

# Light and Color

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# Key issues

- Physical
  - what makes a pixel take its brightness values?
- Inference
  - what can we recover from the world using those brightness values?
- Human
  - What can people do?
    - which suggests problems we might be able to solve



By nickwheeleroz, on Flickr



By nickwheeleroz, on Flickr

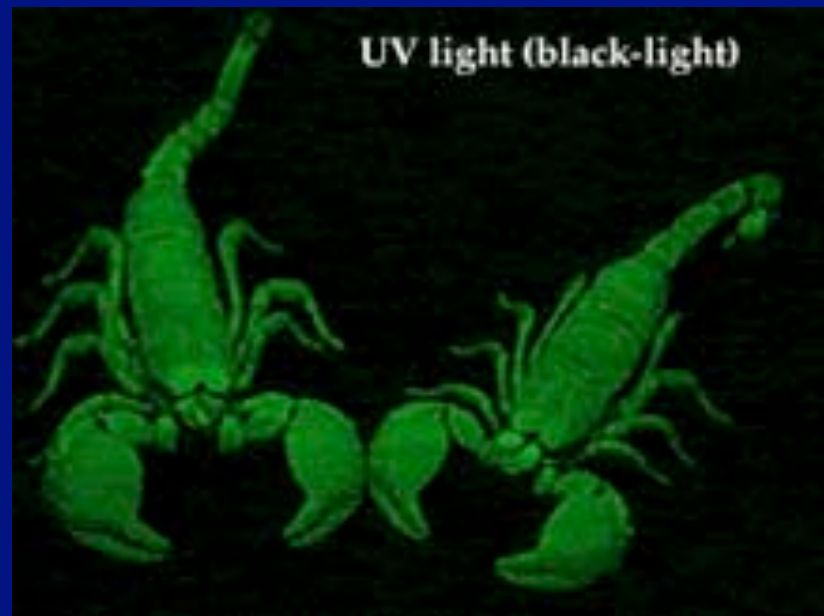
# Processes

- Cameras
  - film: non-linear
  - CCD: linear, with non-linearities made by electronics
- Light
  - is reflected from a surface
  - got there from a source
- Many effects when light strikes a surface -- could be:
  - absorbed; transmitted; reflected; scattered
  - Simplify
    - Assume that
      - surfaces don't fluoresce
      - surfaces don't emit light (i.e. are cool)
      - all the light leaving a point is due to that arriving at that point

White light (indoor)

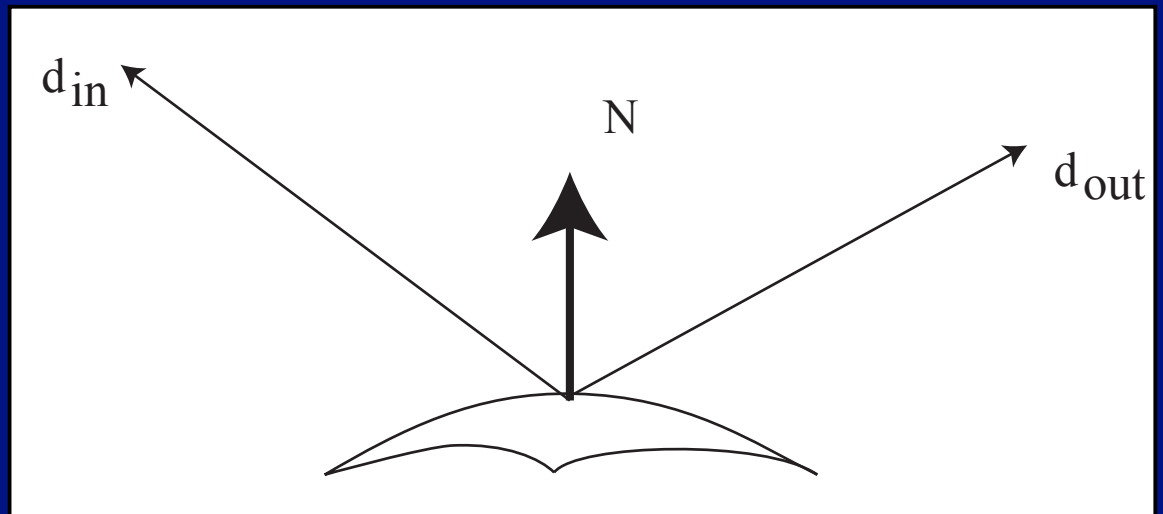


UV light (black-light)



# Specularities

- For some surfaces, reflection depends strongly on angle
  - mirrors (special case)
    - incoming direction, normal and outgoing direction are coplanar
    - angle  $d_{in}$ , normal and angle  $d_{out}$ , normal are the same
  - specular surfaces
    - light reflected in a “lobe” of directions
    - eg slightly battered metal surface
    - can see light sources specularly reflected
      - specularities





Flickr, by suzysputnik



Flickr, by piratejohnny

- Specularities are relatively easy to detect
  - small and bright (usually)



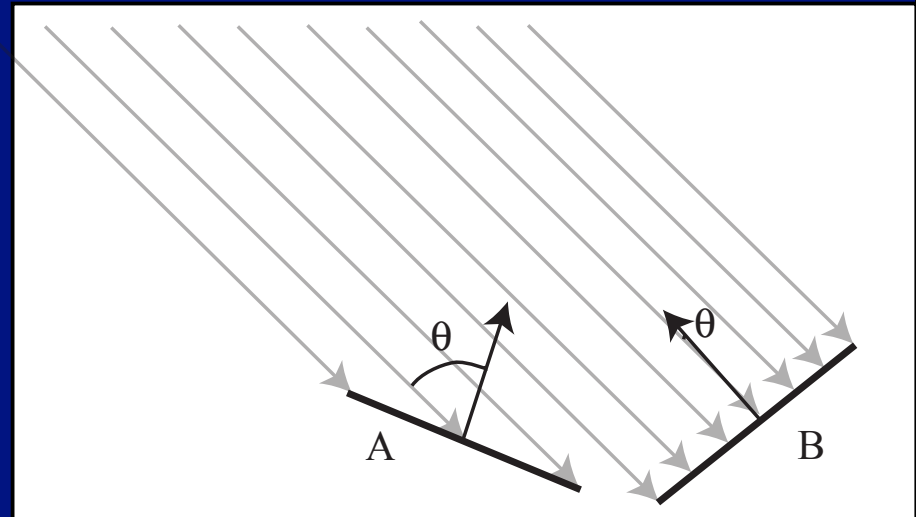
# Diffuse reflection

- Light leaves the surface evenly in all directions
  - cotton cloth, carpets, matte paper, matte paints, etc.
  - most “rough” surfaces
  - Parameter: Albedo
    - percentage of light arriving that leaves
    - range 0-1
      - practical range is smaller

# Point source at infinity

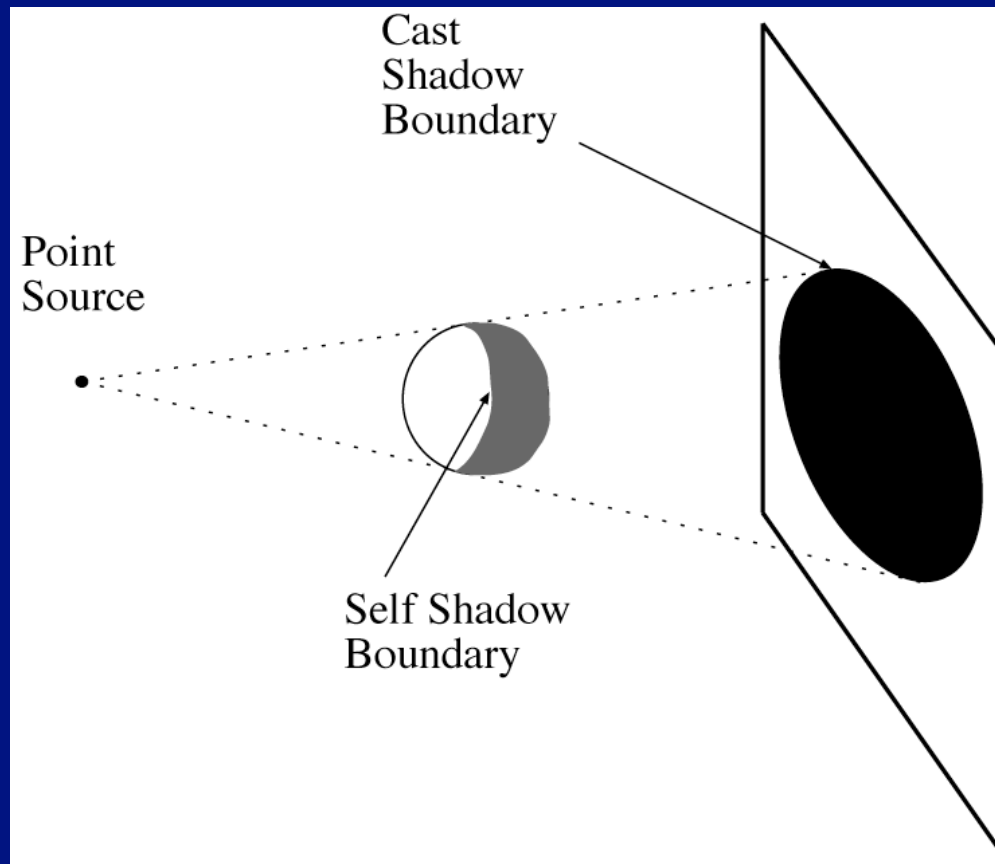
- E.g. the sun
  - energy travels in parallel rays
  - energy density received is proportional to  $\cos \theta$
- Write:
  - $p$  for albedo
  - $S$  for source vector
  - $N$  for normal
  - $I$  for image intensity

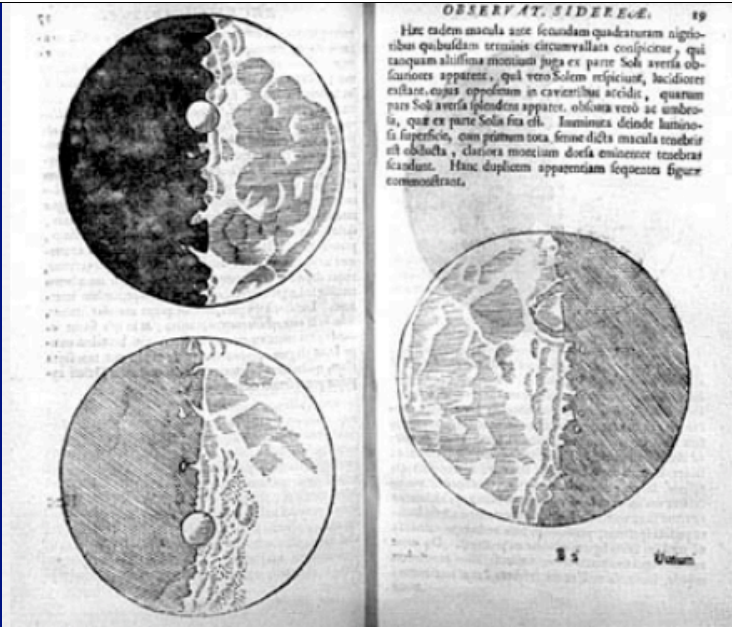
$$I(\mathbf{x}) = \rho(\mathbf{x})\mathbf{S} \cdot \mathbf{N}(\mathbf{x})$$



# Shadows cast by a point source

- A point that can't see the source is in shadow
- For point sources, the geometry is simple



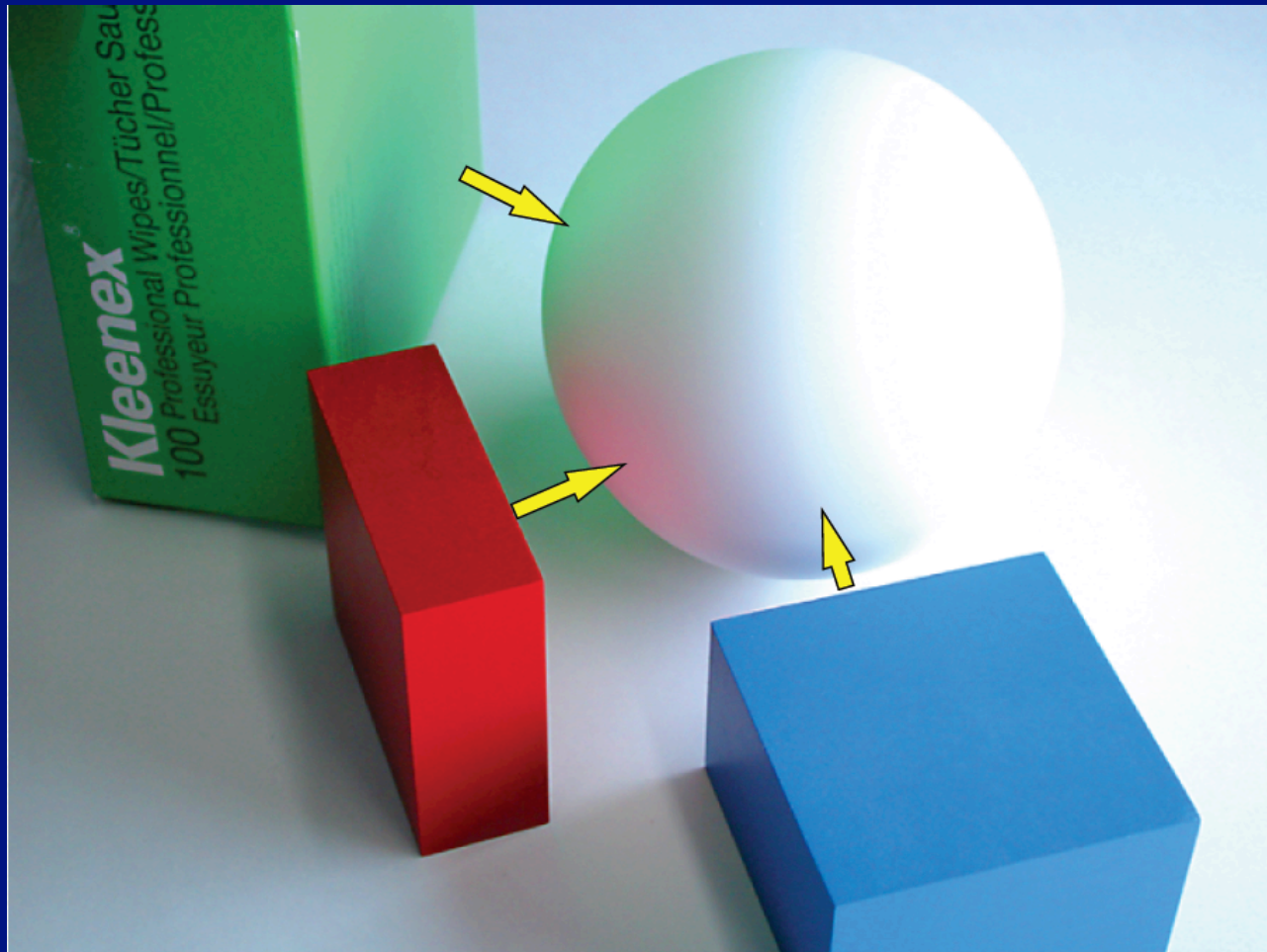


From Koenderink slides on image texture and the flow of light

# Interreflections

- Issue:
  - local shading model is a poor description of physical processes that give rise to images
    - because surfaces reflect light onto one another
  - This is a major nuisance; the distribution of light (in principle) depends on the configuration of every radiator; big distant ones are as important as small nearby ones (solid angle)
  - The effects are easy to model
  - It appears to be hard to extract information from these models

# Interreflections



From Koenderink slides on image texture and the flow of light

# Causes of colour

- The sensation of colour is caused by the brain.
- One way to get it is the response of the eye to the presence/absence of light at various wavelengths.
  - Dreaming, hallucination, etc.
  - Pressure on the eyelids
- Light could be
  - emitted with wavelengths absent (fluorescent light vs. incandescent light)
  - differentially reflected - e.g. paint on a surface
  - differentially refracted - e.g. Newton's prism
  - subject to wavelength dependent specular reflection (most metals).
  - Fluorescence -
    - invisible wavelengths absorbed and reemitted at visible wavelengths.
  - Phosphorescence (ditto, energy, longer timescale)

XXXXX

BLUE

YELLOW

XXXXX

GREEN

BLUE

XXXXX

RED

GREEN

XXXXX

YELLOW

RED

XXXXX

BLUE

YELLOW

XXXXX

RED

GREEN

XXXXX

GREEN

BLUE

XXXXX

BLUE

YELLOW

XXXXX

YELLOW

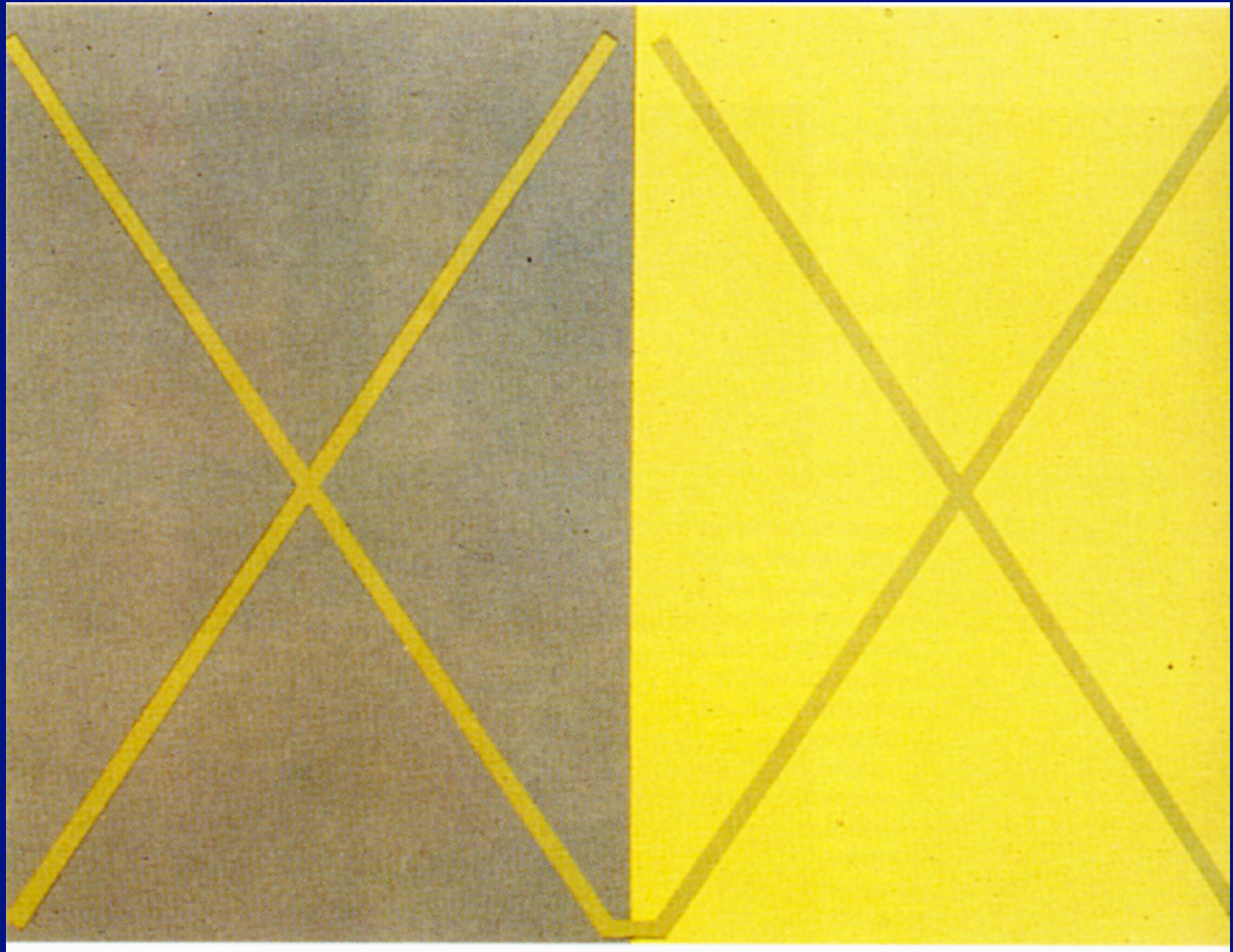
RED

XXXXX

RED

GREEN



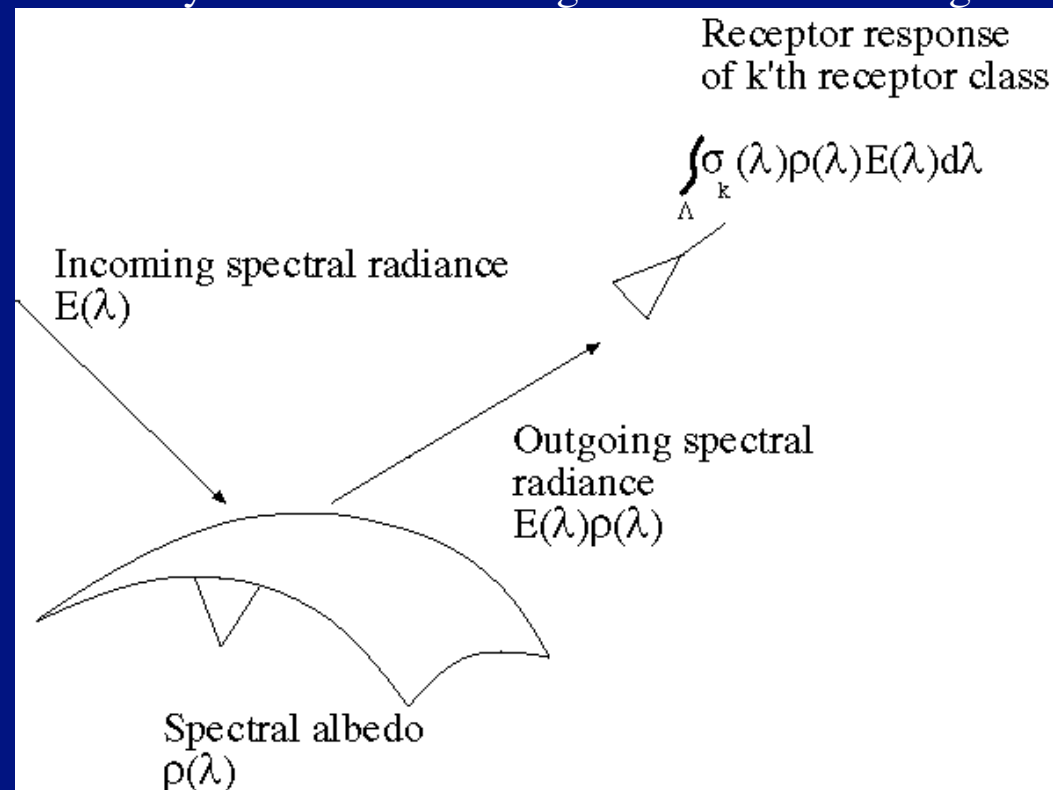


# Trichromacy

- By experience, it is possible to match almost all colors, viewed in film mode using only three primary sources - the principle of trichromacy
- Other modes may have more dimensions
  - Glossy-matte
  - Rough-smooth
  - Most of what follows discusses film mode.

# The color of objects

- Colored light arriving at the camera involves two effects
  - The color of the light source
  - The color of the surface
  - Changes caused by different colored light sources can be large



# Color receptors and color deficiency

- Trichromacy is justified -
  - in color normal people, there are three types of color receptor (shown by molecular biologists).
- Some people have fewer;
  - most common deficiency is red-green color blindness in men. Red and green receptor genes are carried on the X chromosome. Most red-green color blind men have two red genes or two green genes. Yields an evolutionary story.
- Deficiency
  - can be caused by CNS, by optical problems in the eye, or by absent receptors
- Other color deficiencies:
  - Anomalous trichromacy
  - Achromatopsia
  - Macular degeneration

# Stage lighting



From Koenderink slides on image  
texture and the flow of light





Karsch et al in review 10

# Crucial points

- Image brightness affected by
  - albedo
  - surface orientation
  - light intensity
- Image color affected by
  - surface color
  - light color
  - there are methods to disentangle these effects
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