of room surfaces is critical in

Color Spaces - RGB

Colors are usually represented as vectors in a (continuous) 3D color space.



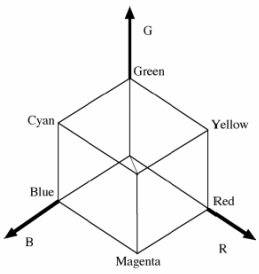


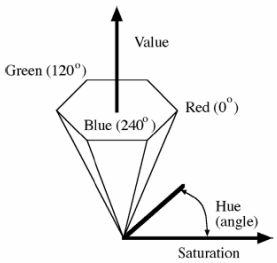
A good source: http://www.cs.rit.edu/~ncs/color

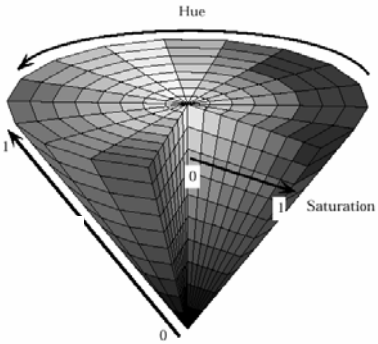
Color Spaces - HSV

The main diagonal of the RGB cube contains colorless graylevels (R=G=B)

RGB space







HSV space

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Color Spaces - CIE

Color Space	Description	Supported Conversions
XYZ	The original, 1931 CIE color space specification.	*xyY*, *uvl*, *u'v'L*, and *L*a*b**
xyY	CIE specification that provides normalized chromaticity values. The capital Y value represents luminance and is the same as in XYZ.	*XYZ*
uvL	CIE specification that attempts to make the chromaticity plane more visually uniform. *l* is luminance and is the same as *Y* in XYZ.	*XYZ*
u'v'L	CIE specification in which *u* and *v* are rescaled to improve uniformity.	*XYZ*
*L*a*b**	CIE specification that attempts to make the luminance scale more perceptually uniform. *L** is a nonlinear scaling of *L*, normalized to a reference white point.	*XYZ*
*L*ch*	CIE specification where *c* is chroma and *h* is hue. These values are a polar coordinate conversion of *a** and *b** in *L*a*b**.	*L*a*b**
sRGB	Standard adopted by major manufacturers that characterizes the average PC monitor.	*XYZ* and *L*a*b**

CIE (1931):
Commission Internationale de l'Éclairage

(International Commission on Illumination)

NTSC: The National Television Systems Committee

YIQ:
Luminance (Y),
hue (I),
saturation (Q).

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What is an image ?

- An n-dimentional matrix of pixels
  - 2D – graylevel image
  - 3D – RGB image
  - 4D – a video sequence of RGB
  - ...
- A topographic surface embedded in 3D space
  - graylevel morphology
- A bug of pixels – data points in n-dimentional space
  - clustering

Example: RGB to Lab

```
c = makecform('srgb2lab')

c_func: @applycformsequence
    ColorSpace_in: 'rgb'
   ColorSpace_out: 'lab'
         encoding: 'uint16'
            cdata: [1x1 struct]
```

```
c.cdata.cforms{1}
   c_func: @applymattrc_fwd
   ColorSpace_in: 'rgb'
  ColorSpace_out: 'xyz'
         encoding: 'uint16'
            cdata: [1x1 struct]

c.cdata.cforms{2}
   c_func: @xyz2lab
   ColorSpace_in: 'xyz'
   ColorSpace_out: 'lab'
   encoding: 'double'
   cdata: [1x1 struct]
```

```
c.cdata.cforms{1}.cdata.MatTRC
   RedColorant: [0.4361 0.2225 0.0139]
   GreenColorant: [0.3851 0.7169 0.0971]
   BlueColorant: [0.1431 0.0606 0.7141]
   RedTRC: [1024x1 uint16]
   GreenTRC: [1024x1 uint16]
   BlueTRC: [1024x1 uint16]
```


Find Human Skin

Why?

- Search image databases
- Fight pornography
- Surveillance