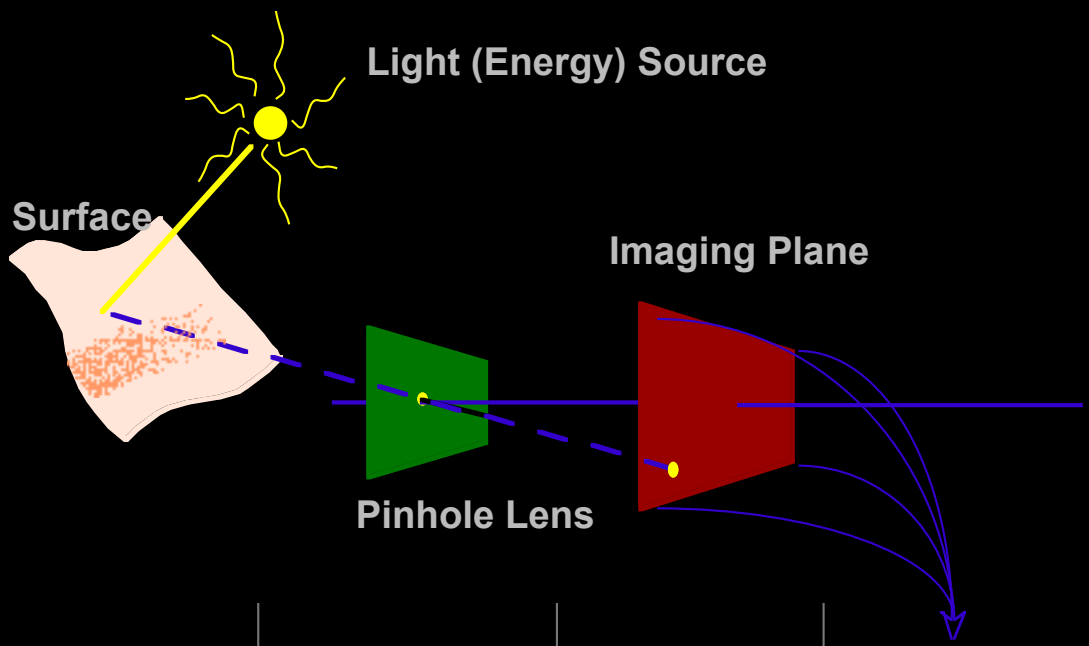
# Image Formation




| World | Optics | Sensor | Signal |
|---|---|---|---|
| | | B&W Film | Silver Density |
| | | Color Film | Silver density in three color layers |
| | | TV Camera | Electrical |

# Last Time

- EM spectrum and visible light
- Distribution of light wavelengths
- Linearity
- Percent of light reflected off a surface.
  - Linearity of reflected light.
- Efficiency of a solar panel as a function of wavelength
  - Linearity of solar panel power.
- Photoreceptor response as a function of wavelength
  - Linearity of photoreceptor output.

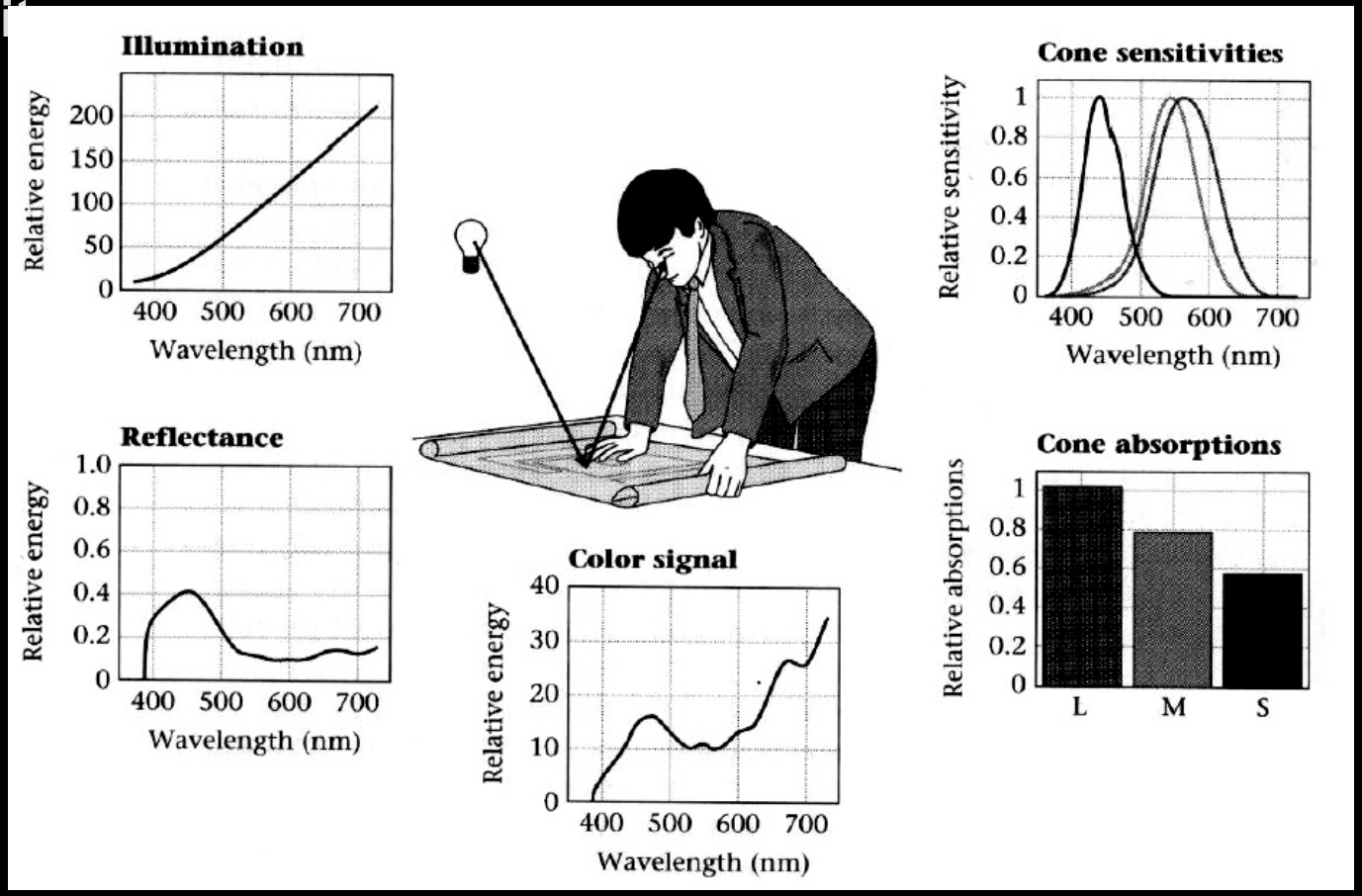


# This lecture

- More about how light originates from a source, interacts with the environment, and produces a response from photoreceptors (either natural or artificial).

# What Do We 'See'?

Light Sources
Surface Reflectance
Eye sensitivi

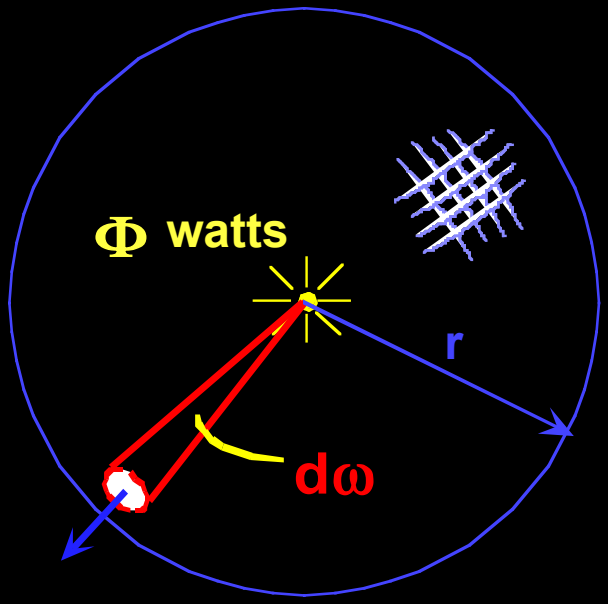


# Point light sources

- Point light sources
- Steradians
- Surface area of a sphere
- Watts
- Inverse Square Law

# Light

- How much light is falling on an area (in watts)?
- Total light power (in watts) * percent of sphere occupied by area.



# Steradians

- 4pi steradians in a sphere
  - Area of a unit sphere is 4pi units.
- How many steradians in a hemisphere?
  - 4pi * 0.5 = 2pi steradians



# Watts on a solar panel

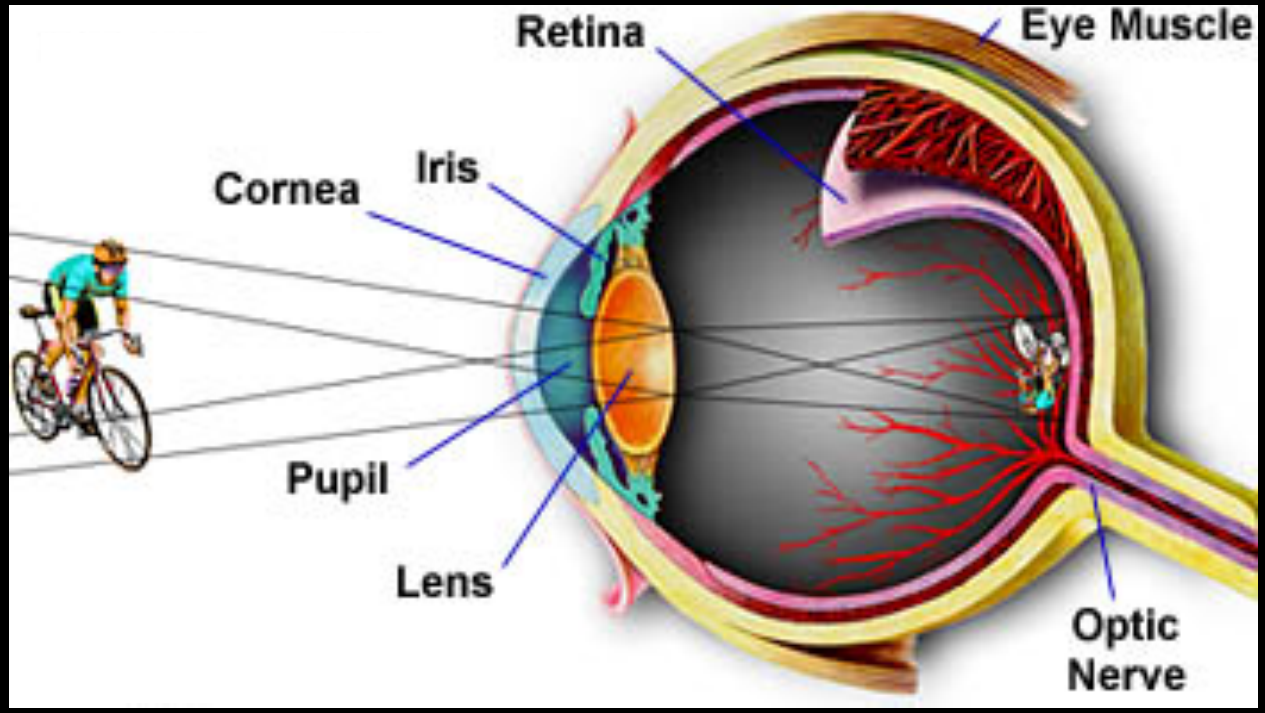
- How many watts fall on a 1 square meter solar panel on a bright sunny day?
- Need
  - distance to sun
  - watts output by sun



# Inverse Square Law

- What happens to amount of light falling on a surface as we move away from a light source?
- If we double the distance from the light source, what happens to the amount of light?

# The Human Eye




Pupil - The opening through which light enters the eye - size from 2 to 8 mm in diameter
Iris - The colored area around the pupil that controls the amount of light entering the eye.
Lens - Focuses light rays on the retina.
Retina - The lining of the back of the eye containing nerves that transfer the image to the brain.
Rods - Nerve cells that are sensitive to light and dark.
Cones - Nerve cells that are sensitive to a particular primary color.

# Rods and Cones

- Cones are located in the fovea and are sensitive to color.
  - Each one is connected to its own nerve end.
  - Cone vision is called photopic (or bright-light vision).
- Rods give a general, overall picture of the field of view and are not involved in color vision.
  - Several rods are connected to a single nerve and are
  - Sensitive to low levels of illumination (scotopic or dim-light vision).

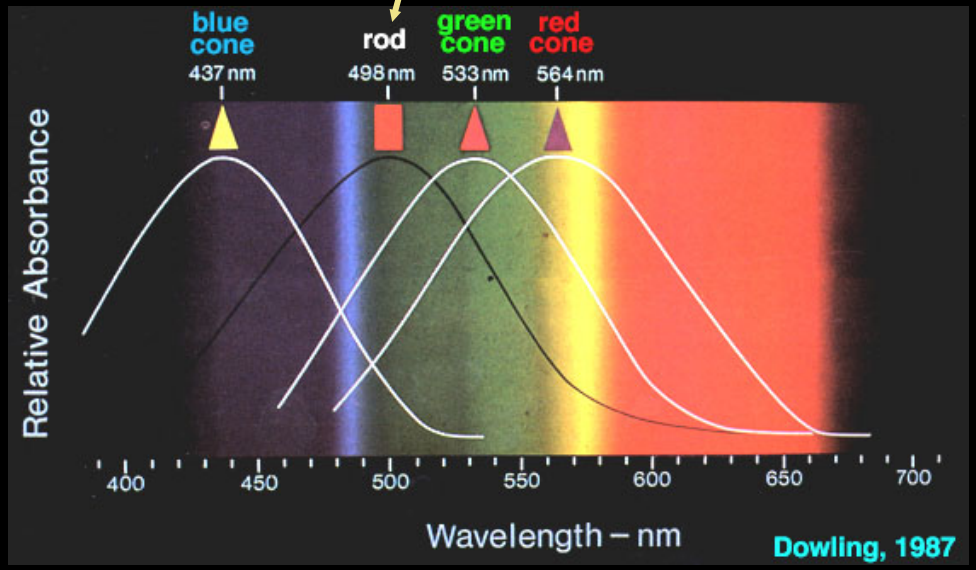
# Human Vision is "Multi-modal"

- Separate color vs. black-and-white detectors.
- Separate motion sensitive sensors (different time sampling properties).
- Uneven spatial sampling rates.

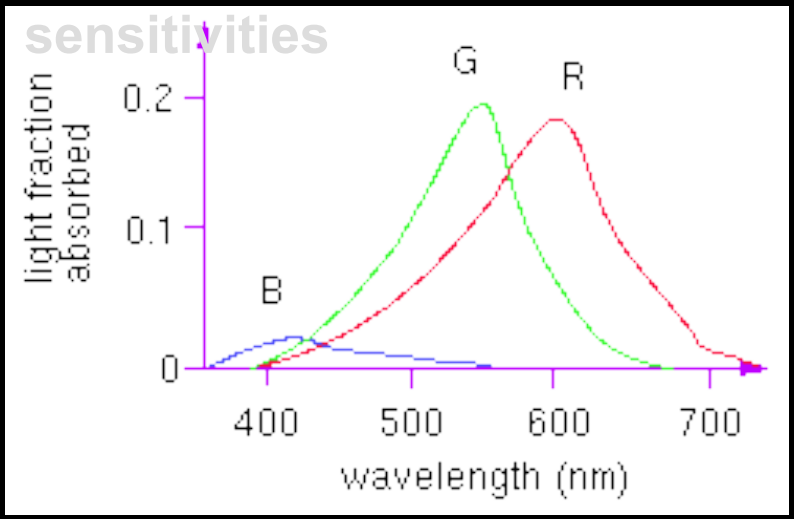
- Modern high-tech camera systems starting to use these ideas (see Shree Nayar's Laboratory):
  - High resolution slow-speed camera coupled with low resolution high speed.
  - Interleaved sensors with different dynamic range for high dynamic range

# Absorption Curves

Rods: achromatic vision

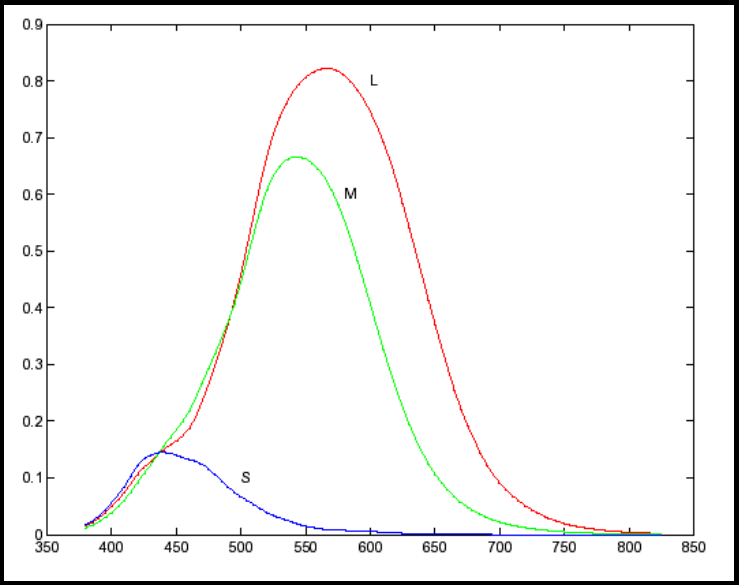



The different kinds of cells have different spectral sensitivities




Peak sensitivities are located at approximately 437nm, 533nm, and 610nm for the "average" observer.

# Responses




Cone sensitivity curves

Response from i-th cone type:

$$c_i = \int s_i(\lambda) t(\lambda) d\lambda$$

$s_i(l)$ = sensitivity of i-th cone
$t(l)$ = spectral distribution of light
$l$ = wavelength

How can we find color equivalents?

Introduction to
Computer Vision

end