Image Intensity: Simple Physics

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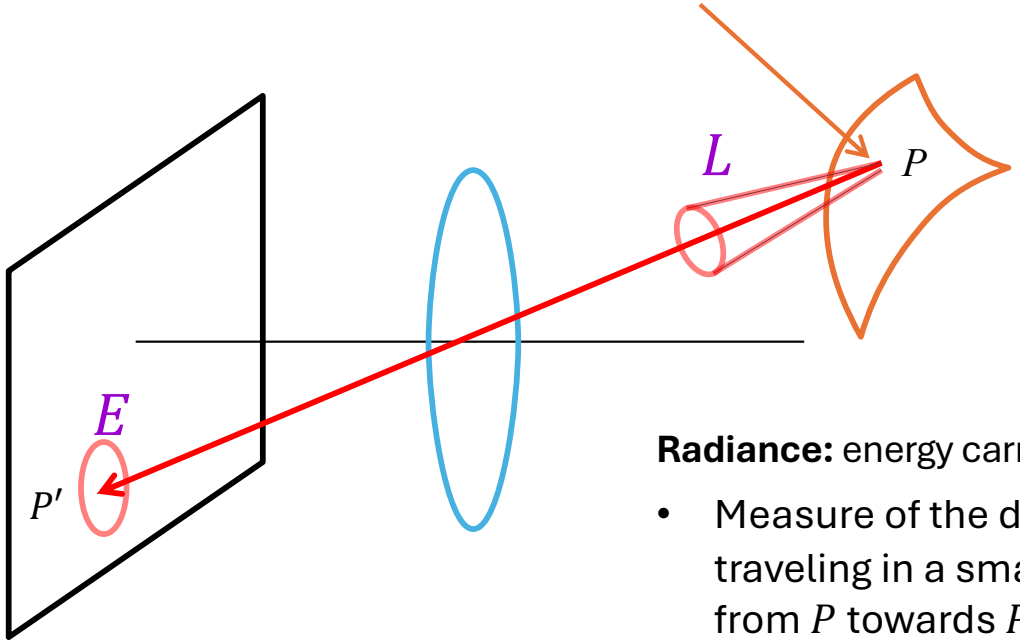
Radiometry of image formation



Irradiance: energy arriving at a surface

- Incident power per unit area (not foreshortened)
- Units: Watts per square meter

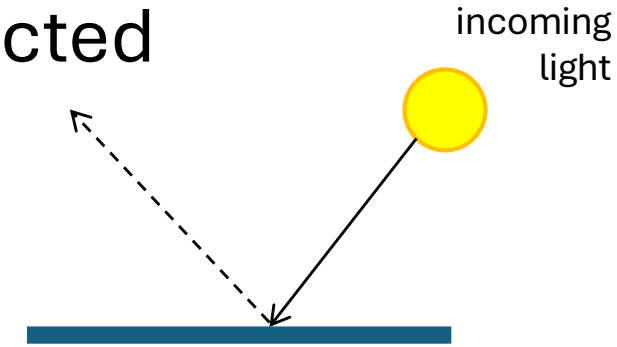
Radiance: energy carried by a ray

- Measure of the density of photons traveling in a small cone of directions from P towards P'
- Power per unit area perpendicular to the direction of travel, per unit solid angle
- Units: Watts per square meter per steradian

What is the relationship between E and L?

Basic models of reflection

- **Specular reflection:** light is reflected about the surface normal



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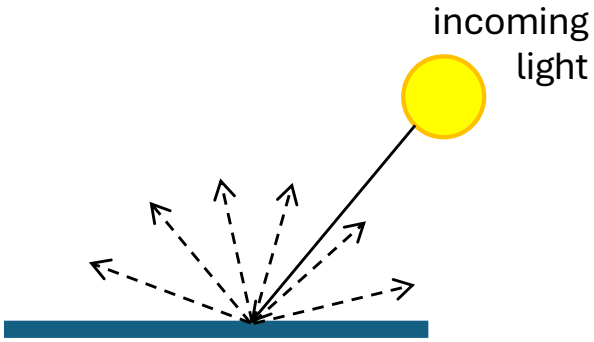
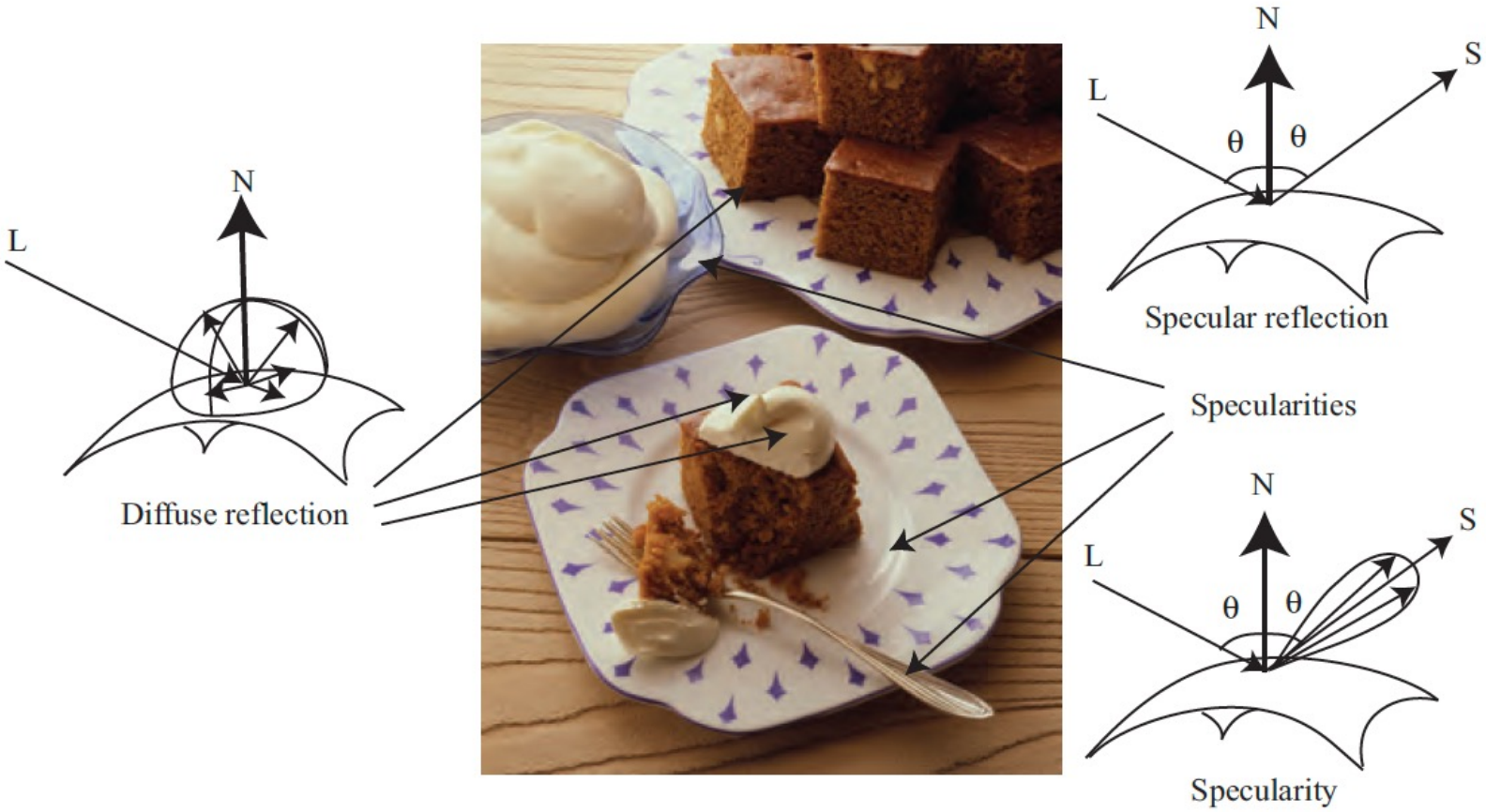
- **Diffuse reflection:** light scatters equally in all directions



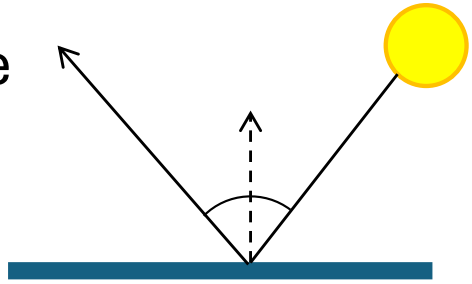
Slide from D. Hoiem

Diffuse and specular reflection



Specular reflection

- Radiation arriving along a source direction leaves along the **specular direction** (source direction reflected about normal)

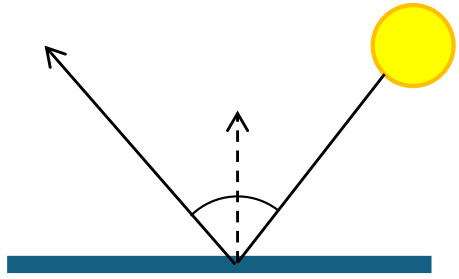


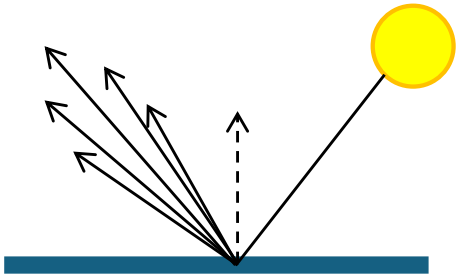
- Classic case: Mirror

- Diagnosis
  - When you look at a specular surface from different directions, appearance changes
  - True specular surfaces are “really like” mirrors
    - Form a clear image
- Q:
  - Why do mirrors reverse left and right, but not up and down?

Specularities

- On real surfaces, energy usually goes into a “lobe” of directions
  - So image is blurred
  - More usually, you see only the source

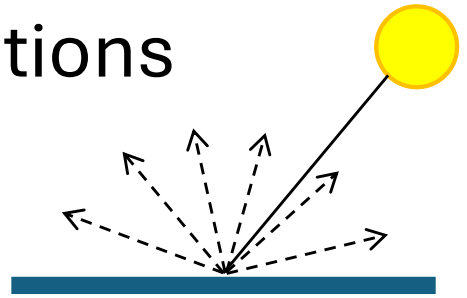




- Specularities: narrow bright patches
  - On metals: color of the metal
  - Others: color of the light source

Diffuse reflection

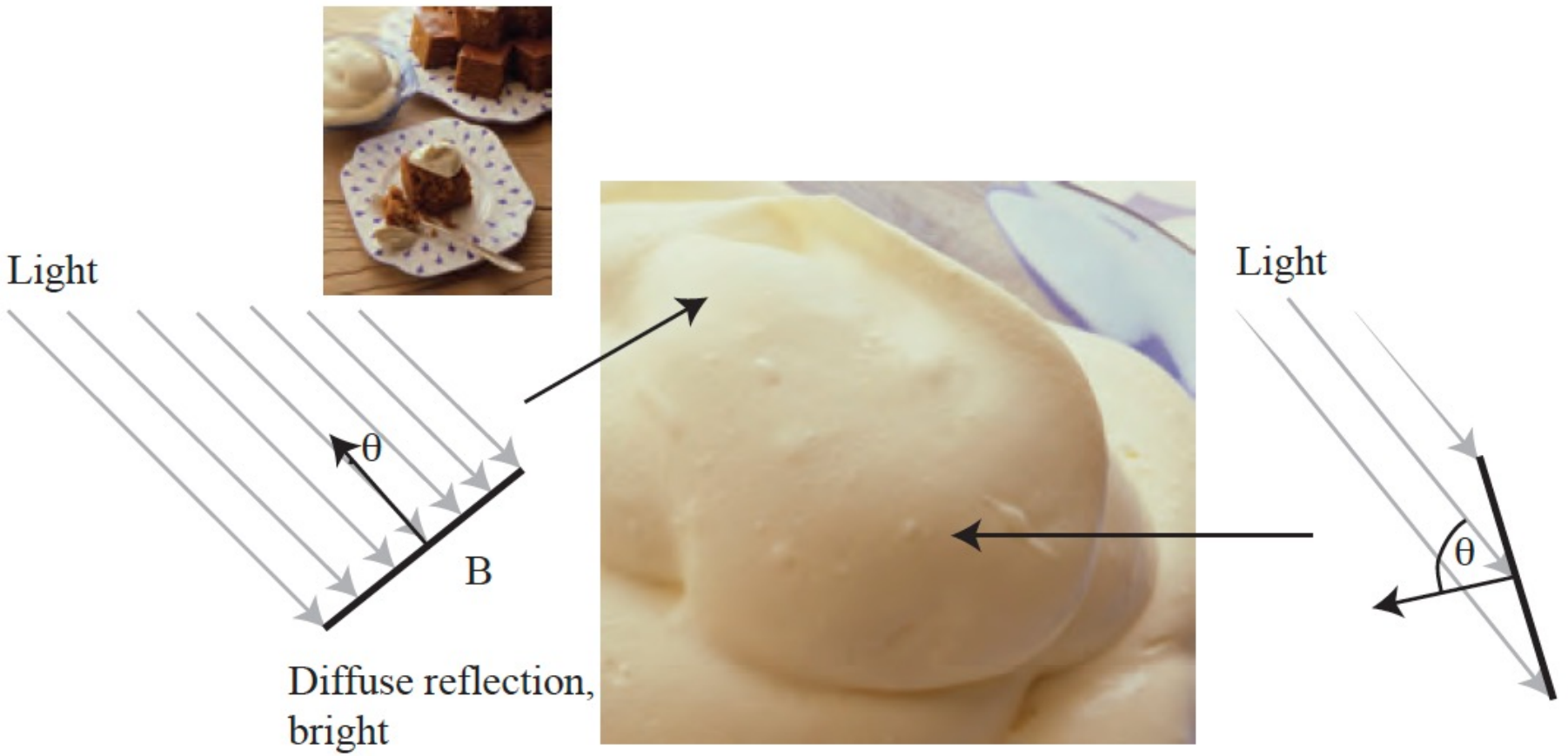
- Light scatters equally in all directions
  - E.g., brick, matte plastic, rough wood



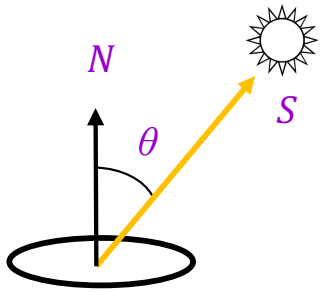
- Diagnosis:
  - Surface has the same brightness when looked at from different directions
    - (under fixed illumination)
- Extremely common
  - Very often surfaces are “largely” diffuse

Image source

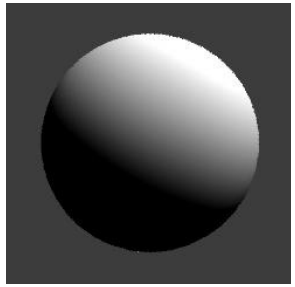
Orientation of diffuse surfaces



Diffuse reflection: Lambert's law



$$I = \rho\,(S \cdot N)$$
$$= \rho \|S\| \cos\theta$$



I: reflected intensity (technically: *radiosity*, or total power leaving the surface per unit area)

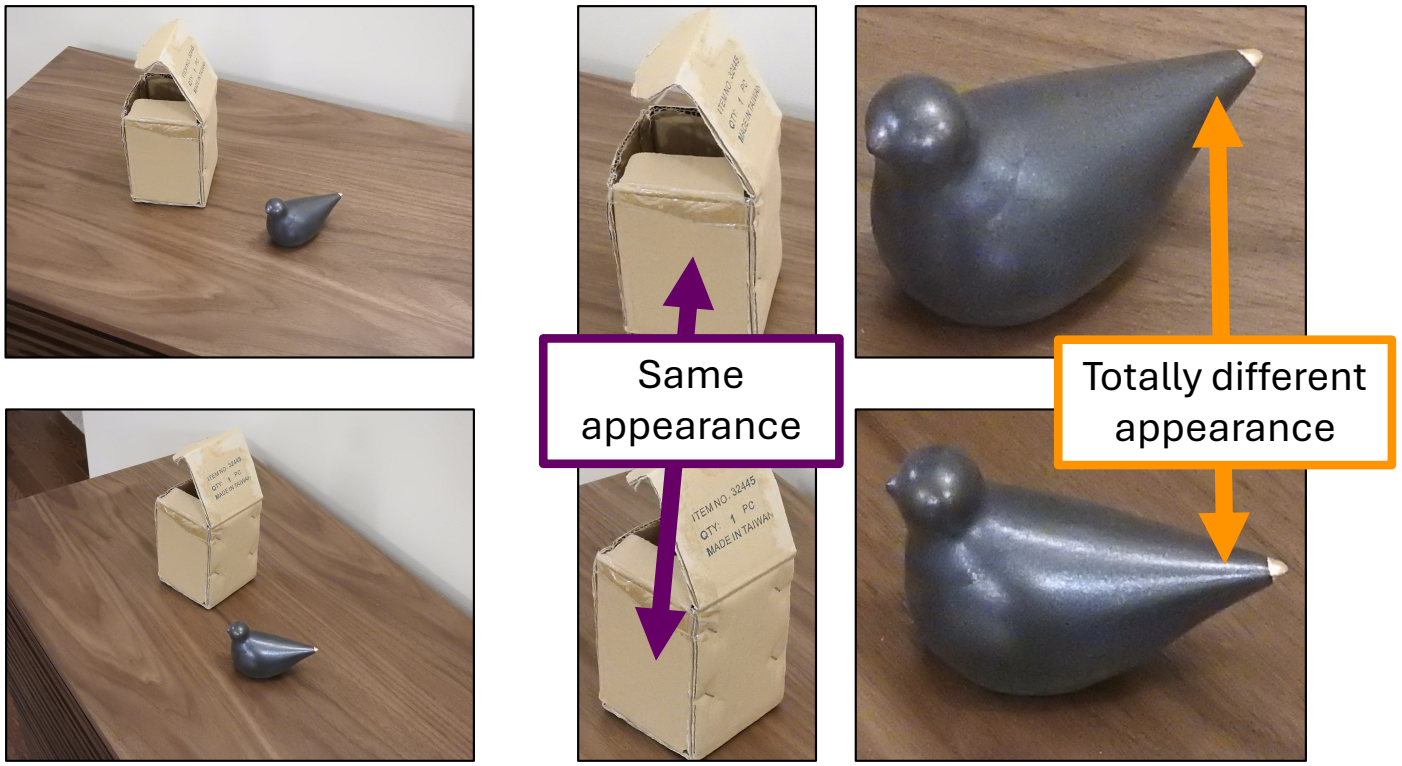
ρ: albedo (fraction of incident irradiance reflected by the surface)

S: direction of light source (magnitude proportional to intensity of the source)

N: unit surface normal

Diffuse vs. specular: Significance

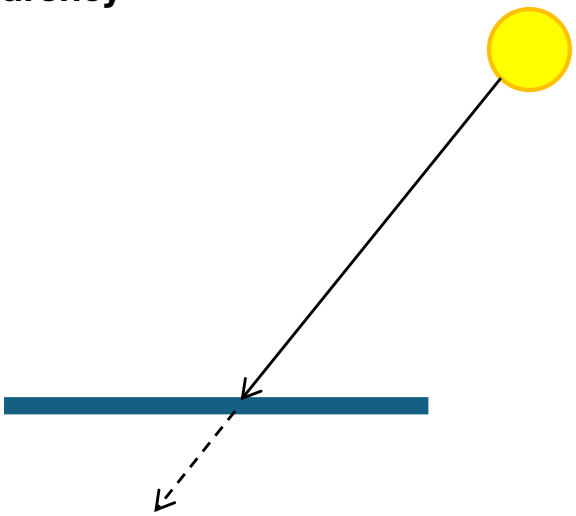
Same lighting, as close as possible camera settings, but different **camera position**



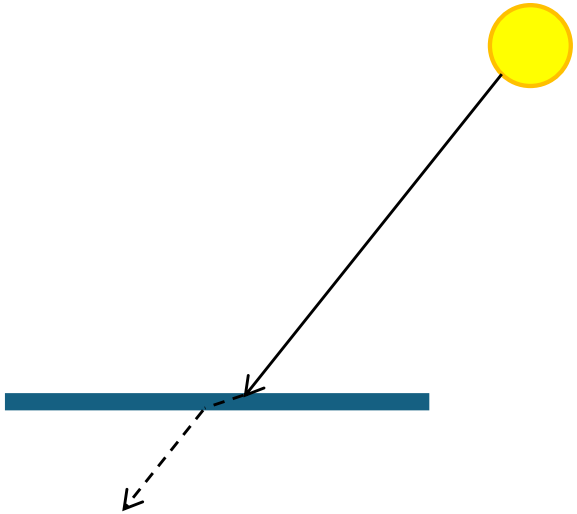
Source: J. Johnson and D. Fouhey

Light at surface – other effects

- **Transparency**



- **Refraction**



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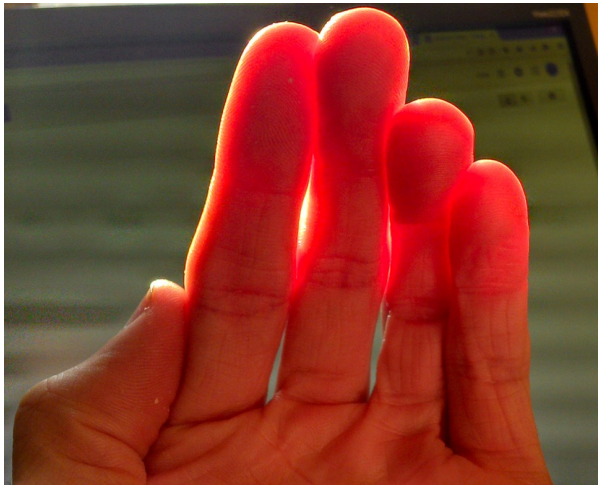
Light at surface – other effects

- **Subsurface scattering**



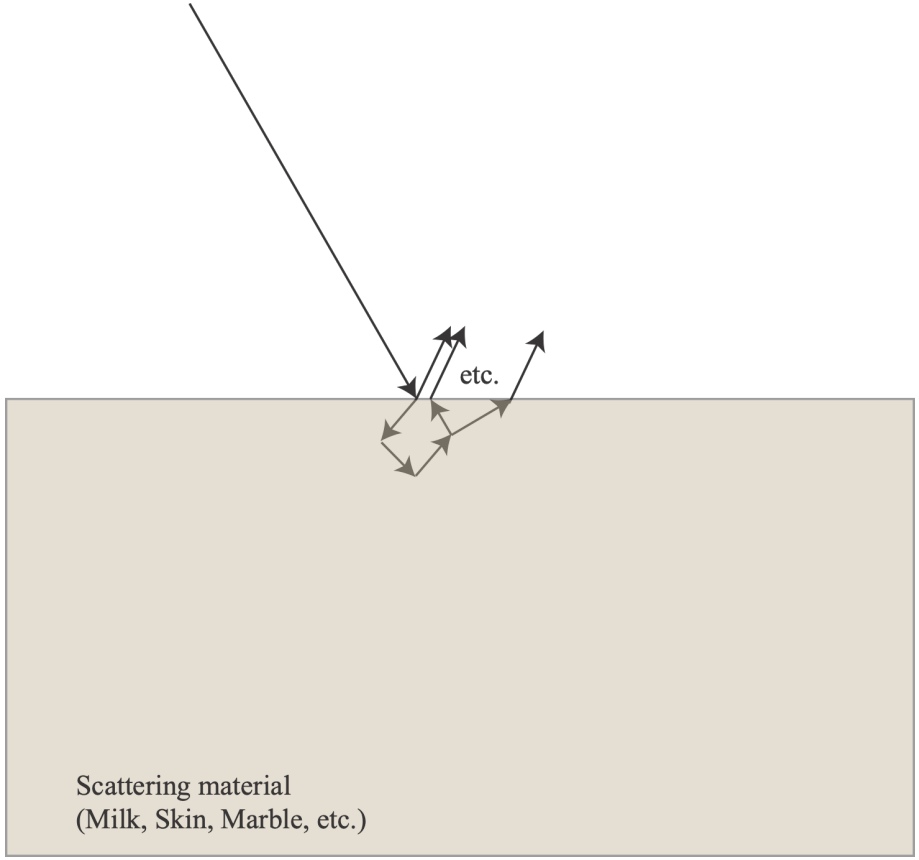


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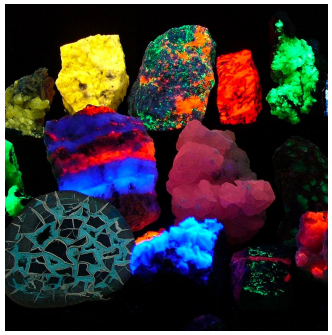
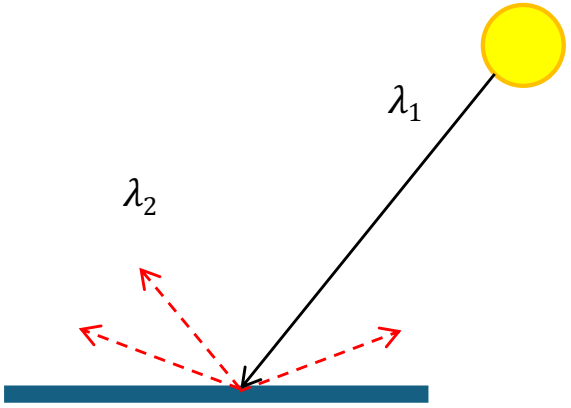
Image source

subsurface scattering in skin (not rendered!)

Light at surface – other effects

- **Fluorescence**





- **Phosphorescence**

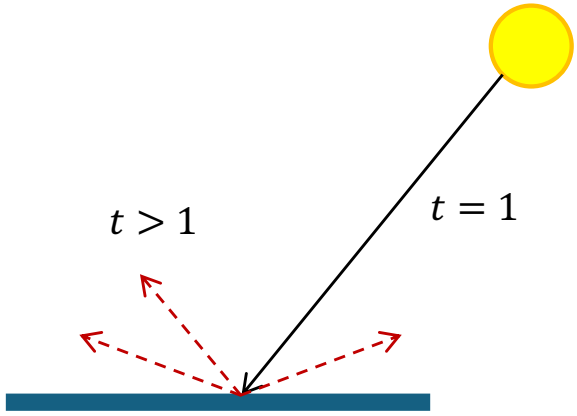


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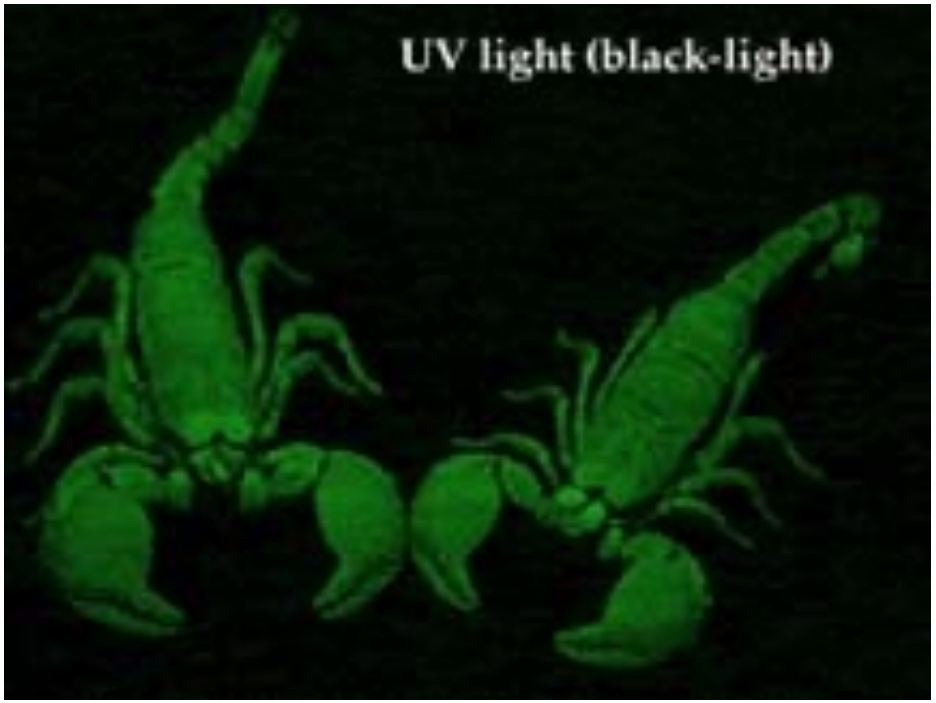
Image source

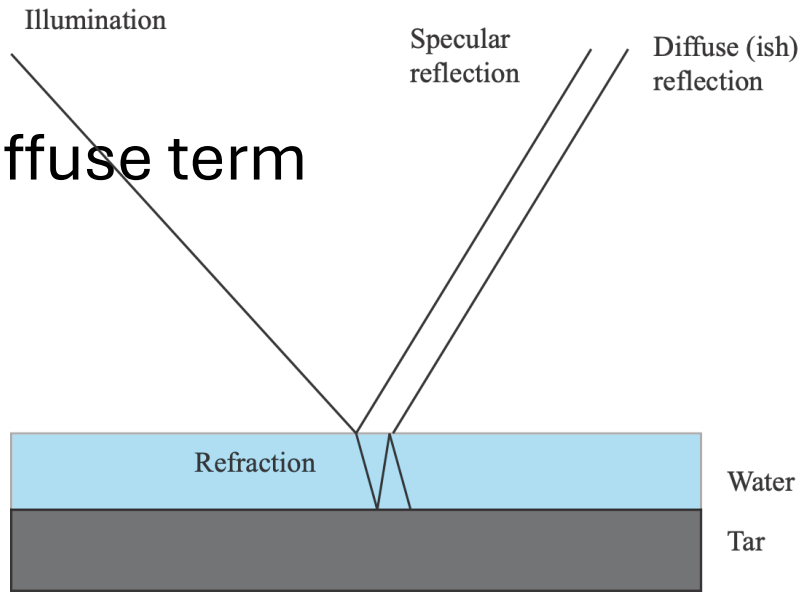
Fluorescence in nature

Many examples, mostly obscure:
scorpions, deep sea fish, teeth, nylon, chitons

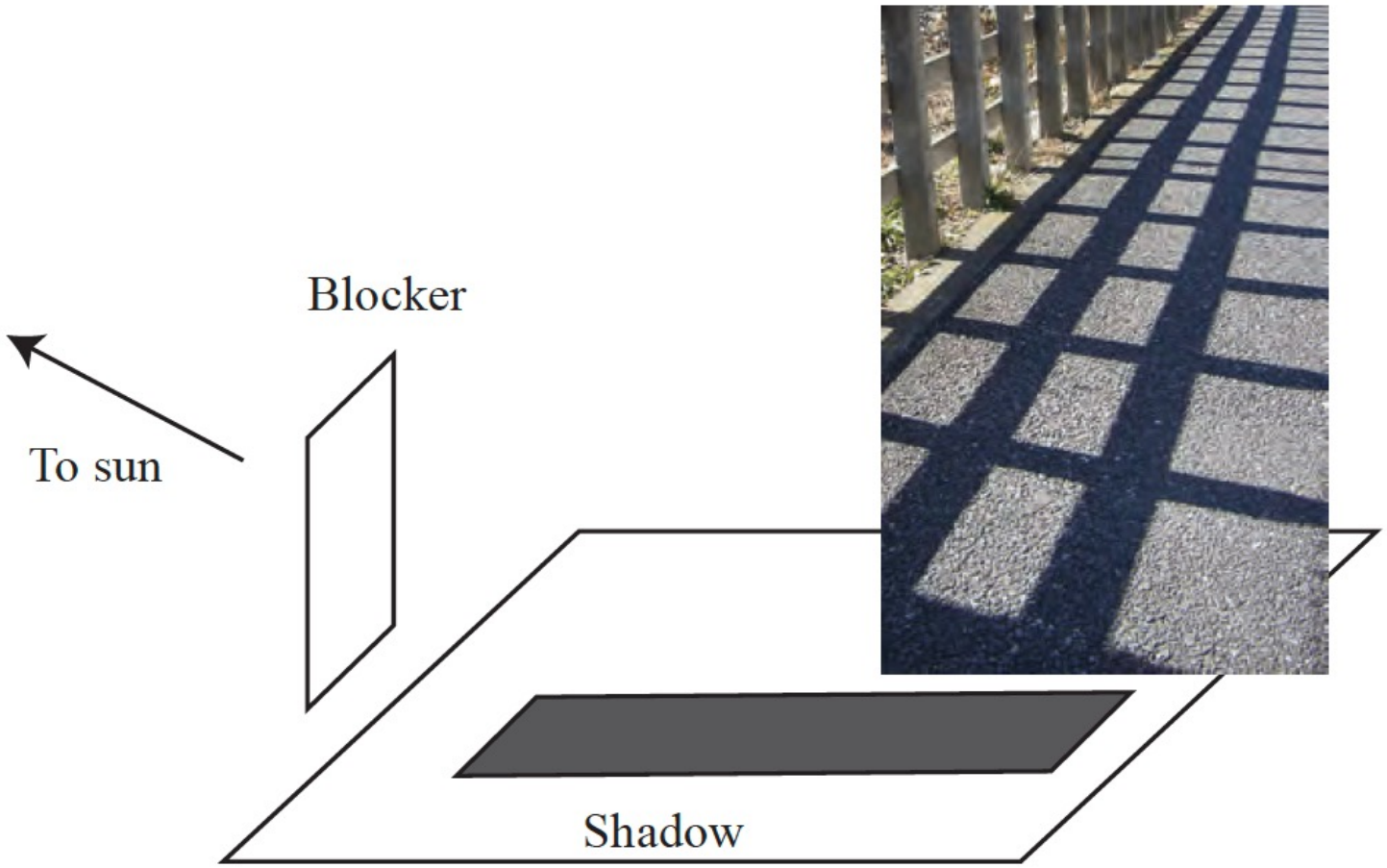


Films on surfaces

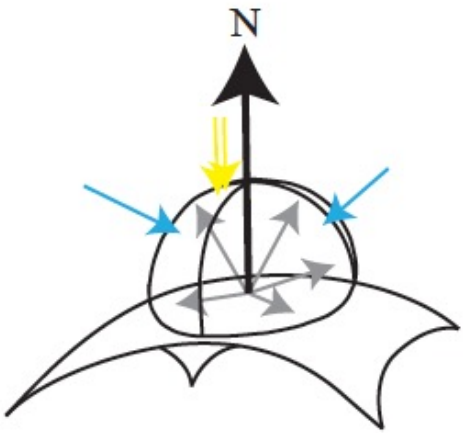
- eg water
- Assume:
  - film is thin
- You see:
  - specular reflection+diffuse term

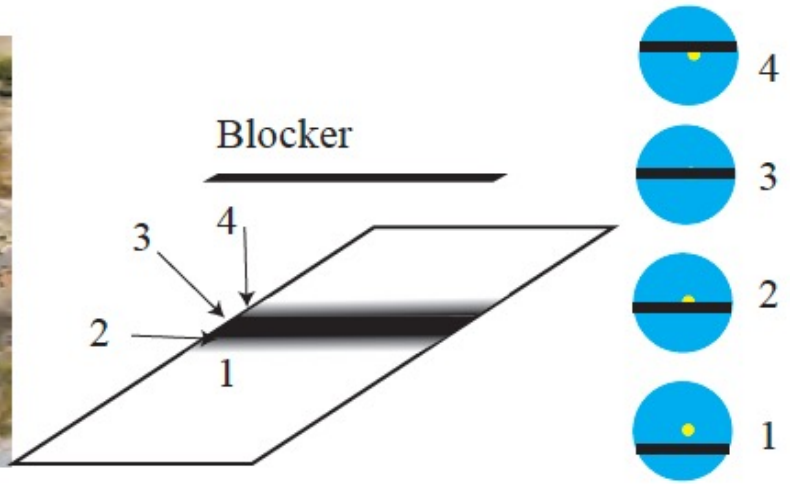


Shadows

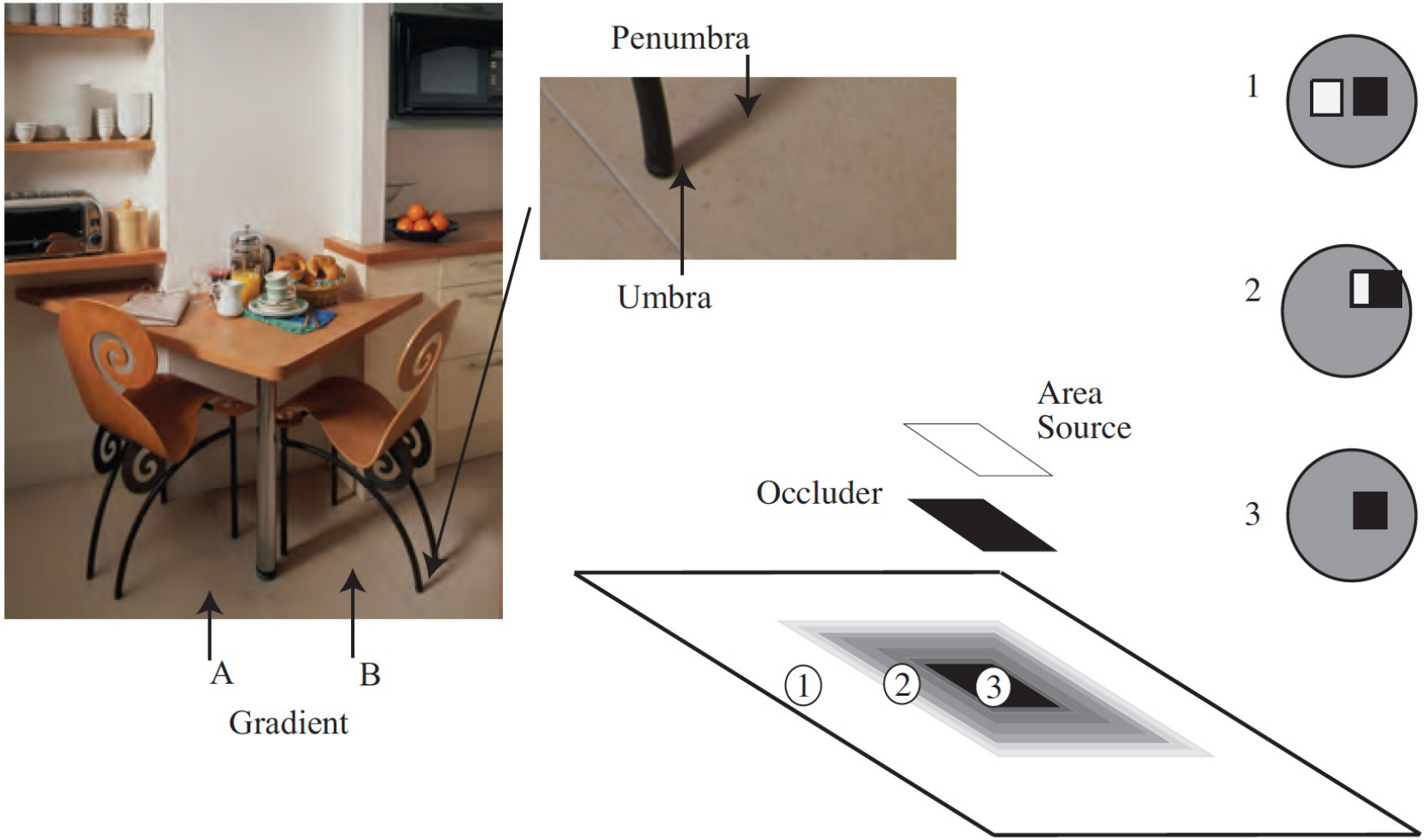


Blurred shadows





Area sources and their effects

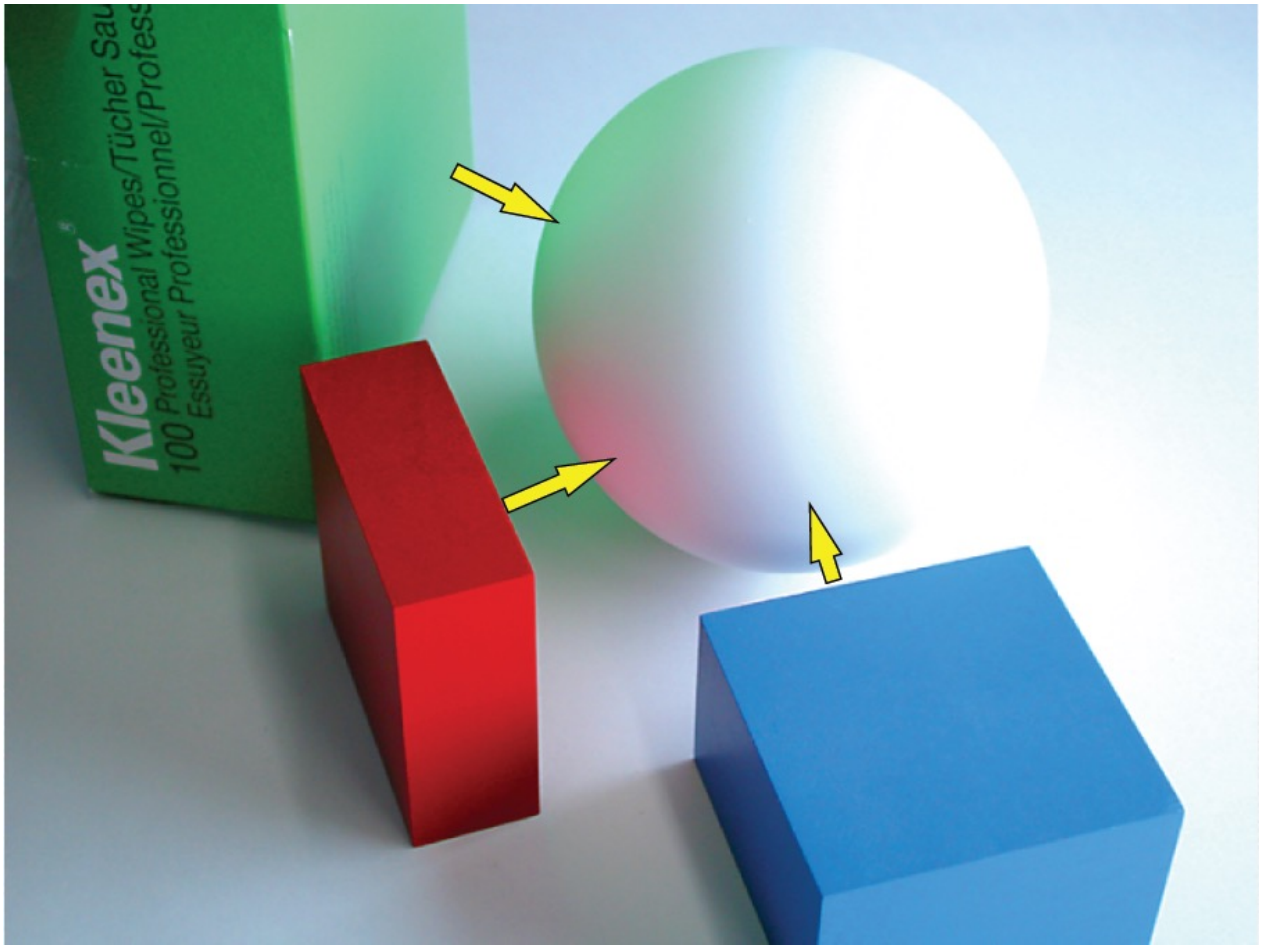


Dark shadows are rare indoors

Interreflections

- local shading model is poor
    - because surfaces reflect light onto one another
- 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 are a problem



- but not a major one for photometric stereo – why?

From Koenderink slides on image texture and the flow of light

Things to think about

- Most people aren’t aware of colored interreflections
  - even when you describe the physics
  - WHY?
- Why is it hard to use shadows as a shape cue?