# Physics: Surface appearance effects

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# Key issues

- Physical
  - what makes a pixel take its brightness values?
  - Effects
    - at surfaces
    - in volume
  - Human: what can people do?
    - which suggests problems we might be able to solve
- Sensing
  - can we sense in ways that reduce significance of effects?
  - sensor fusion, etc.
- Inference
  - what can we recover from the world using sensed values?

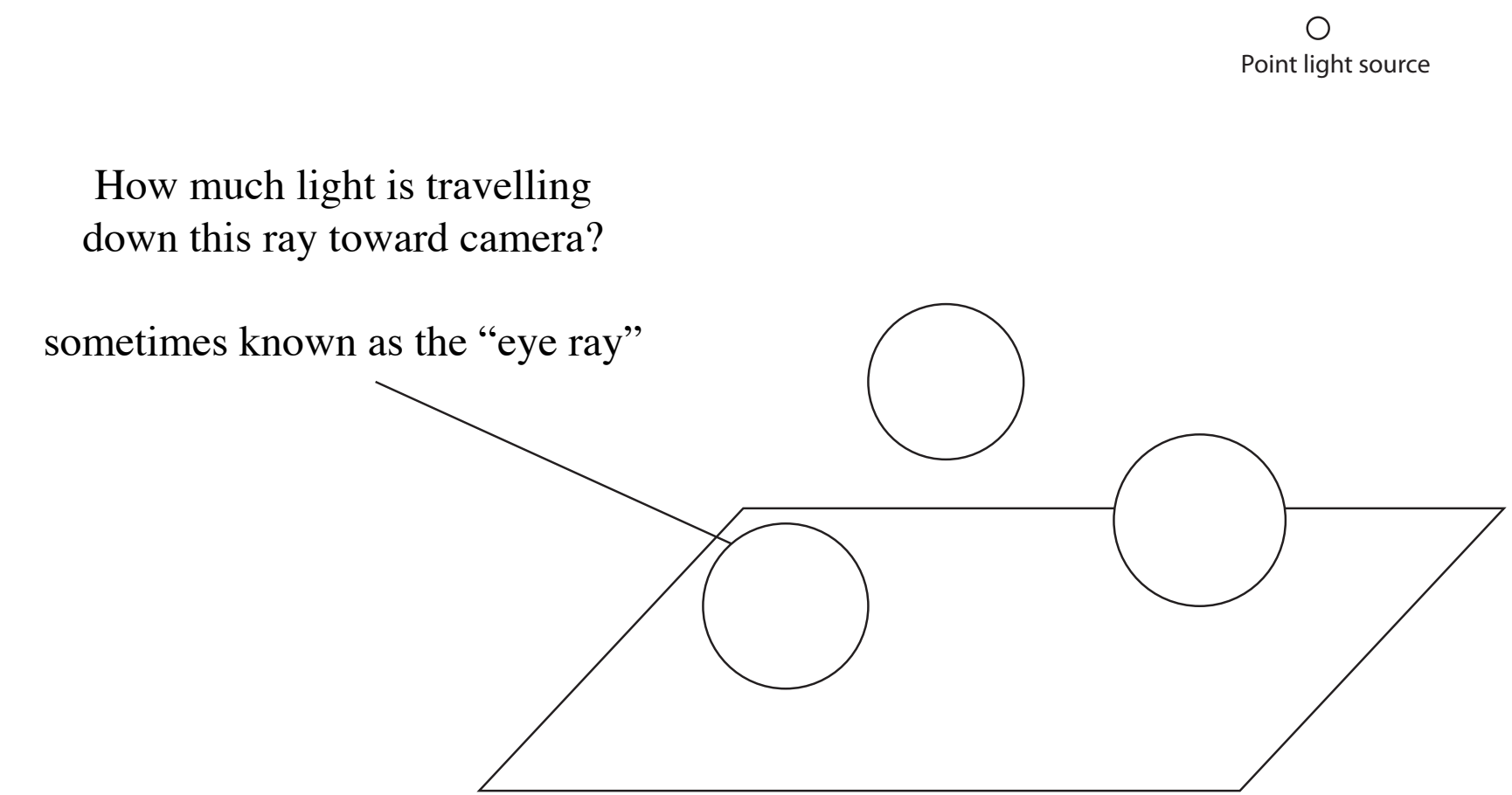
# Effects at surfaces

- We assume:
  - we see the world in a vacuum
    - or very clear air, no fog, nothing

nickwheeleroz

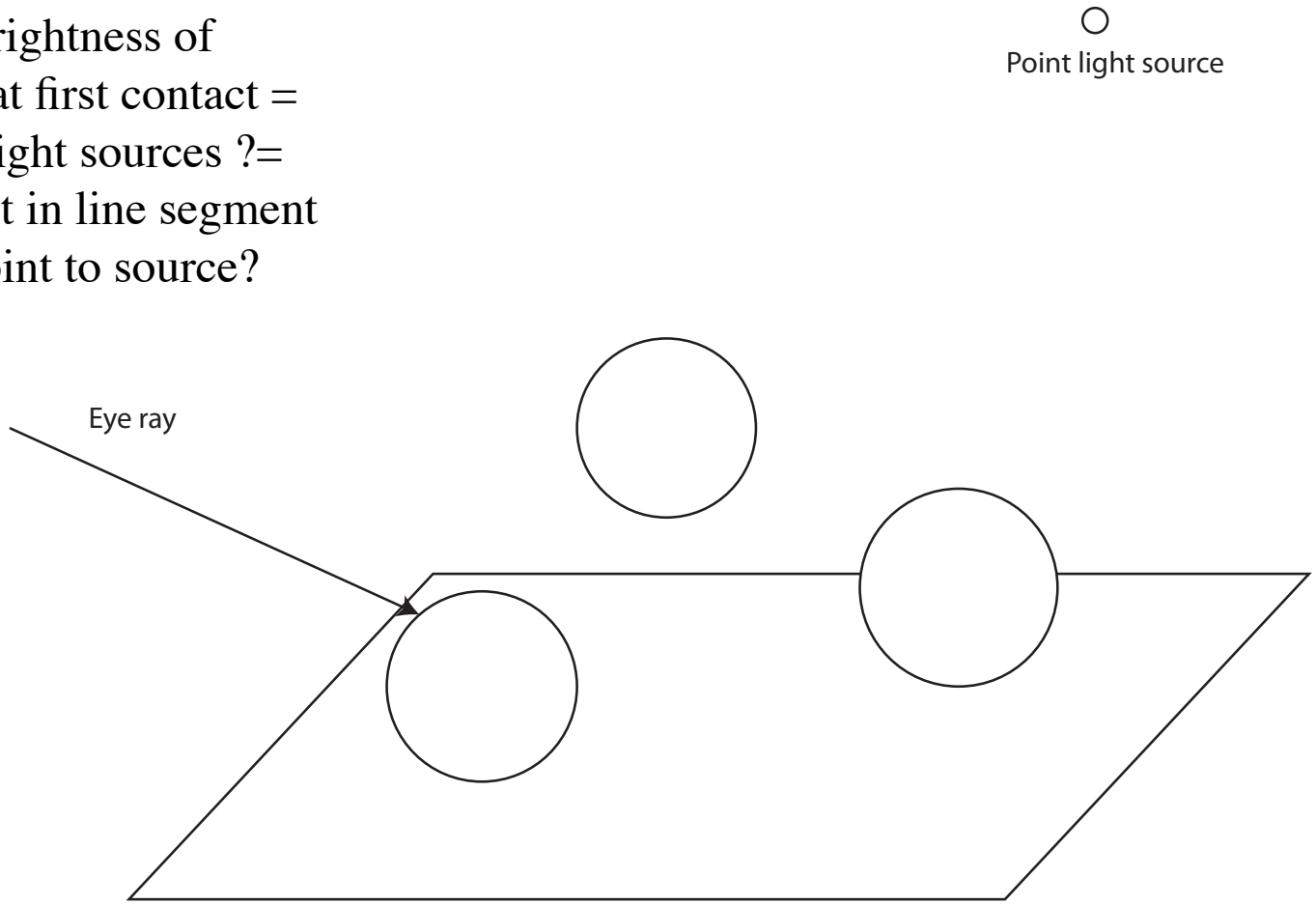
By nickwheeleroz, on Flickr

# Very simple ray-tracing



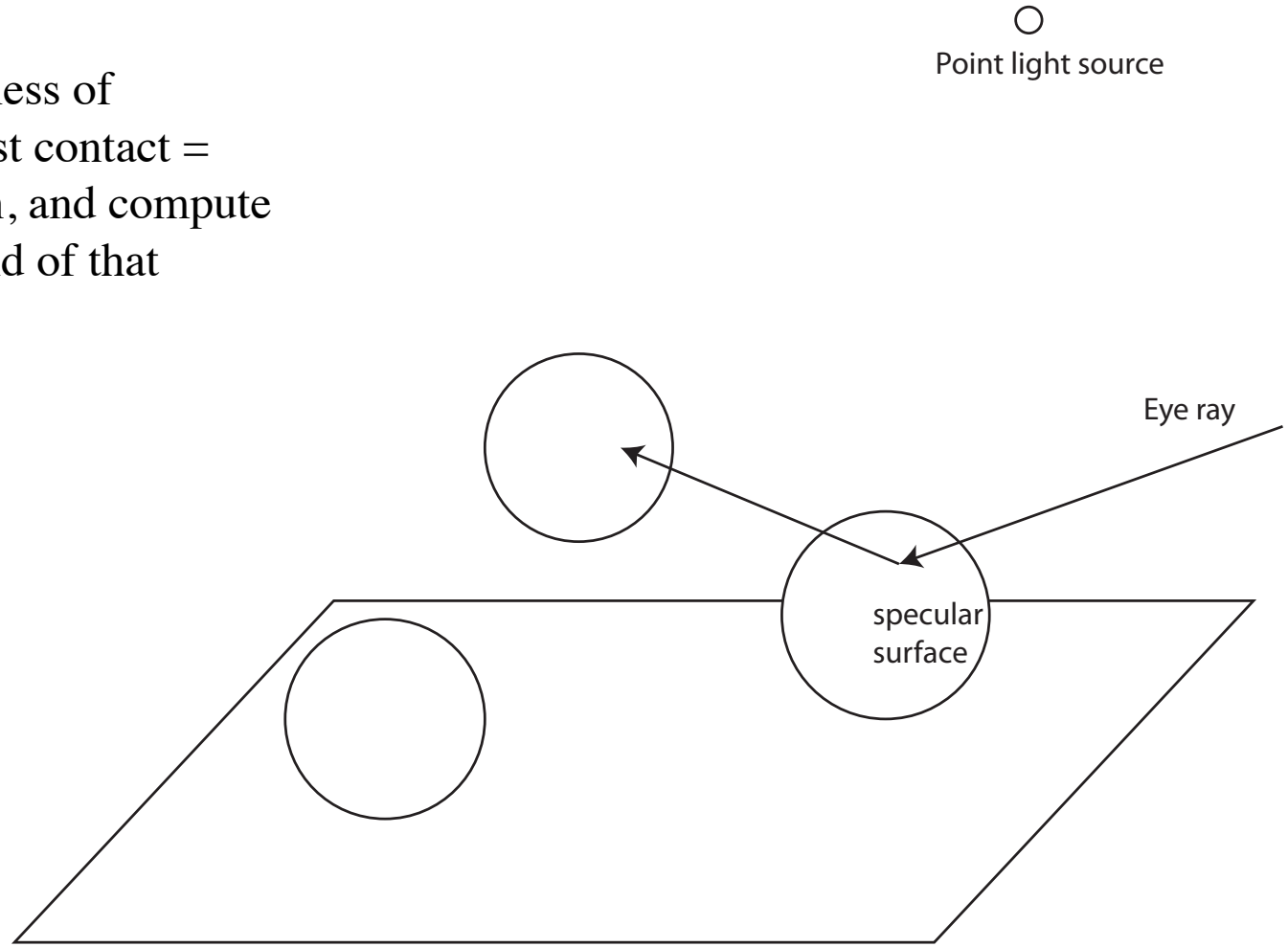
# Eye ray strikes diffuse surface

Compute brightness of diffuse surface at first contact = Can it see the light sources ?= Is there an object in line segment connecting point to source?



# Eye ray strikes specular surface

Compute brightness of specular surface at first contact = eye ray changes direction, and compute brightness at the end of that



# Lighting model

- Light arrives at a surface ONLY from a luminaire
  - this is an object that “makes light”
    - through chemical, mechanical, etc means
- Wild oversimplification, good for us right now
  - wait a few slides and it’ll get more complicated

# Light at a surface

- Simpler effects
  - Diffuse reflection
  - Specular reflection
  - Diffuse+specular model
  - Shadows
  - Color shifts and constancy
- More complex effects
  - Films
  - Interference
  - Scattering
  - Fluorescence

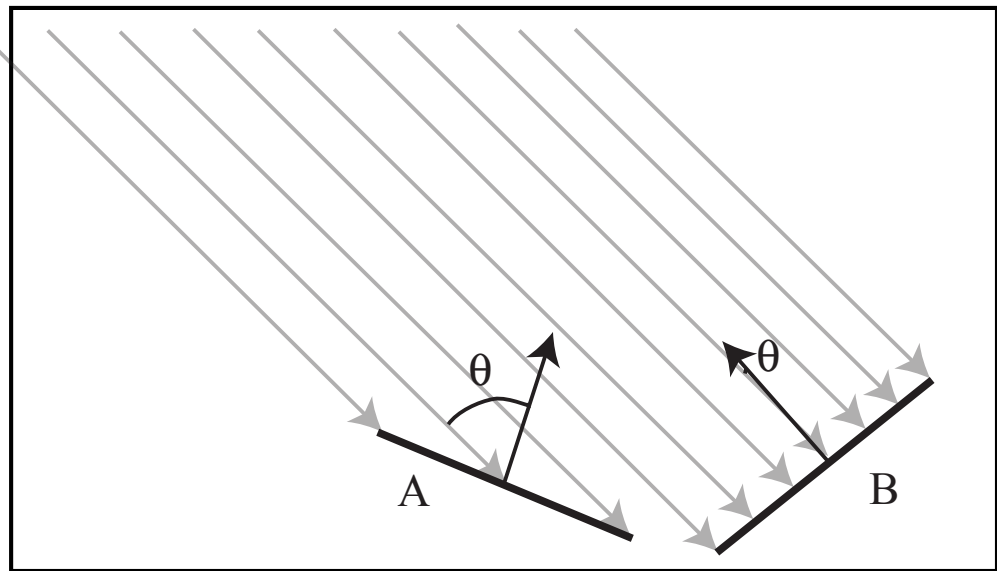
# Diffuse reflection

- 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
- Test:
  - surface has same apparent brightness when viewed from different dir’ns

# Point source at infinity

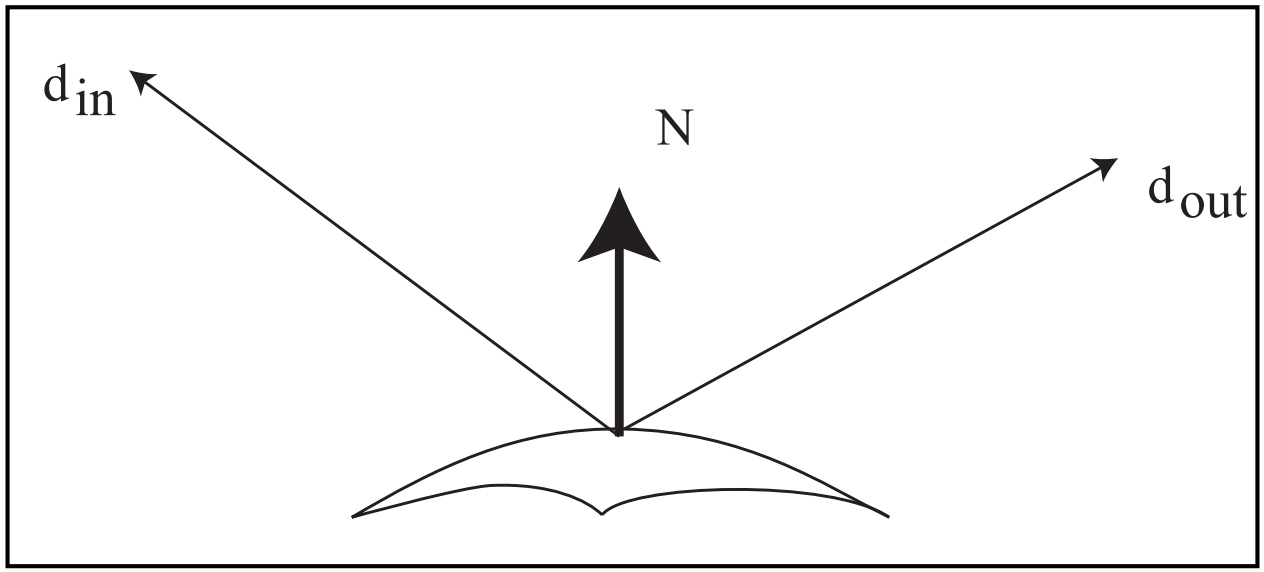
- E.g. the sun
  - energy travels in parallel rays
  - energy density received is proportional to cos theta
- Write:
  - p for albedo
  - S for source vector
    - from surface to source
    - length=intensity of source
  - N for normal
  - I for image intensity

$$I = \rho(N \cdot S)$$



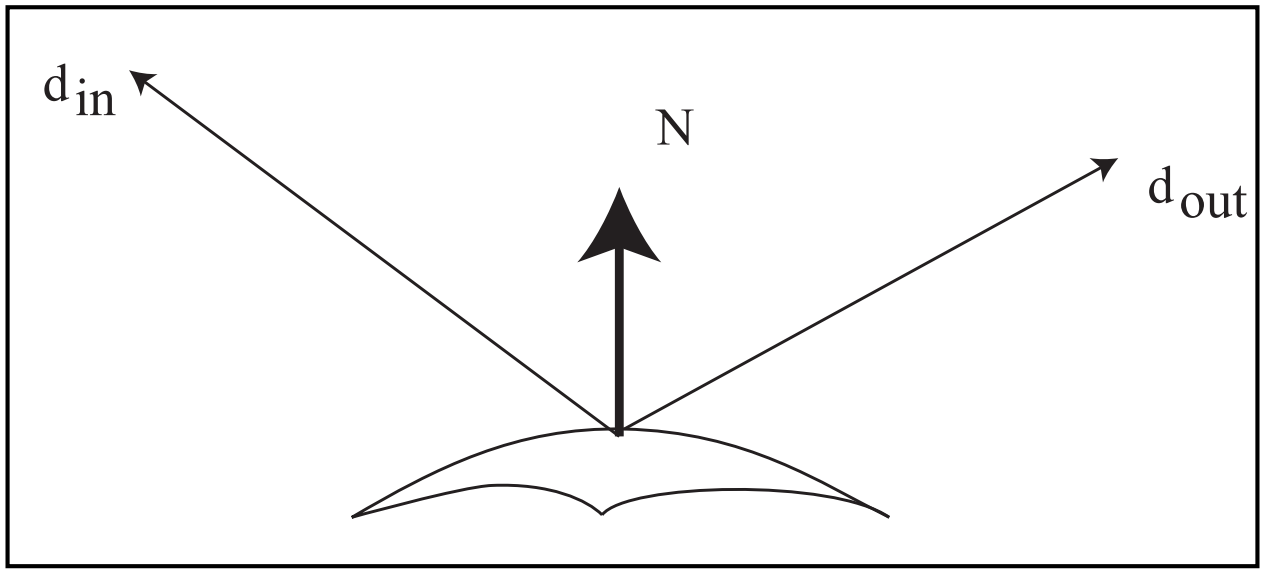
# Specular reflection

- For some surfaces, reflection depends strongly on angle
  - mirrors (special case)
    - incoming direction, normal and outgoing direction are coplanar
    - angle din, normal and angle dout, normal are the same



# Specularities

- More common effect
  - 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

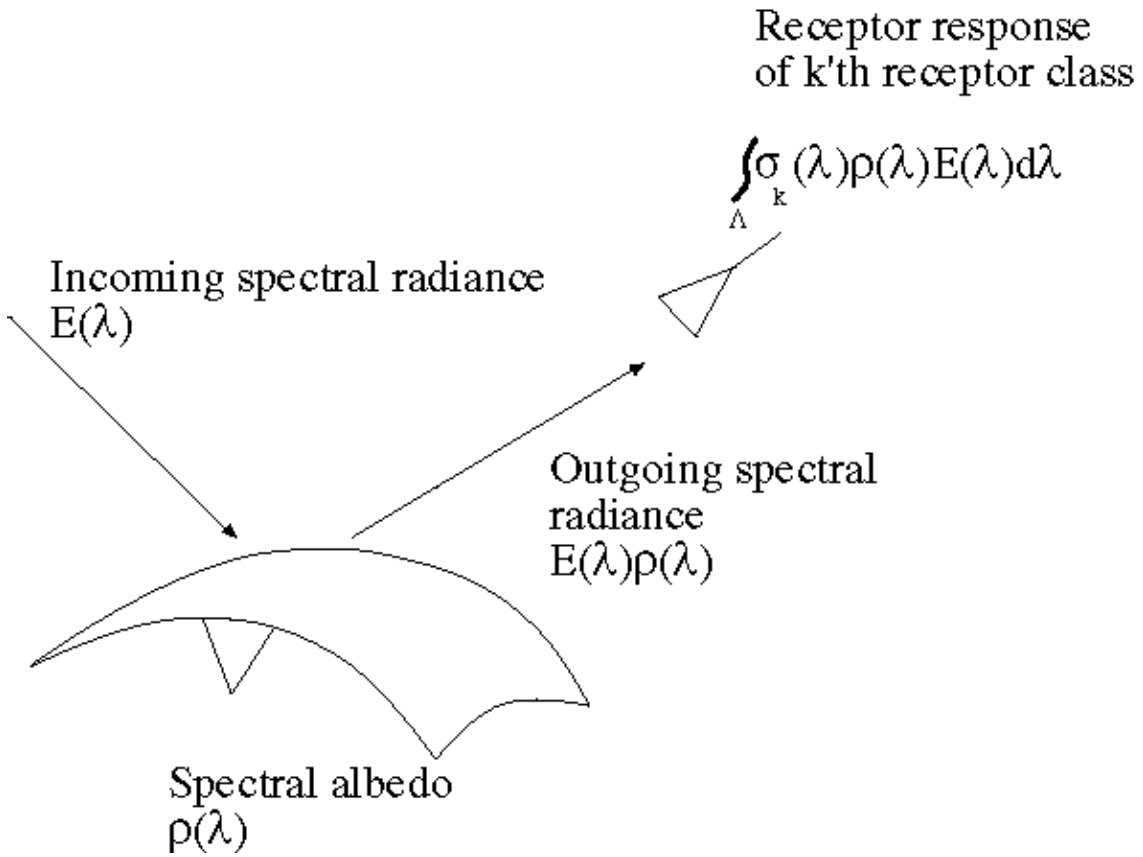
- Specularities are relatively easy to detect
  - small and bright (usually)

# Diffuse + specular model

- Widespread model
  - all surfaces are diffuse plus specular component
- Advantages
  - easy to manipulate
  - very often quite close true
- Disadvantages
  - some surfaces are not
    - e.g. underside of CD's, feathers of many birds, blue spots on many marine crustaceans and fish, most rough surfaces, oil films (skin!), wet surfaces
  - Generally, very little advantage in modelling behaviour of light at a surface in more detail -- it is quite difficult to understand behaviour of D+S surfaces

# 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



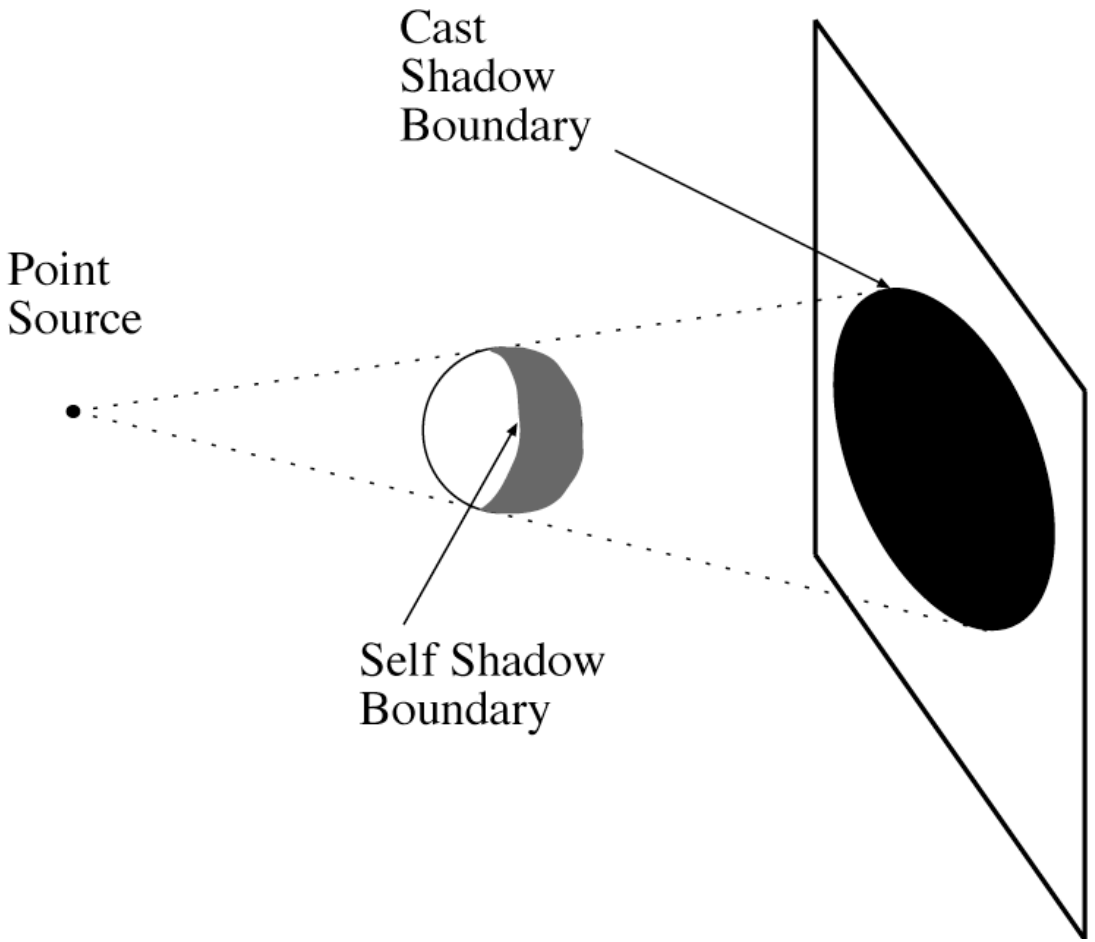
# Constancy

- You perceive objects in terms of their properties
  - rather than what they look like in an image
- Examples:
  - size constancy
    - distant objects are small in pictures, nearby objects bigger
      - but you don't think of them as changing size
  - lightness constancy
    - dark things in bright rooms can be brighter than light objects in dark rooms
      - but you perceive their lightness (=albedo)
  - color constancy
    - image color changes when lighting color changes
      - but you perceive the surface color
  - object constancy

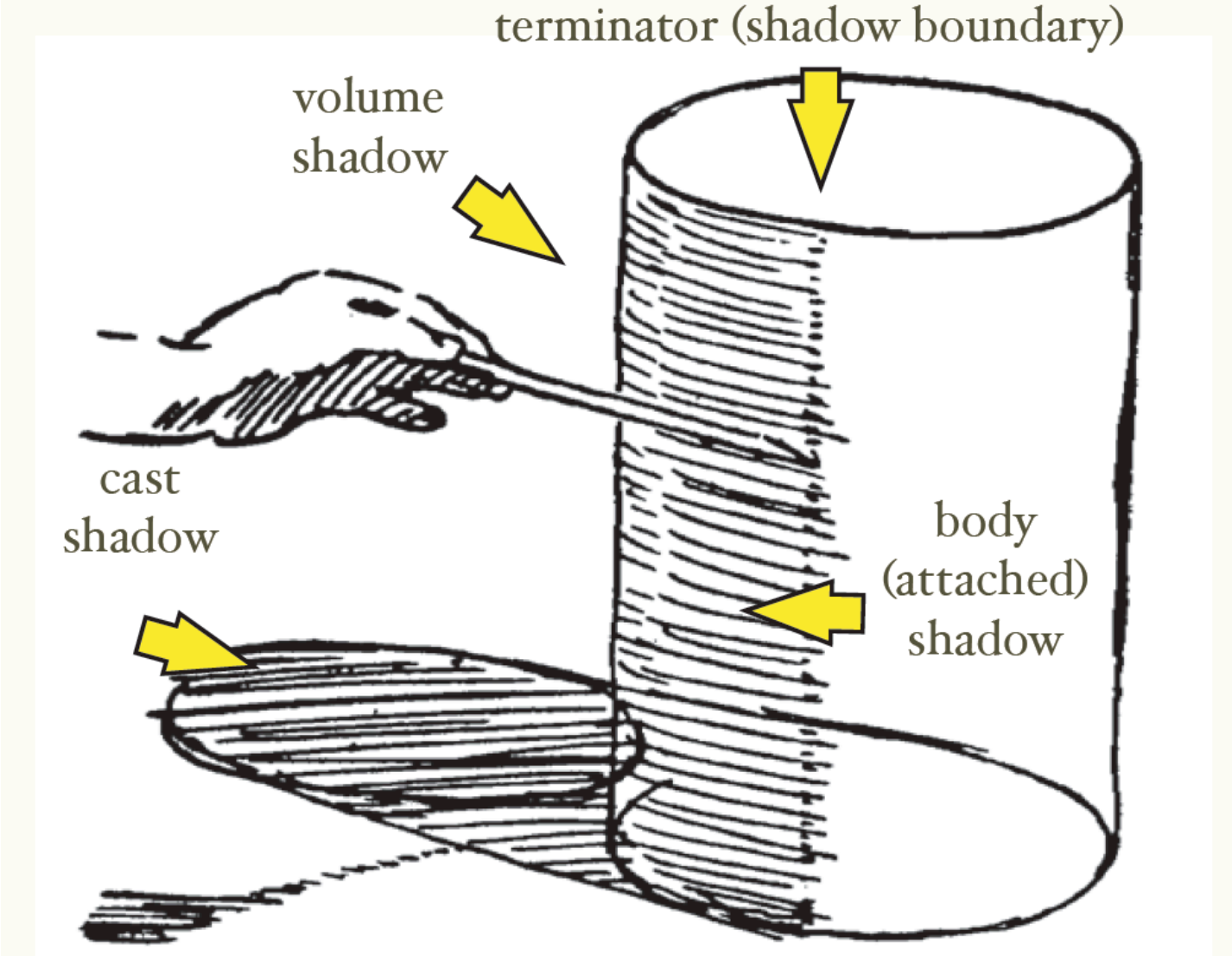
Which fish is bigger?

# Shadows cast by a point source

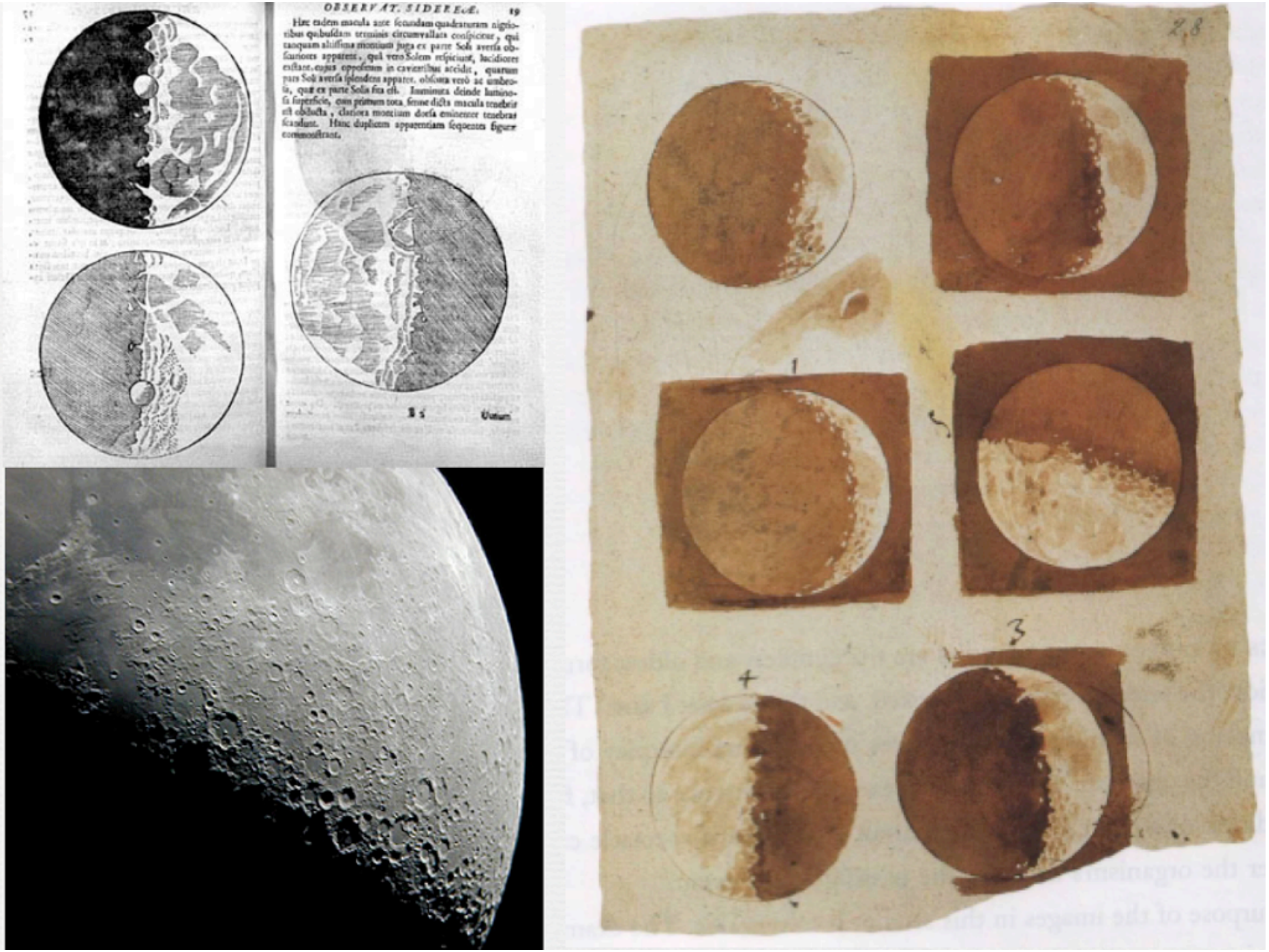
- A point that can't see the source is in shadow
- For point sources, the geometry is simple



# Cues to shape - shadows




From Koenderink slides on image texture and the flow of light



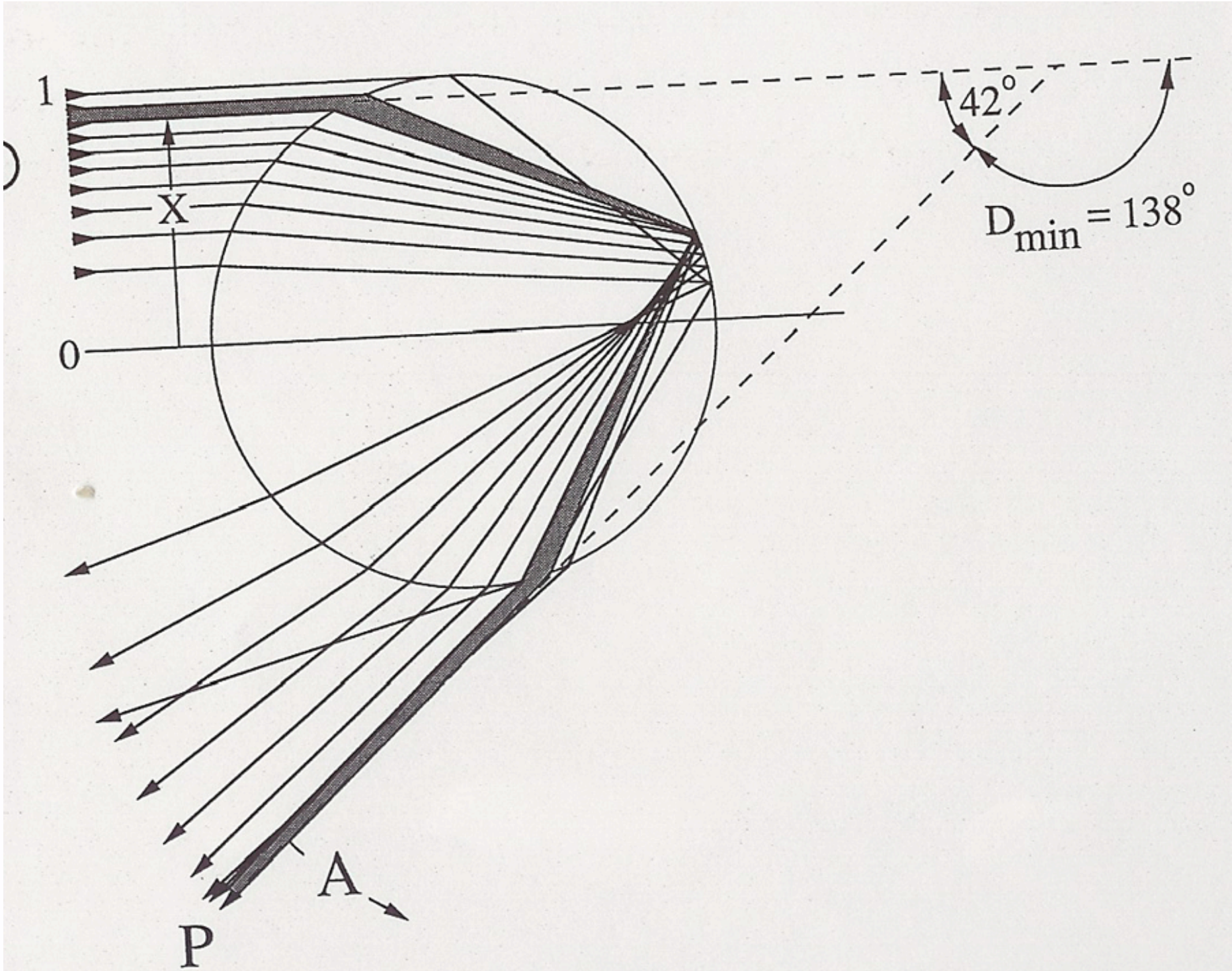

From Koenderink slides on image texture and the flow of light

Shadow geometry can be very nasty

From Hel Des, on Flickr

# Refraction

- Light striking an interface changes direction
  - between translucent surfaces with different speed-of-light
  - (refraction)
- At critical angle, total internal reflection




From Lynch and Livingstone, Color and Light in Nature

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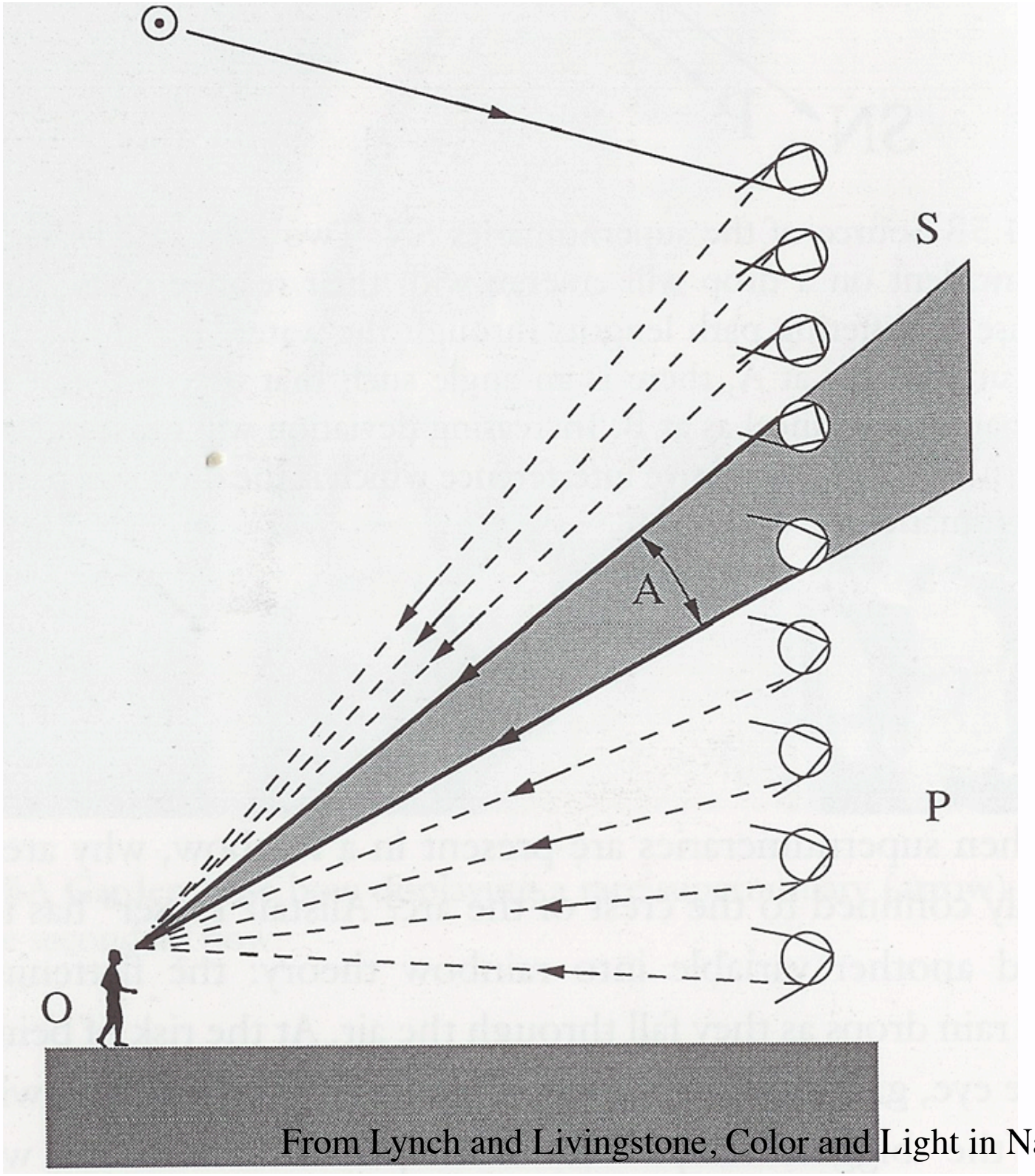


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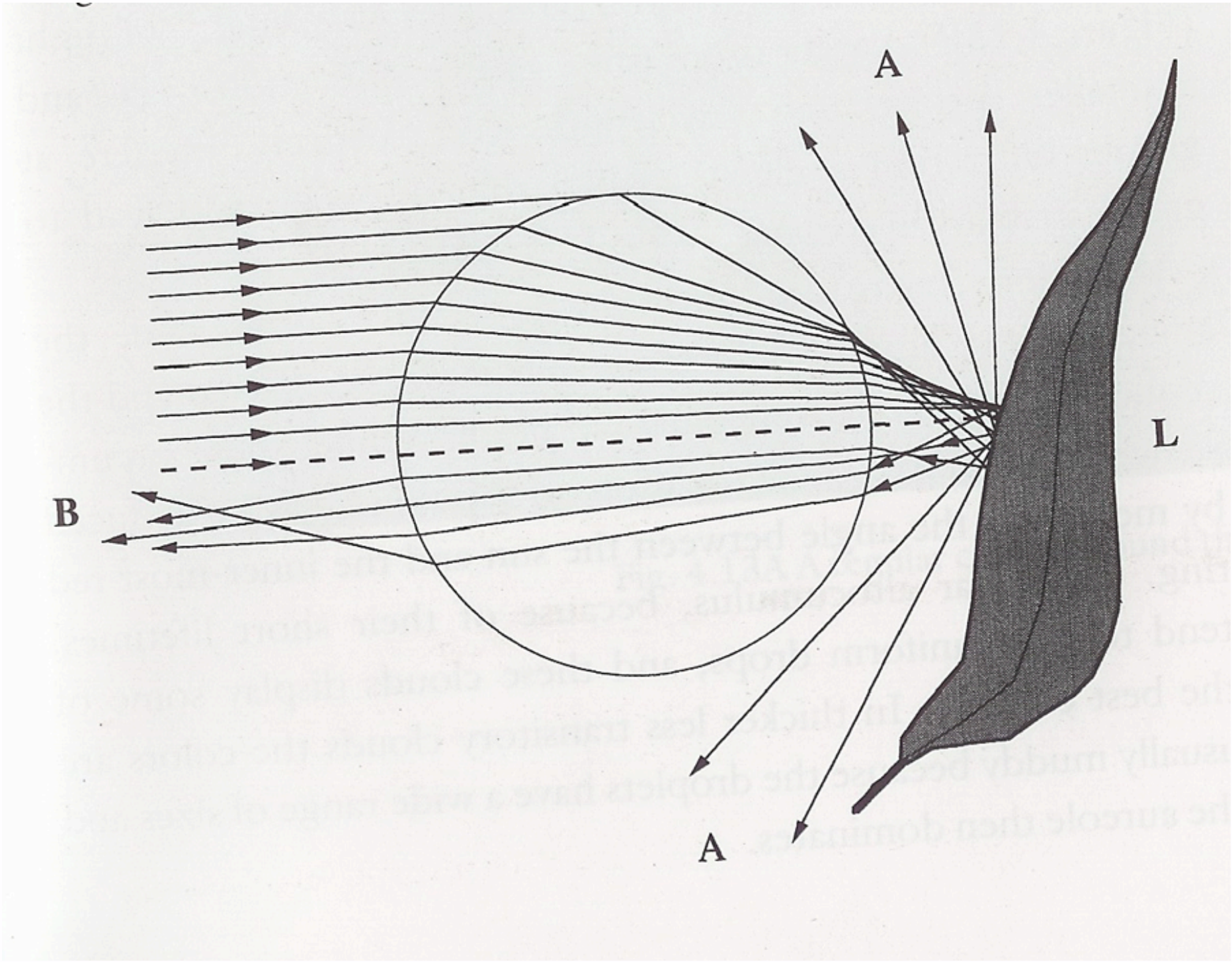


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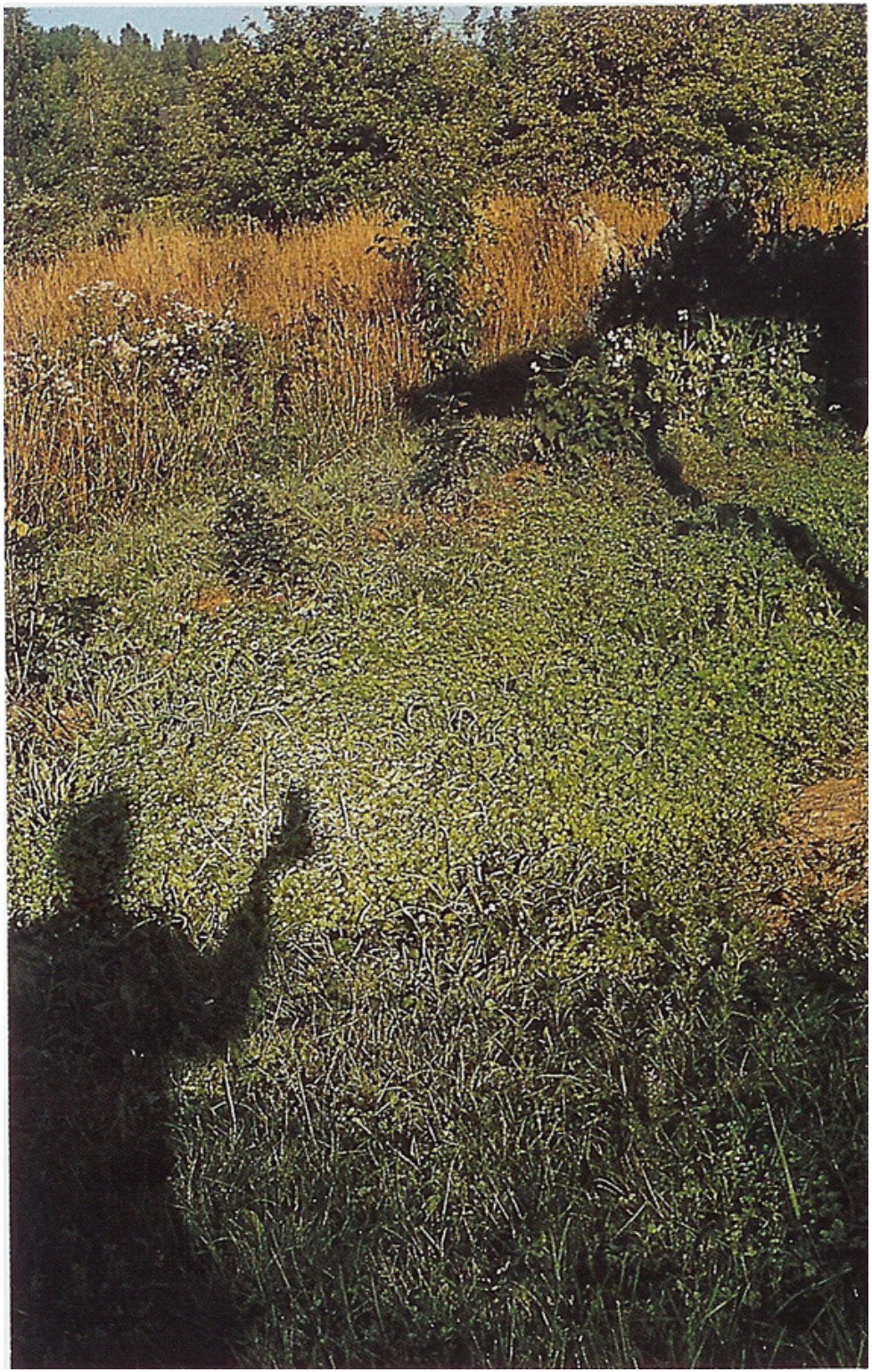
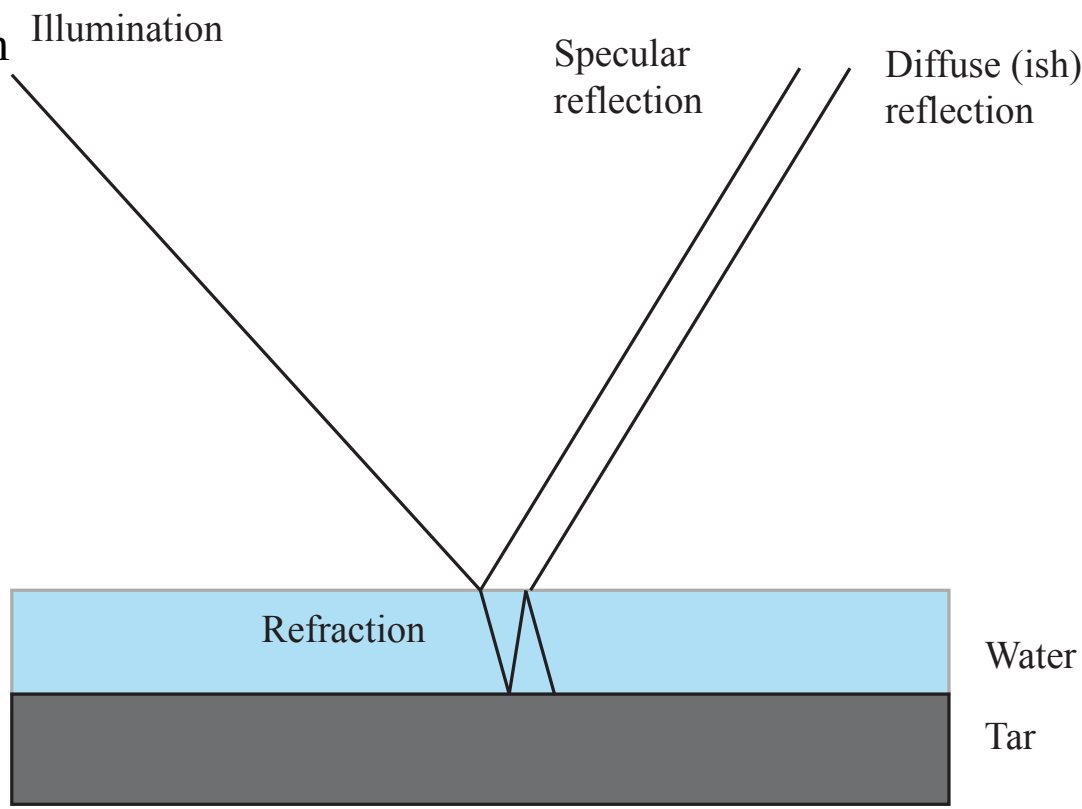


Minnaert, Light and Color in the outdoors
Heiligenschein

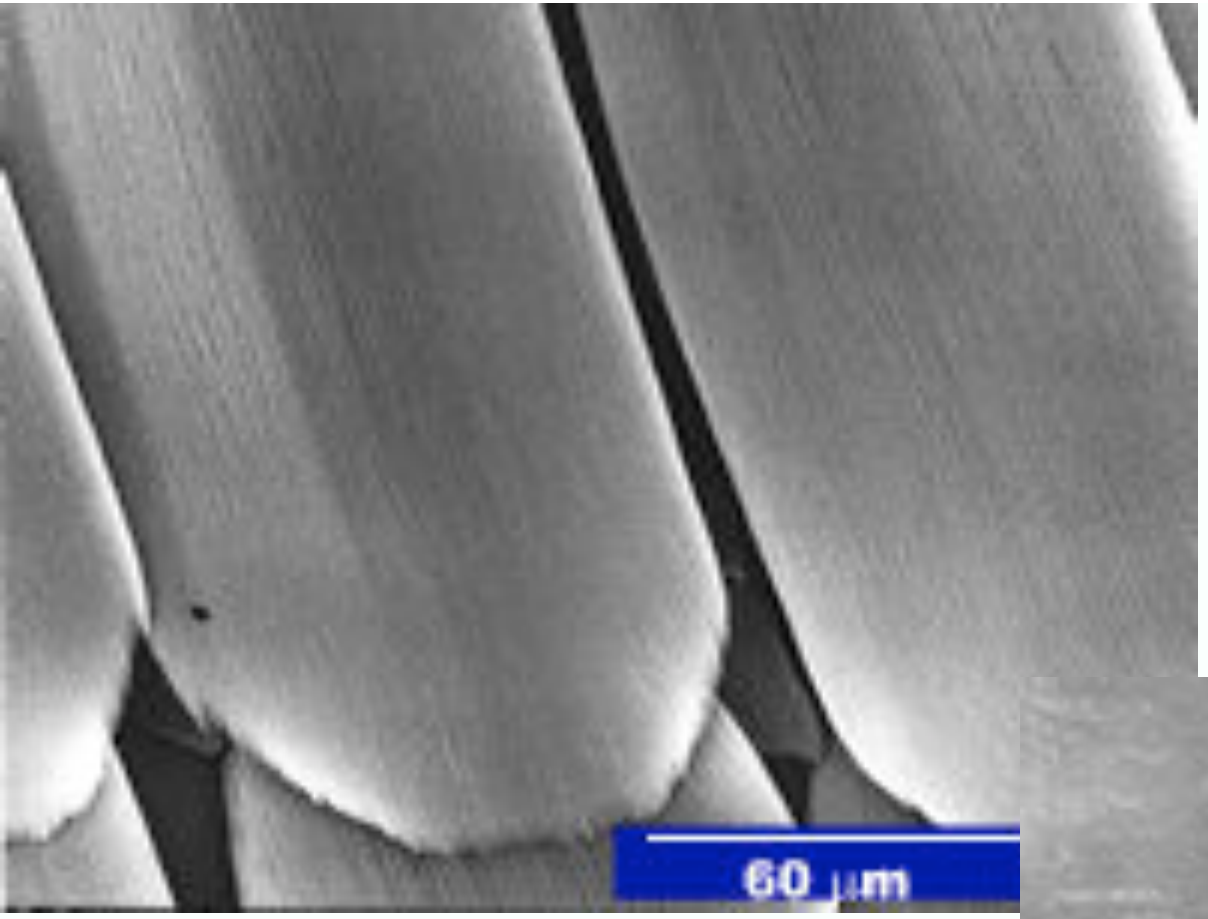
# Films on surfaces

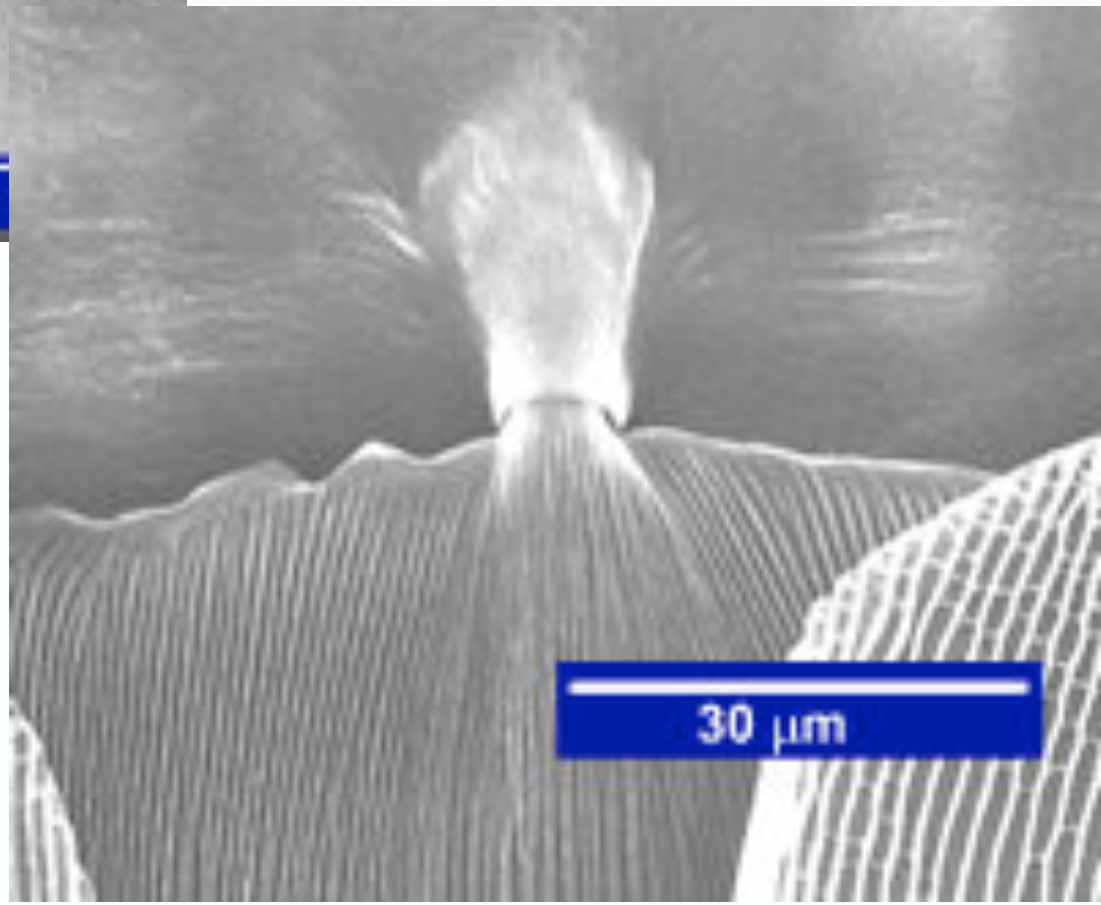
- eg water
- Assume:
  - film is thin
- You see:
  - specular reflection+diffuse term

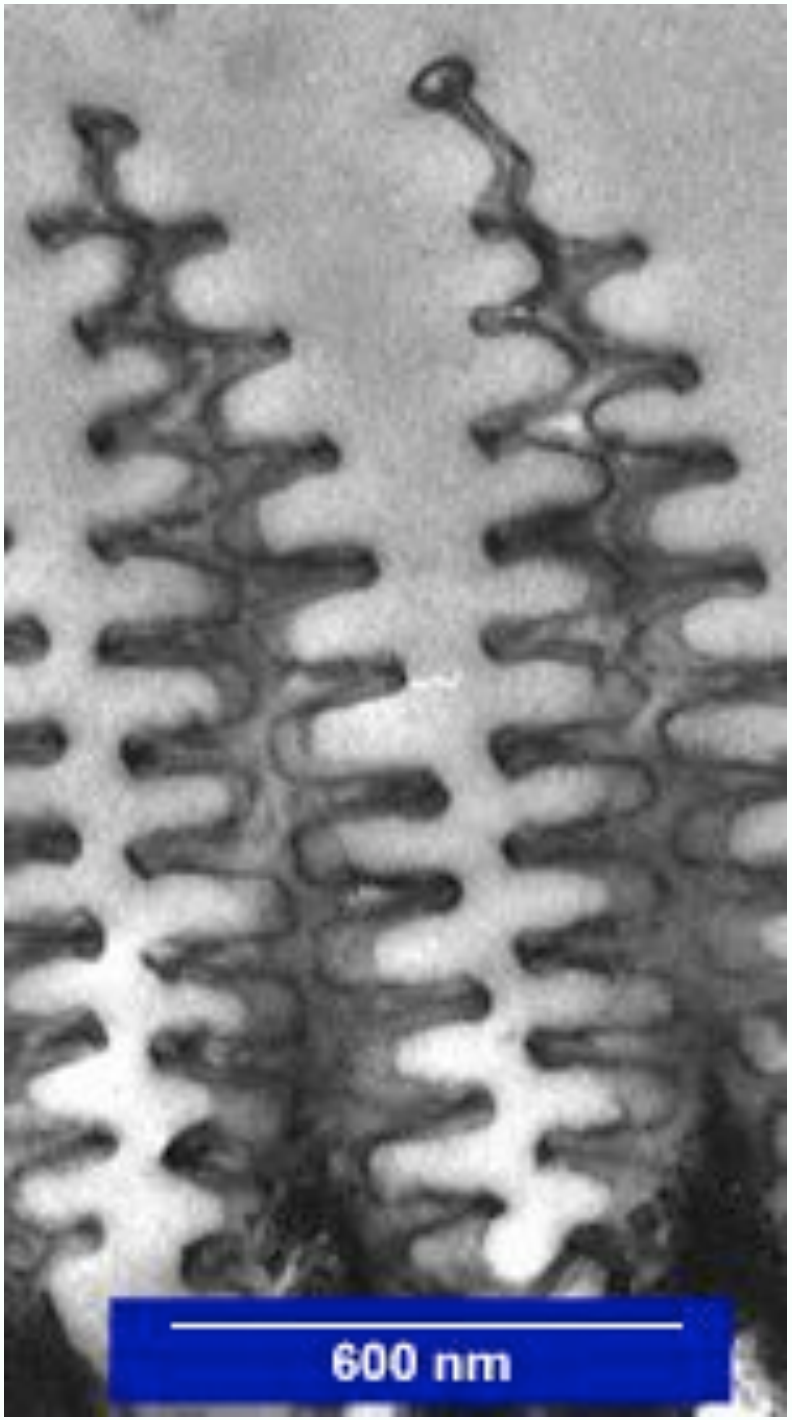


# Interference effects

- Sometimes seen on films
  - if the film is the right number of wavelengths thick
    - waves will interfere destructively (resp constructively)
    - can give rise to intense colors
      - oil films on water often do this

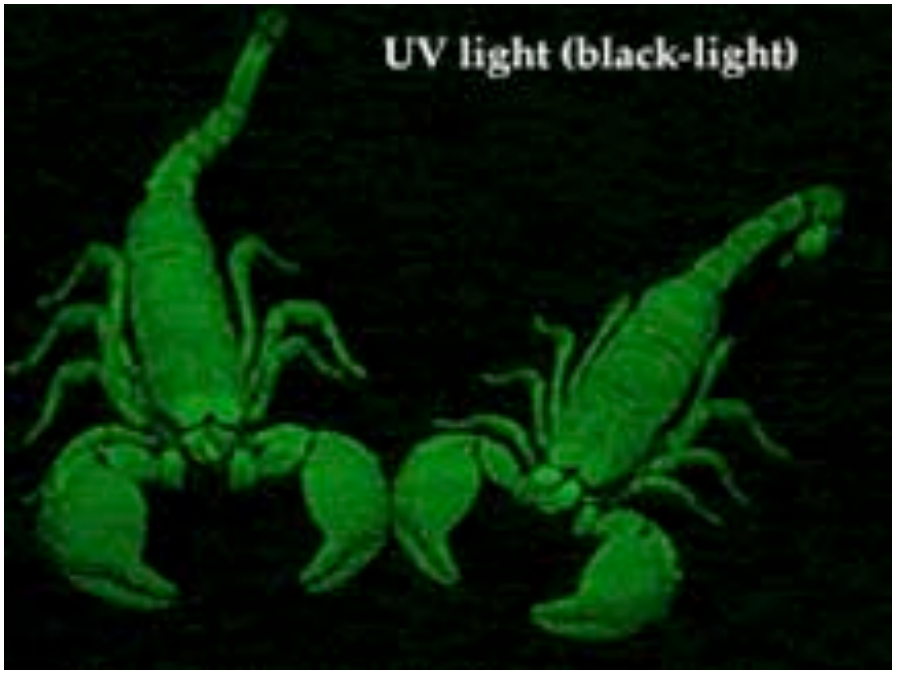

60 µm

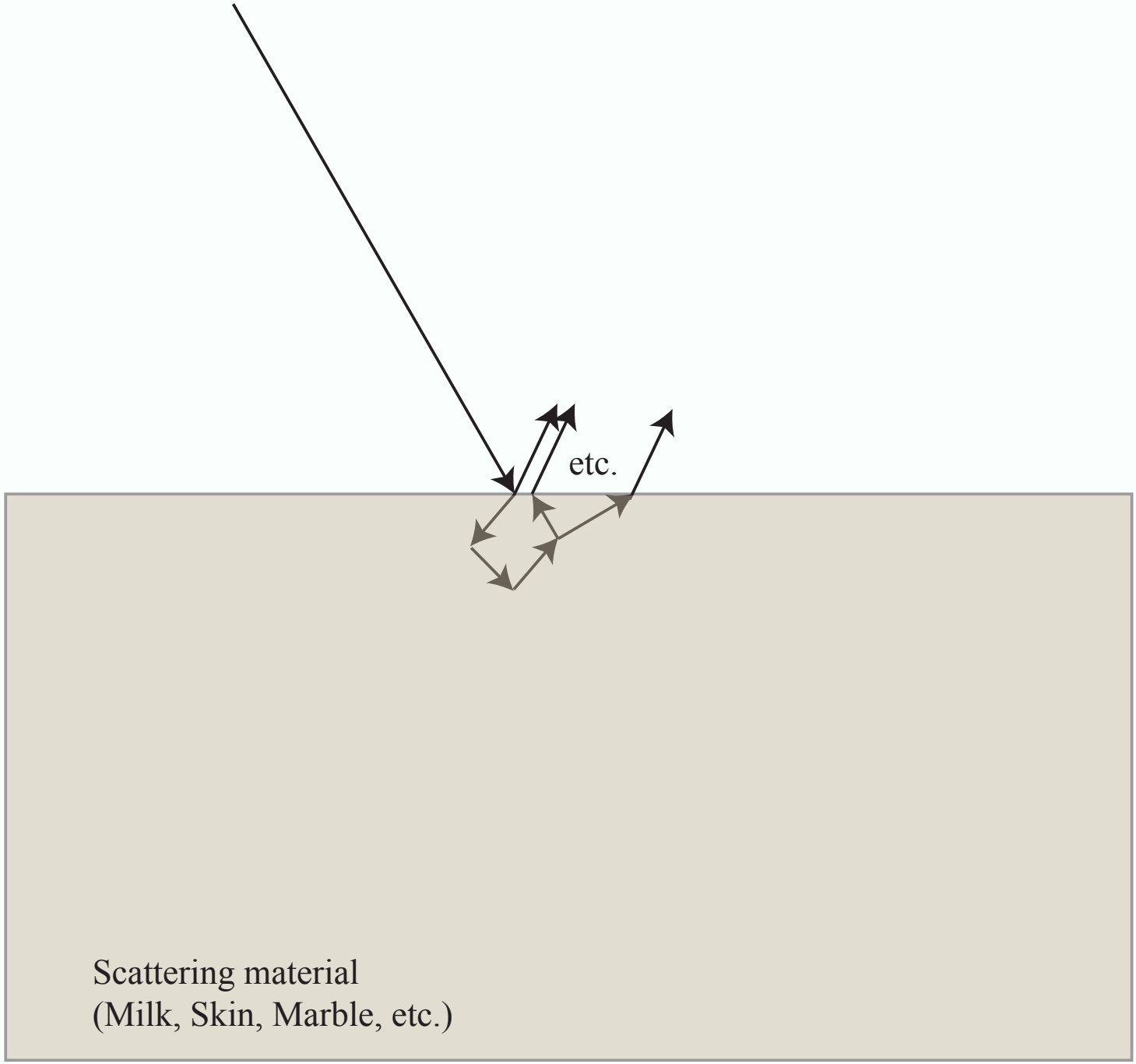

30 µm


600 nm

# Fluorescence

- Light arrives, is absorbed
  - then light at a different wavelength is emitted
- Many examples, mostly obscure
  - scorpions, some deep-sea fishes, washing powder, teeth, nylon


etc.
Scattering material
(Milk, Skin, Marble, etc.)


RENDERED USING DALI - HENRIK WANN JENSEN 2001

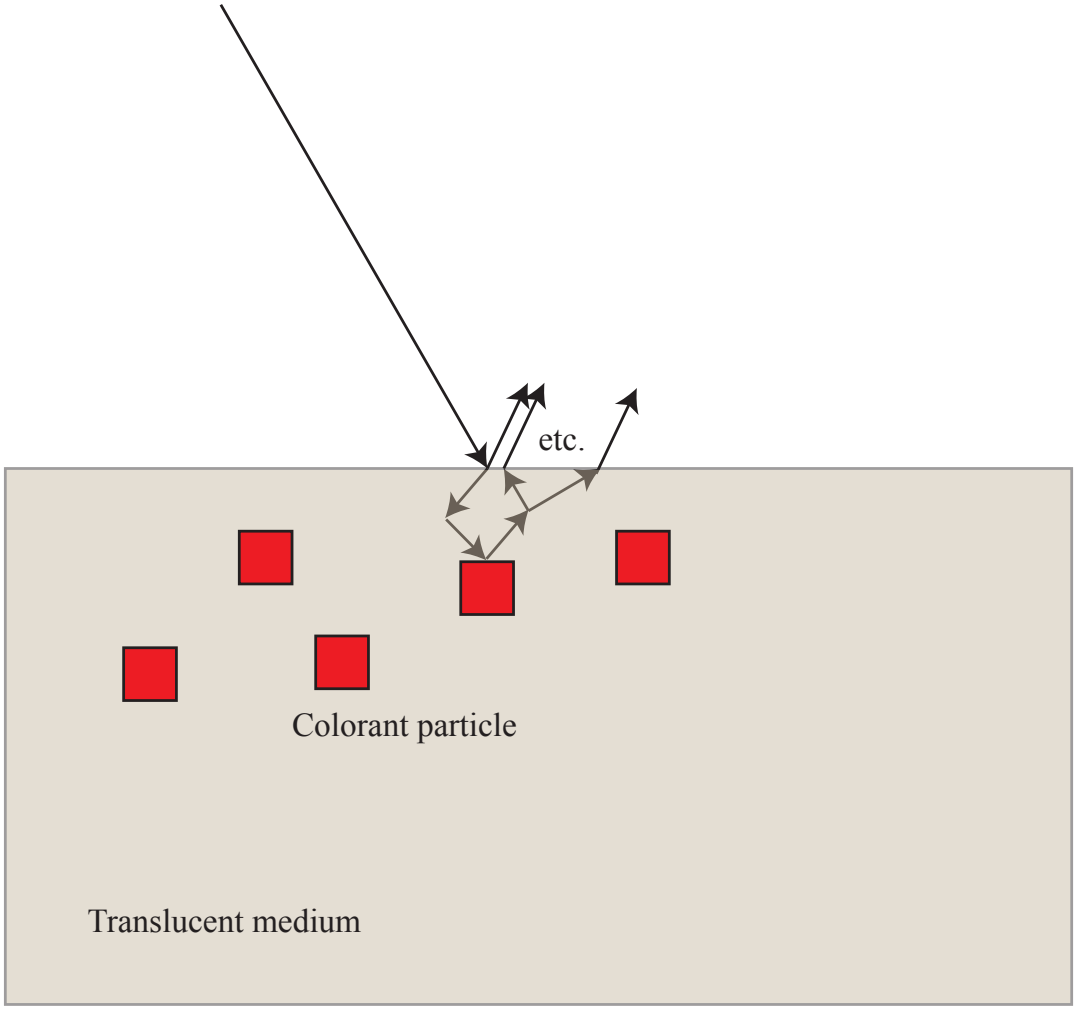

HENRIK WANN JENSEN 2000


HENRIK WANN JENSEN 2001


HENRIK WANN JENSEN 1999

subsurface scattering in skin (not rendered!)

# Paints are films with colored scatterers



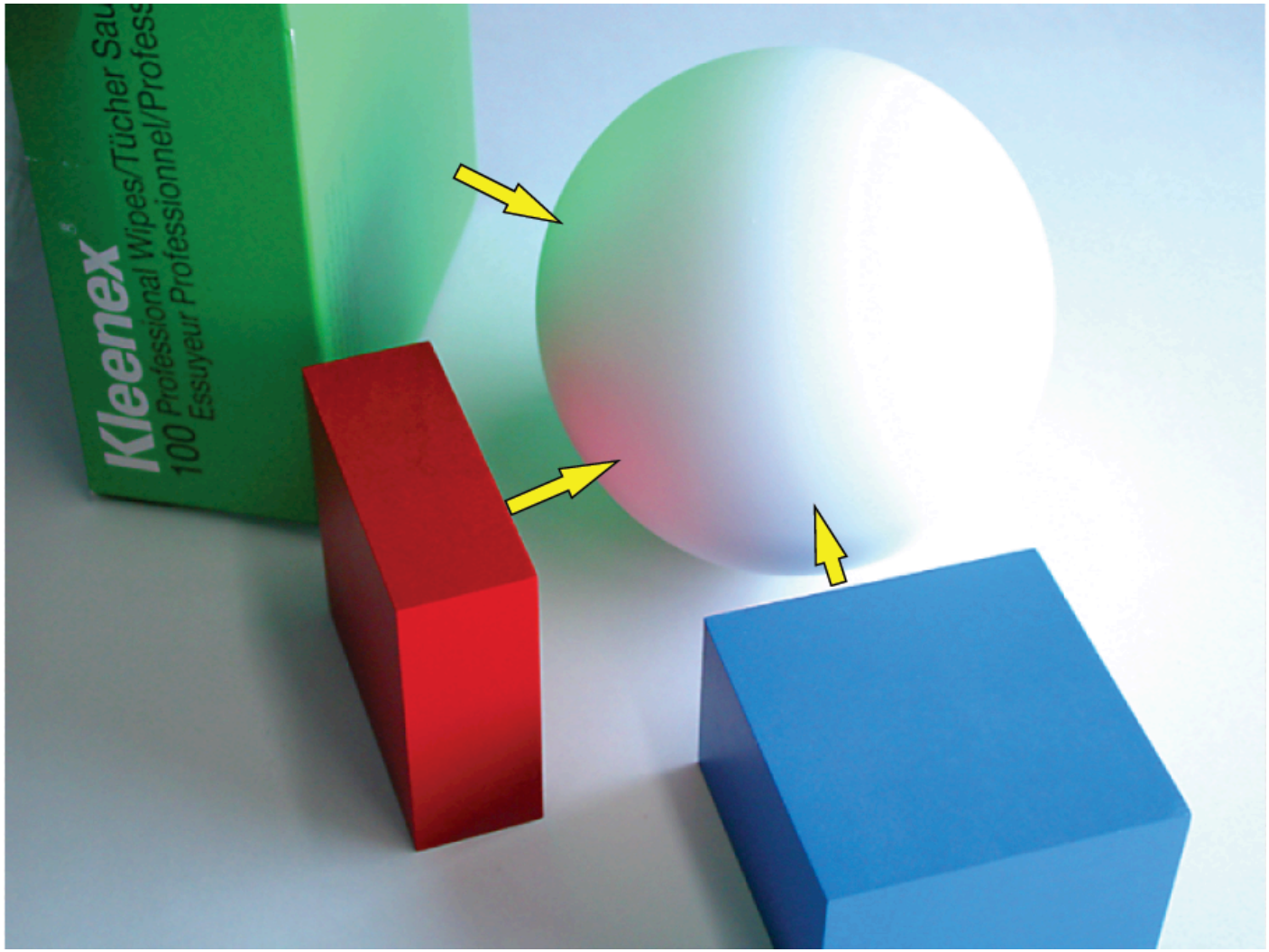
# Glowing paint from specular refl’ns

# More complex lighting effects

# 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

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