Brief Introduction to Vision and Images

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Version 1.1

Structure of the Retina

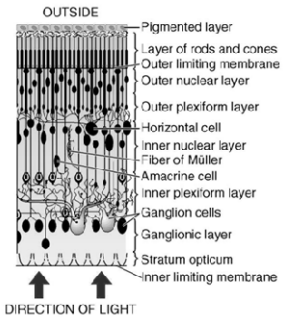

Figure 50-1from Guyton & Hall, 10th ed.

There is only one kind of rod. Rods are very sensitive and used mainly in dim light.

There are 3 kinds of cones. Each kind has a different spectral response. They are used for color vision. Most cones are in the fovea.

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Details of Retina

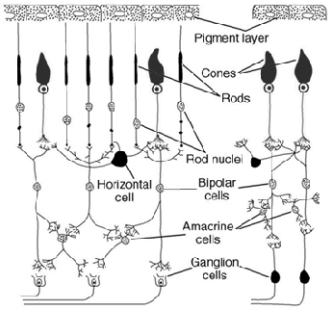

Figure 50-11 from Guyton & Hall, 10th ed.

Some processing (edge & motion detection; data compression?) is done in the retina.

More processing and interpretation is done in the brain (and mind?).

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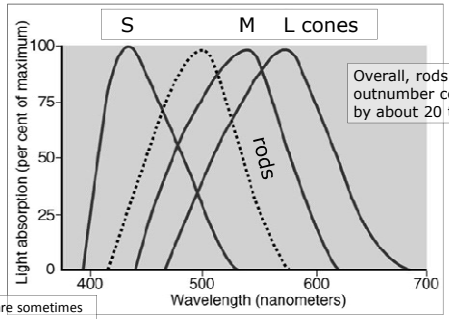
Spectral Sensitivity



Overall, rods outnumber cones by about 20 to 1.

Cones are sometimes labeled β (beta), γ (gamma) and ρ (rho).

Figure 50-7 from Guyton & Hall, 10th ed.

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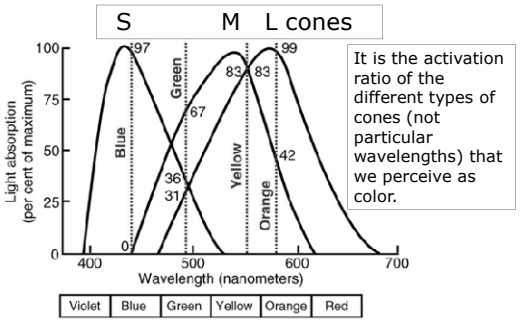
Color-Wavelength Connection



It is the activation ratio of the different types of cones (not particular wavelengths) that we perceive as color.

Figure 50-9 from Guyton & Hall, 10th ed.

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CIE Color Space

- Experiments lead to the develop of the original CIE color space in the 1930s.
- Different wavelengths and wavelength combinations were mixed to match colors.

X & Y values specify a "color" (hue and saturation). Intensity (value, brightness) must also be specified.

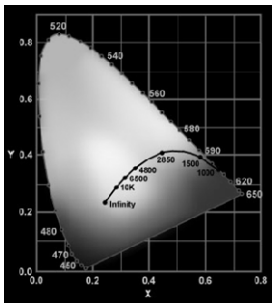

Image source: Photo Net website.

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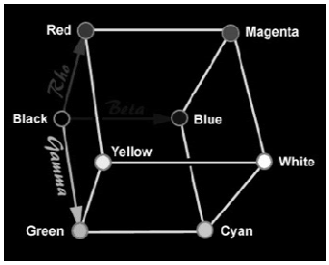
Color Displays

- Modern displays typically have three types of pixels (red, green & blue).
- Their intensities can be varied to display millions of colors.



Note that 100% red plus 100% green produces yellow, etc.

Image source: Photo Net website.

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Color Cube

- All hues, saturations & values combinations occur in or on the cube.
- The shown edge is the full spectrum at full saturations & values.

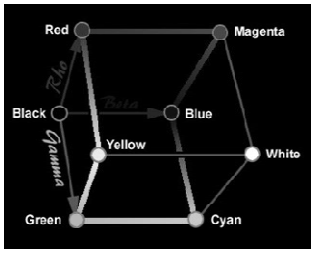

Image source: Photo Net website.

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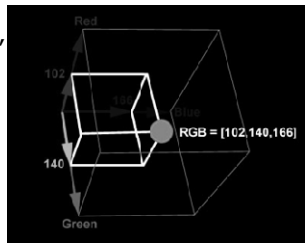
A Particular "Color"

- This example shows how a particular "blue" color can be produced by mixing the primary colors.
- The data range can be 0 to 255 as will be explained shortly.



Note Matlab like vector notation.

Image source: Photo Net website.

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Raster Graphics

- Raster graphics is the most common way to represent image data in computer files.
- A raster graphic image consists of a matrix with each data value in the matrix representing the color of the correspond location (pixel) in the image.
- Raster images can be binary (pure black and white), color mapped, grayscale or full color.

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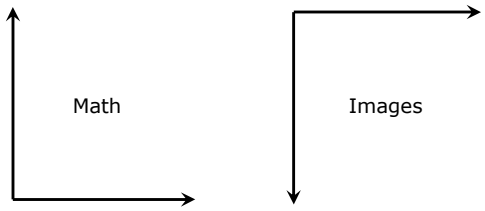
Typical Axis Directions



Set the axis *YDir* property to *reverse* to correctly display most image data.

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Binary Images

- Each pixel in a binary image must be either black or white (or on or off).
- For example, following matrix corresponds to the following image:

```
0 0 0 0
0 1 1 0
1 1 0 0
1 0 0 0
```

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Color Mapped Images

- Each pixel value in a color mapped image corresponds to a different color.
- A table describing the correspondence between pixel values and colors is called the image's color map.
- Color maps may contain just a few to thousands of colors. Maps containing 256 and 64k colors are common.

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Color Map Example

Image matrix

0	0	0	1
0	1	2	3
1	2	3	4
3	3	4	4

Color map

0	Black
1	Brown
2	Orange
3	Yellow
4	White

Image

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More About Color Maps

- Some image data and file formats (like .gif files) always use color maps (also known as indexed colors).
- Color mapping was necessary when computer displays could only display a limited number of colors.
- Some medical images are inherently gray scale and benefit from color mapping (called false color).
- Color mapping is sometimes used to present 3D data ($z = f(x,y)$).

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More about Color Mapping

- Enter and run the following Matlab code (you may omit the comments):

```
load spine % Loads a saved Matlab workspace
figure % Create & display a new figure
colormap bone % Set the color map to bone
image(X) % Display the image
```

- Try other color maps, like jet and hot.
- See Matlab Help > Matlab > Graphics > Examples of Images and Colormaps.

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Grayscale Images

- In grayscale raster images, pixel values represent shades of gray.
- Value ranges of 0 to 1 or 0 to 255 are common.
- Here's an example:

```
0.00  0.00  0.00  0.25
0.00  0.25  0.50  0.75
0.25  0.50  0.75  1.00
0.75  0.75  1.00  1.00
```

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Full Color Representation

- There are a number of ways to represent full color in raster images.
- The most common mimics the physiology of the eye and stores red, green and blue intensities for each pixel (usually in this order and abbreviated RGB or rgb).
- Alternatives include cyan, magenta, yellow and black (cmyk); hue, saturation and value (hsv) and 1931 CIE (XYz) approaches.
- Some examples follow.

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RGB Separation

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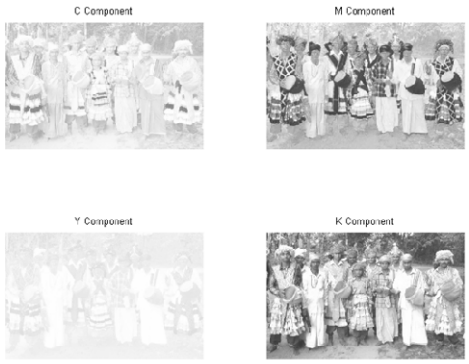

CMYK Separation

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HSV Separation

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Some Matlab Details

- Matlab can store and process full color, grayscale, binary (pure black and white), color mapped, grayscale and full color images.
- Like doing most things Matlab, dealing with images is both easy and hard.
- Matlab provides powerful tools, but their use requires some detailed understanding.

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Matlab Data Types

- Matlab can store values in a variety of ways (referred to as data types).
- Some data types used in imaging include:
  - *double* – can store floating point values in the range of $\pm 1.0 \times 10^{\pm 308}$ with 12 or more significant digits. This is the default.
  - *uint8* and *uint16* – can store integer values from 0 to 255 and 0 to 65535.
  - *int8* and *int16* – can store integer values from -128 to 127 and -32768 to 32767.

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Image Data Values

- Matlab generally assumes pixel values that are of type uint8 to be in the 0 to 255 range of this variable type.
- Matlab generally assumes pixels values that are of type double (the default Matlab numeric type) to be in the range 0 to 1.
- Explicit scaling and type conversion is sometimes necessary.

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Loading & Displaying Images

- To load an existing image into Matlab use the *imread* function. For example the command `ct = imread('HarvardCT3.gif');` loads the *HarvaardCT3.fig* image file into an array called *ct*. Examine the Workspace entry for the *ct* matrix. It should be a 288 by 377 *unit8* matrix.
- Use the *imshow* function to display an image. Also try *image* and *imagesc*.

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Loading & Displaying (cont)

- Next use *imread* to load *mri2.jpg* into a matrix called *mri*.
- Examine the Workspace entry for the *mri*. It should be a 512 by 510 by 3 uint8 matrix. In this case, a gray scale image is represented in RGB format (due to limitations with the jpg format).
- Use the *imshow* function to display an image data. Also try *image* and *imagesc*.

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Loading & Displaying (cont)

- Next use *imread* to load *grace.jpg* into a matrix called *grace*.
- Examine the Workspace entry for the *mri*. It should be a 450 by 600 by 3 uint8 matrix. This is a true RGB image.
- Use the *imshow* and image functions to display an image data.

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Exploring an Image

- After displaying an image, you can use the *Tools > Data Cursor* menu choice and click on parts of the image to see the points indices and numeric value(s).
- True grayscale and black and white images have single values at each pixel.
- Load and explore a few other images from ones I sent you and or posted online.

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Figures and Axes

- The distinction between figures and axis can be useful when dealing with images (and in general).
- The *figure* command creates a new figure or makes the specified figure the current figure.
- The *axes* command creates a new axis or makes the specified axis the current axis.

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Figures and Subplots

- The *subplot* function (and command syntax) permits the specification and selection of multiple axes within a single figure.
- It is typically used as *hAxis* = subplot(*rows*, *cols*, *current*) where *rows* and *cols* specified the number of rows and columns the figure should be divided into and *current* specifies which location for which the axis handle should returned or made current.

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Root, gca and gcf

- All figures are children of the root graphical object. This object always has a handle value of 0.
- *gcf* returns the handle of the current figure.
- *gca* returns the handle of the current axis.

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Example

- See my SubplotTests.m script for examples of using:
  - The various image display commands (*image*, *imshow* and *imagesc*).
  - The *figure* and *subplot* functions.
  - The *axis* and *axes* functions.
  - Colormaps and the *gcf*, *gca* and *get* commands.
- To display images.

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References

- Medical Physiology, 10th ed. By Guyton & Hall.
- Spectral Selectivity tutorial by Ed Scott and Hollis Bewley at http://photo.net/learn/optics/edscott/spectsel.htm.

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