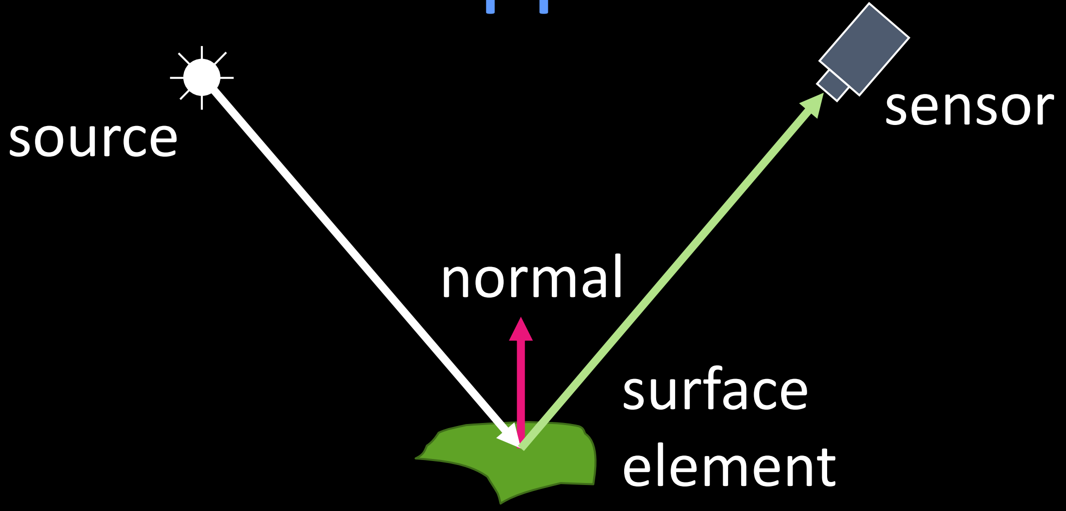
CS4495/6495
Introduction to Computer Vision

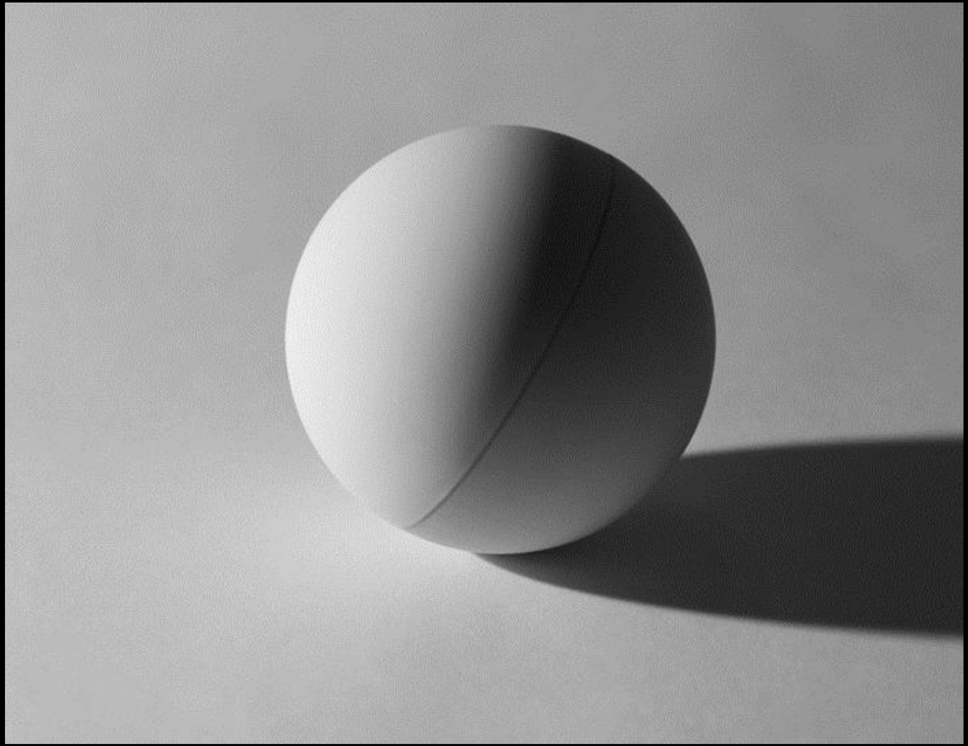
5B-L1 *Lightness*

Last time: Surface appearance

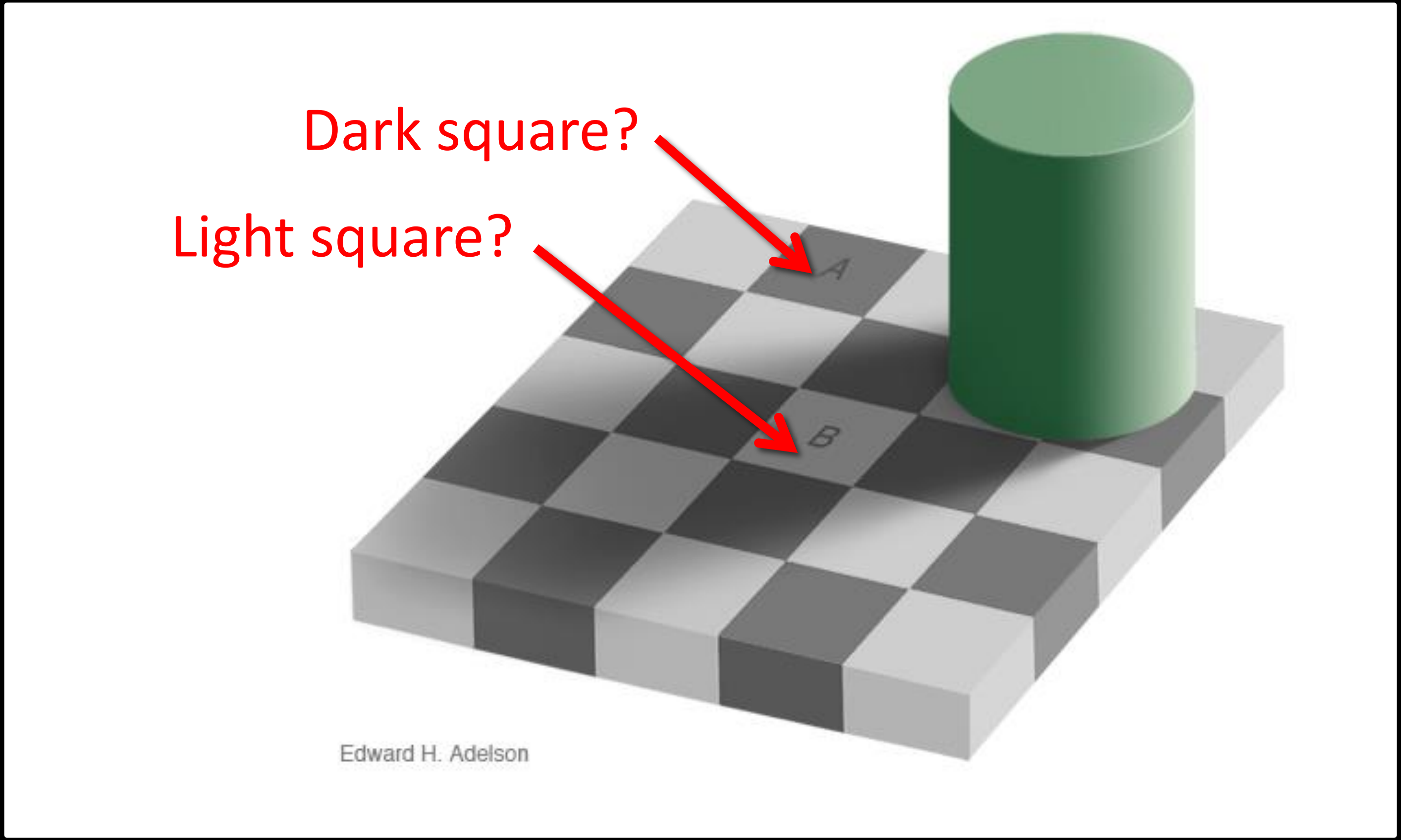


- Image intensity = f (normal, surface reflectance, illumination)
- Surface reflection depends on both the viewing and illumination directions

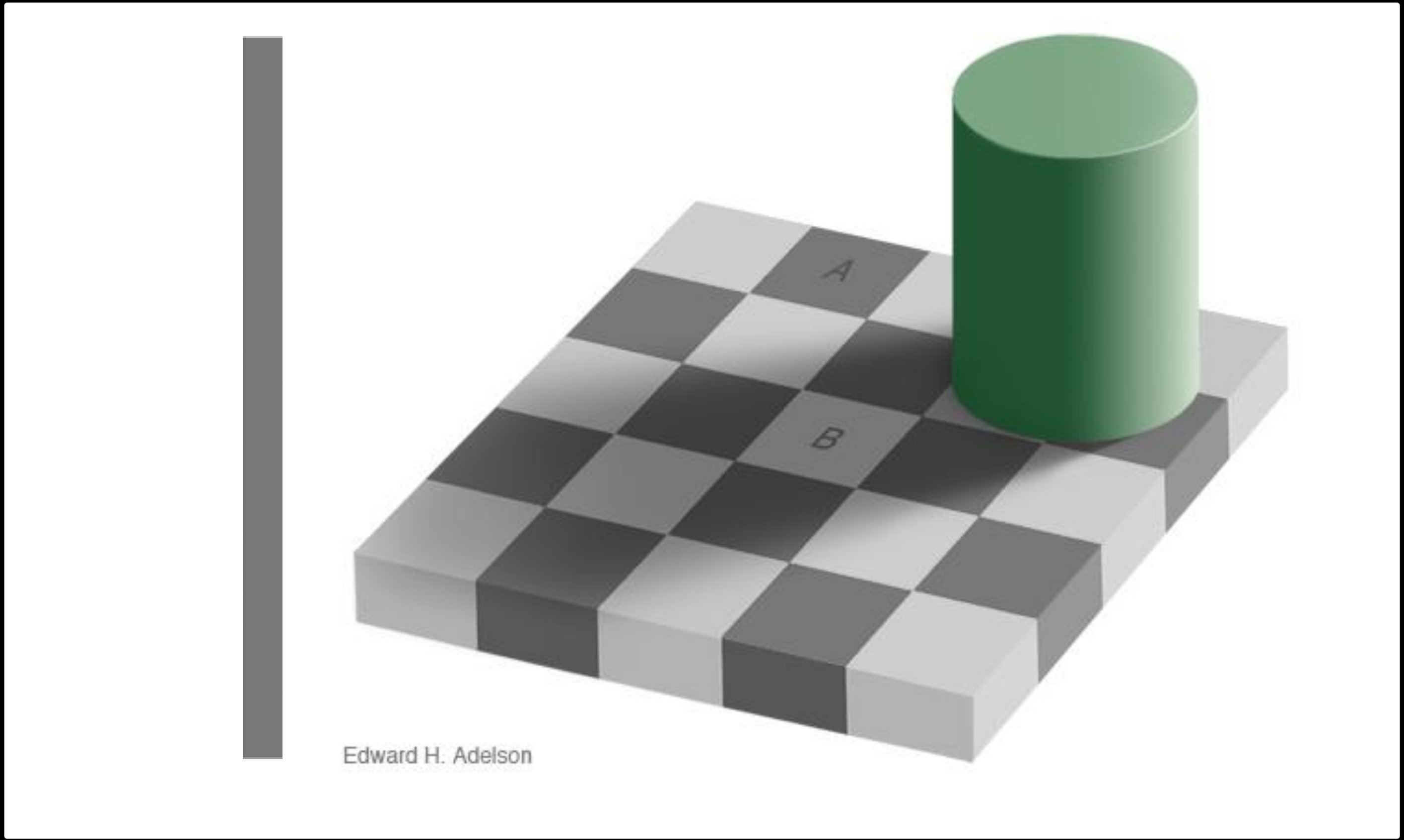
What do you see?



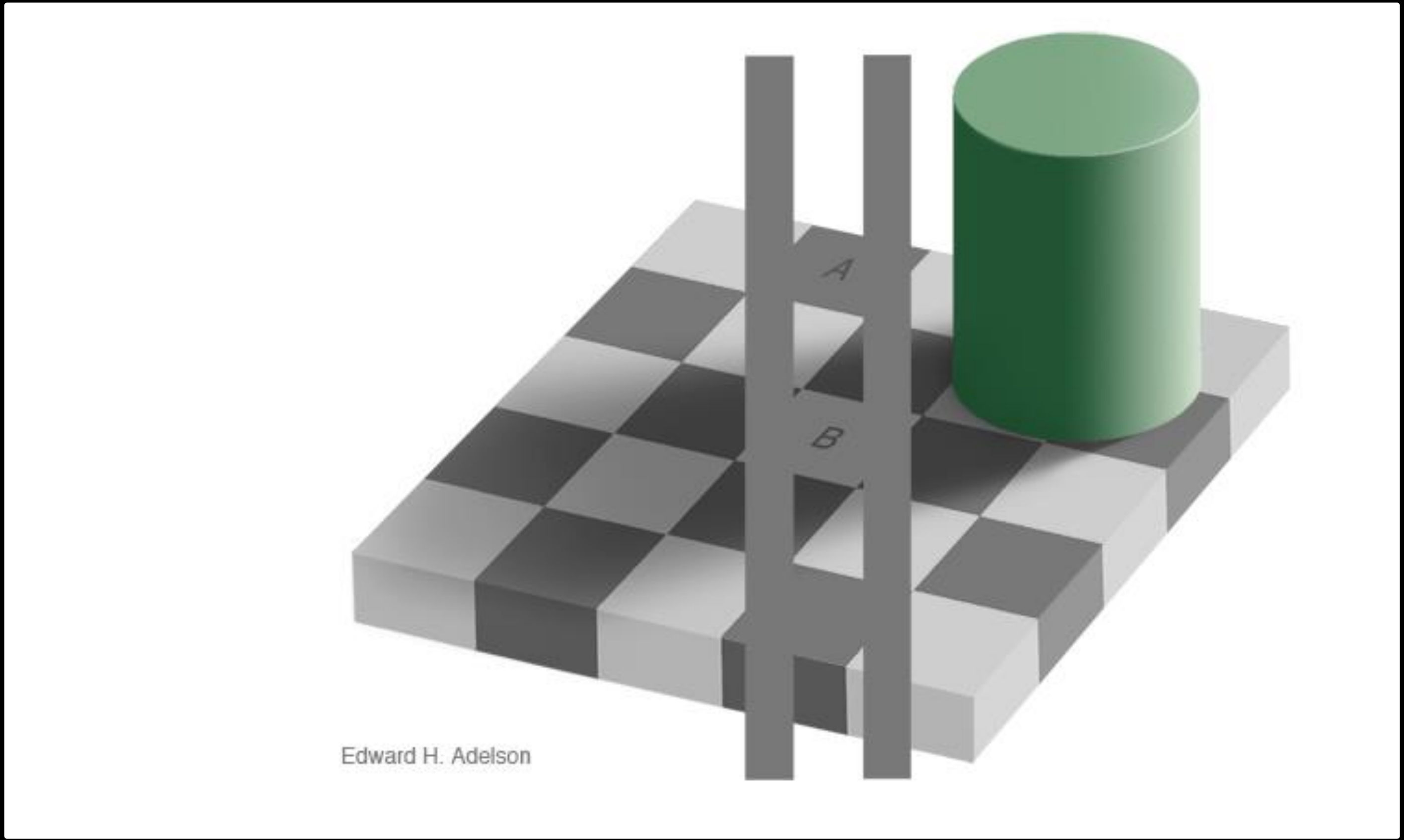
Simple scene right?



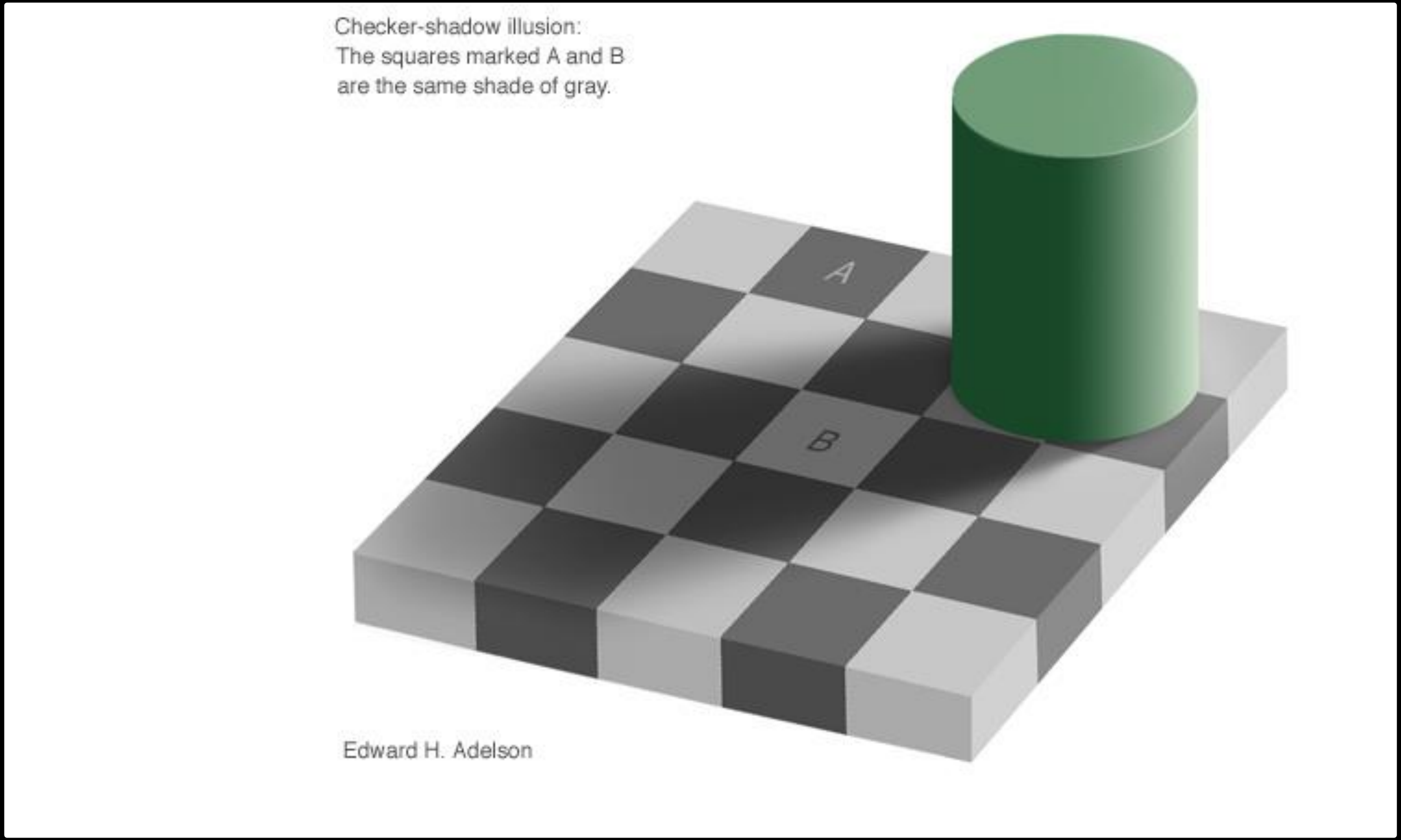
Really?



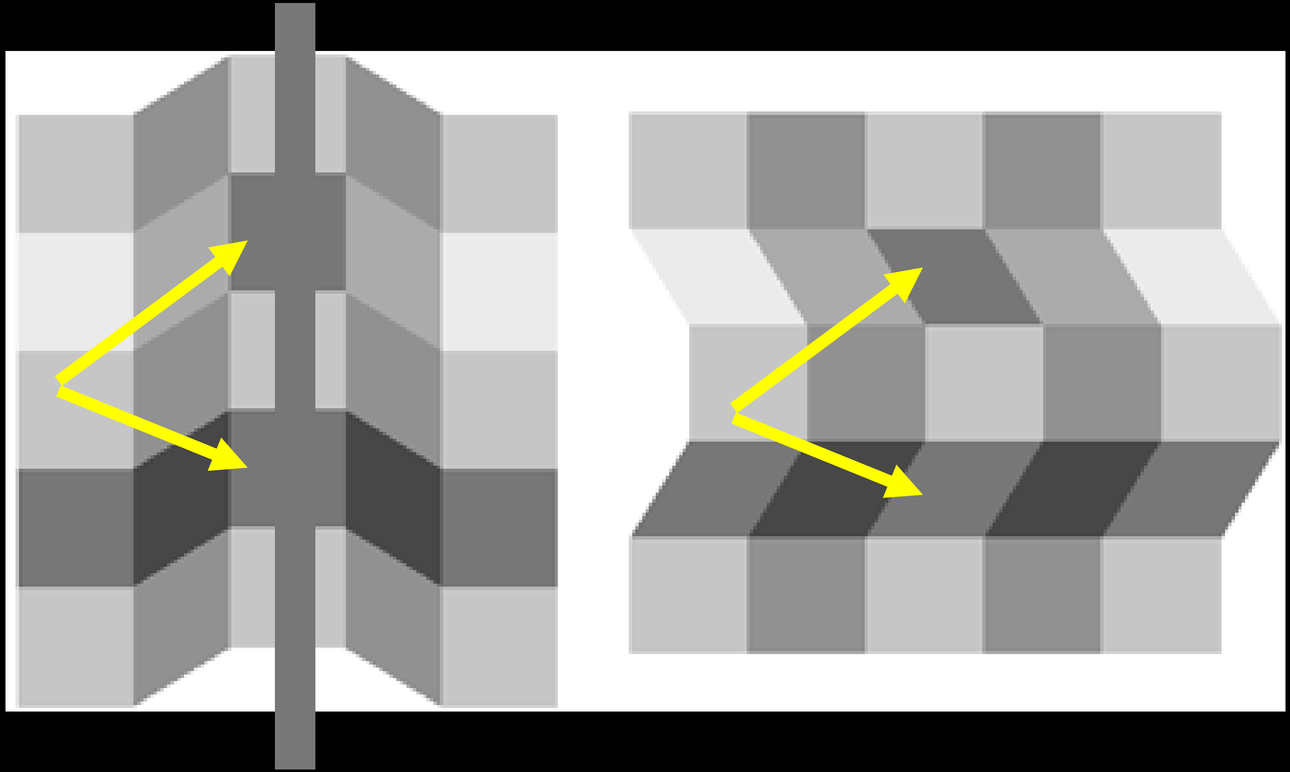
Really!



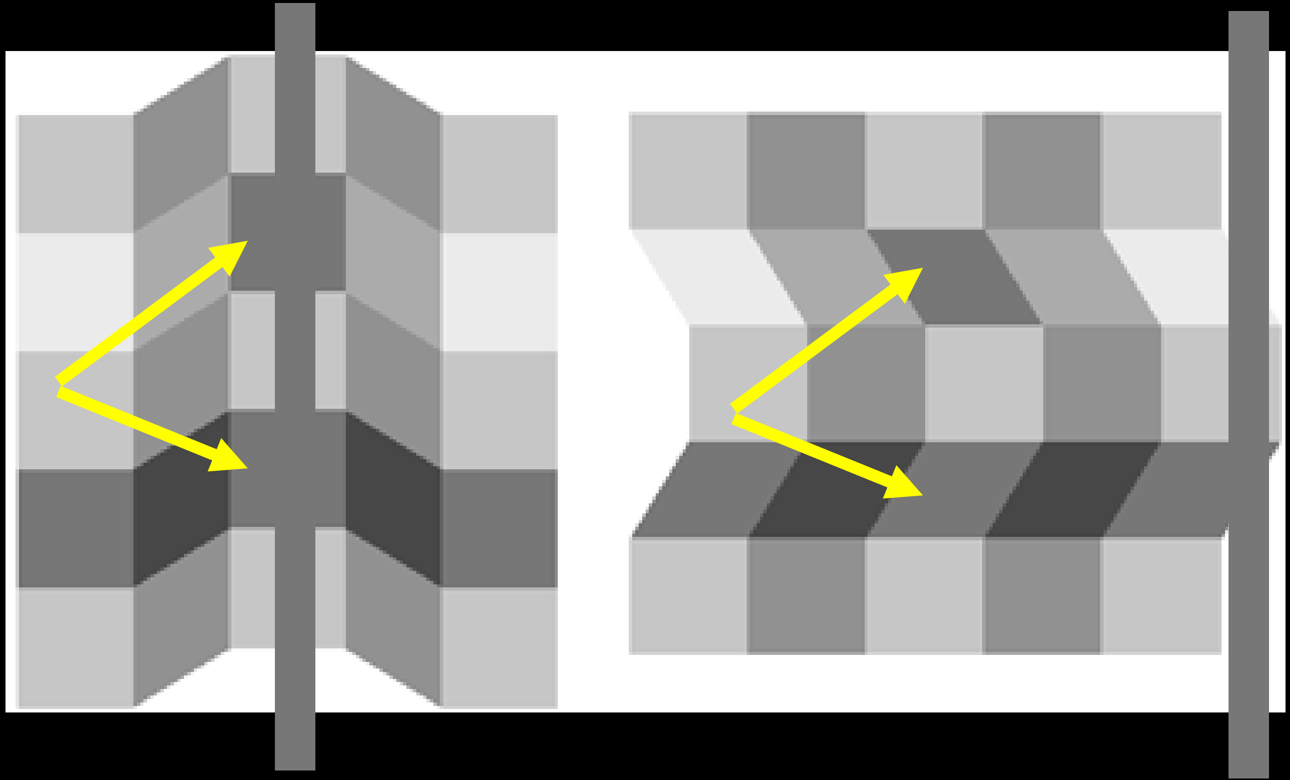
Compensating for the "shadow"



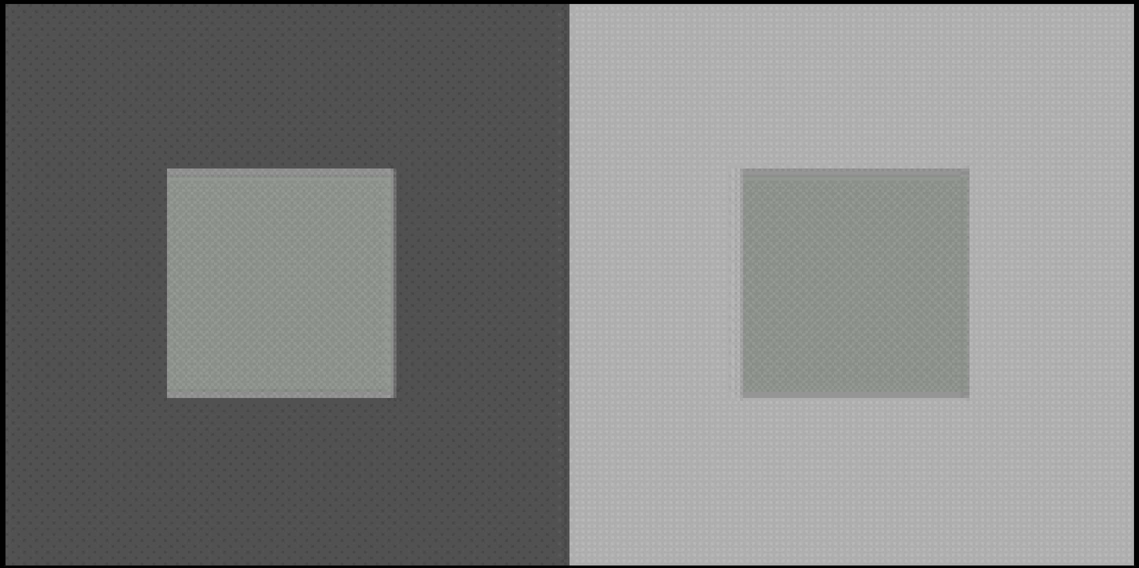
Lightness perception is influenced by 3D cues



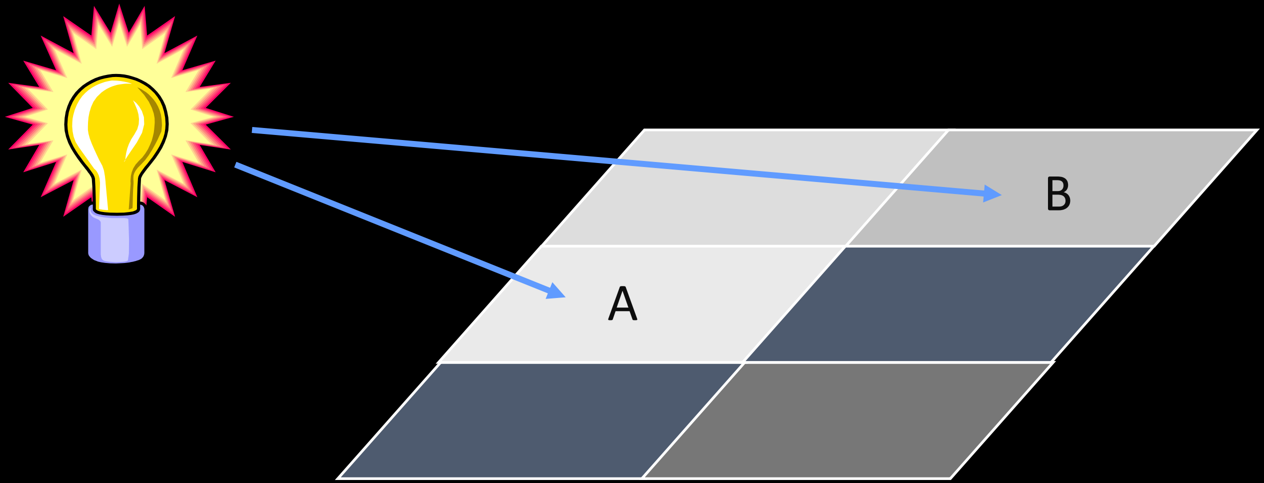
Lightness perception is influenced by 3D cues



Simultaneous contrast effect



Basic problem of lightness



Is B darker than A because it reflects a smaller proportion of light, or because it's further from the light?

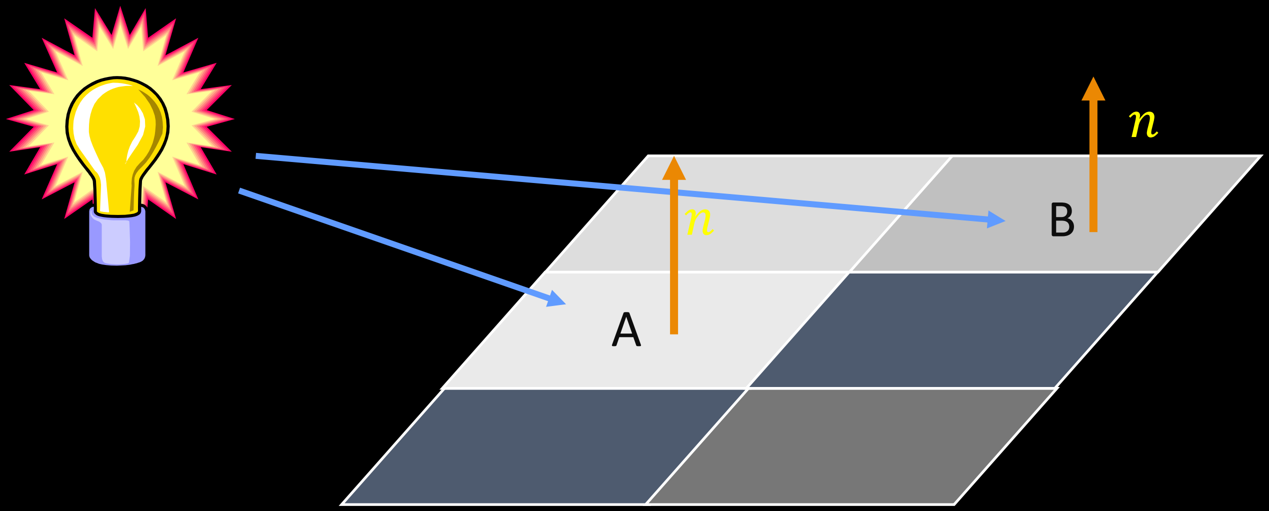
Planar, Lambertian material:

$$L = I * \rho * \cos(\theta)$$

where: ρ is reflectance (aka albedo)

θ is angle between light and n

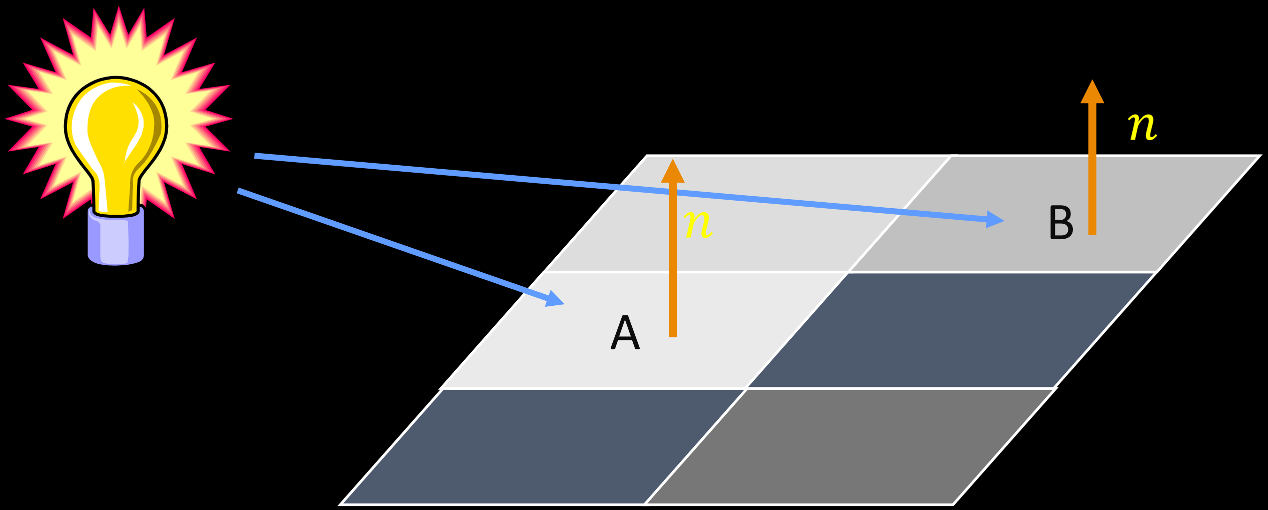
I is illuminance (strength of light)



Ambiguity of lighting and reflectance

If we combine θ and I at a point into $E(x, y)$, and have a reflectance function $R(x, y)$ then:

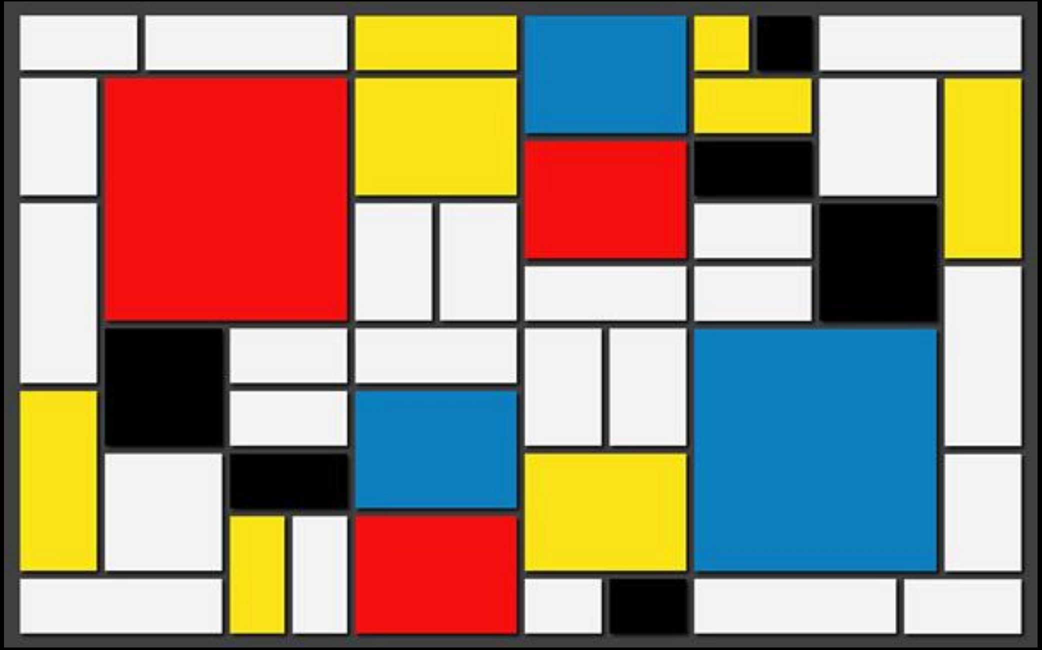
$$L(x, y) = R(x, y) * E(x, y)$$



Assumptions

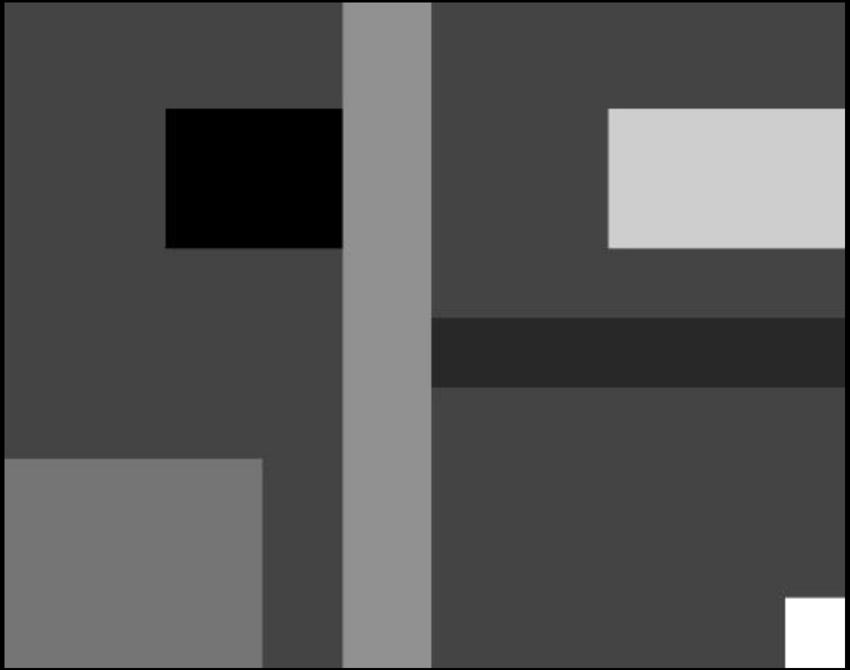
1. Light is slowly varying
   - This is reasonable for planar world: nearby image points come from nearby scene points with same surface normal.
2. Within an object reflectance is constant
3. Between objects, reflectance varies suddenly.

The Mondrian world



Piet Mondrian (1872-1944)

The Mondrian world

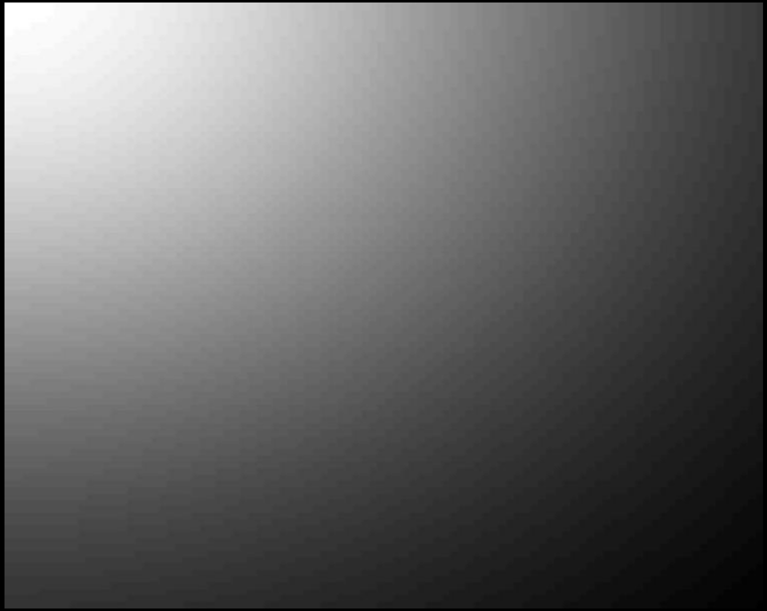


Piet Mondrian (1872-1944)

Illumination: slowly varying

$$L(x, y) \; = \; R(x, y) * E(x, y)$$

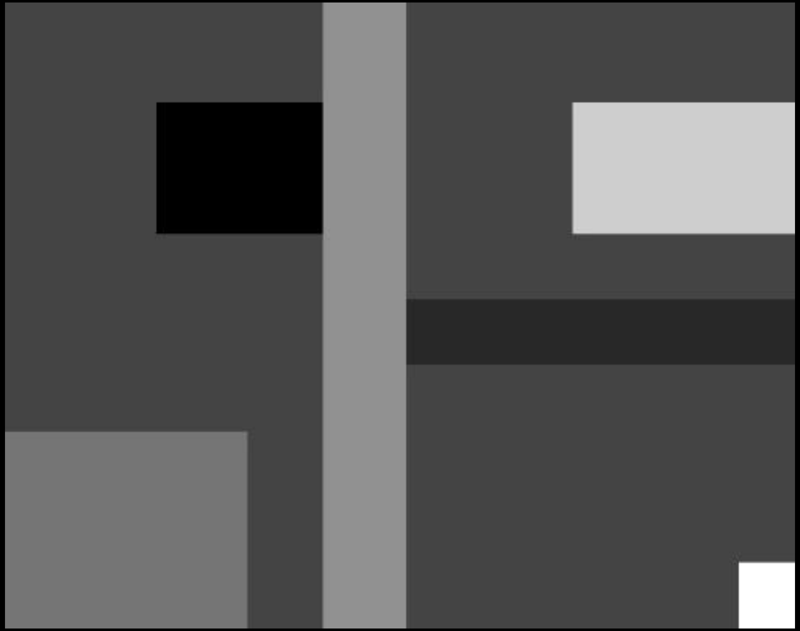
Formally, we assume that illuminance, E, is low frequency



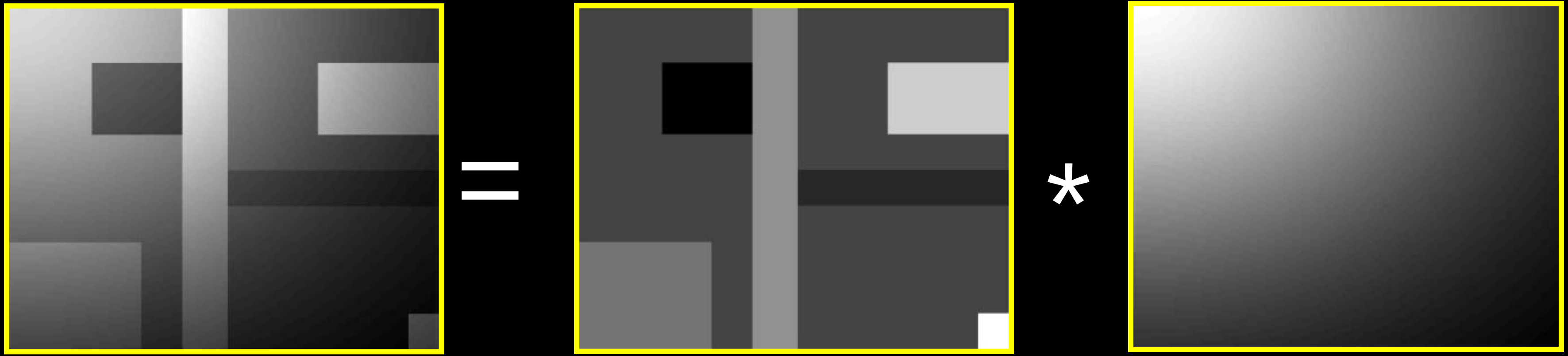
Albedo: constant patches

$$L(x, y) = R(x, y) * E(x, y)$$

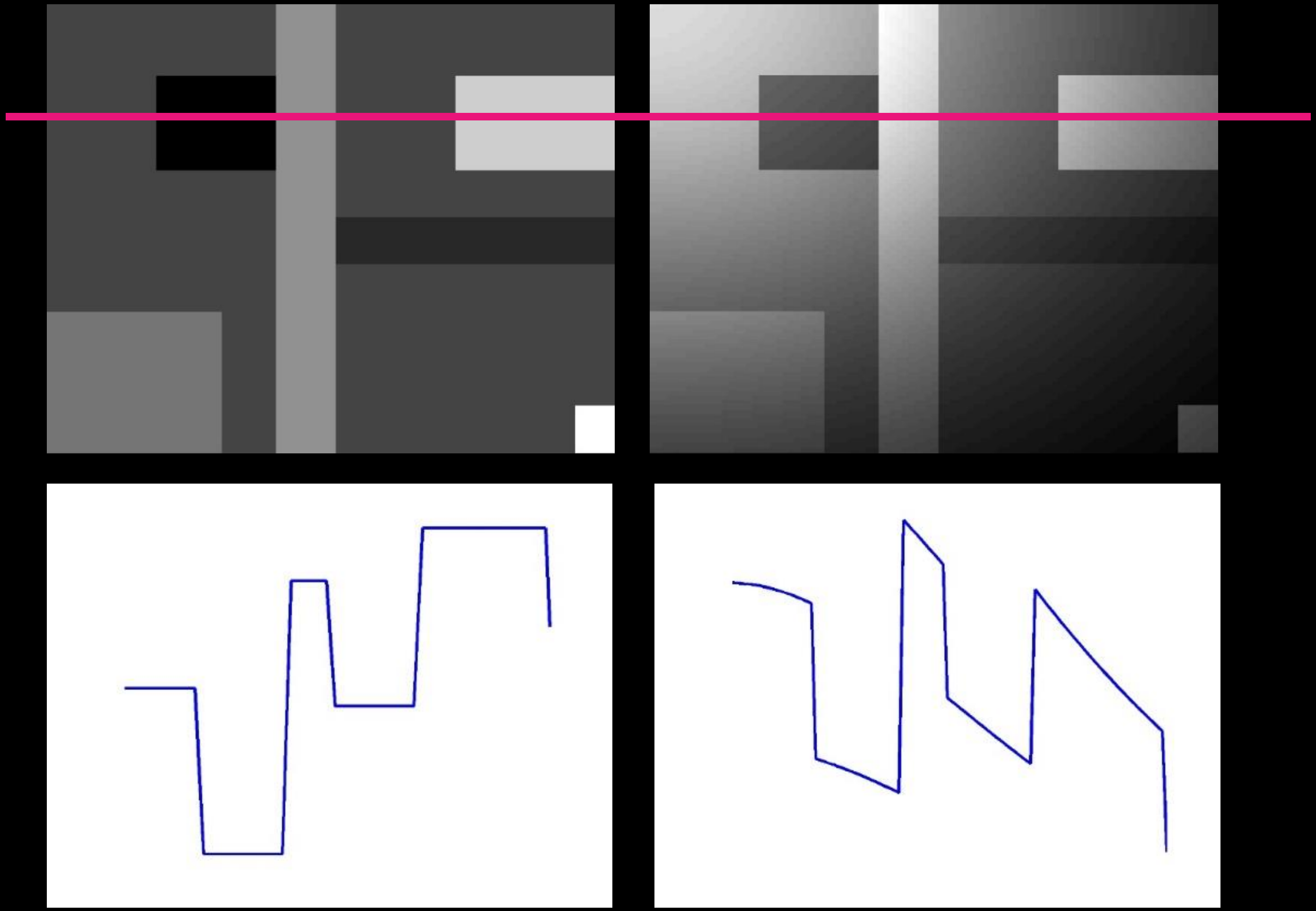
Reflectance R, is constant over patches separated by edges.



Lighting the Mondrian world



$$L(x,y) \;=\; R(x,y) * E(x,y)$$



Land's Retinex Theory

- Edwin Land (1909-1991) – inventor of Polaroid Land camera
- Early demonstrations that humans perceive different lightness (or color) for same objective brightness

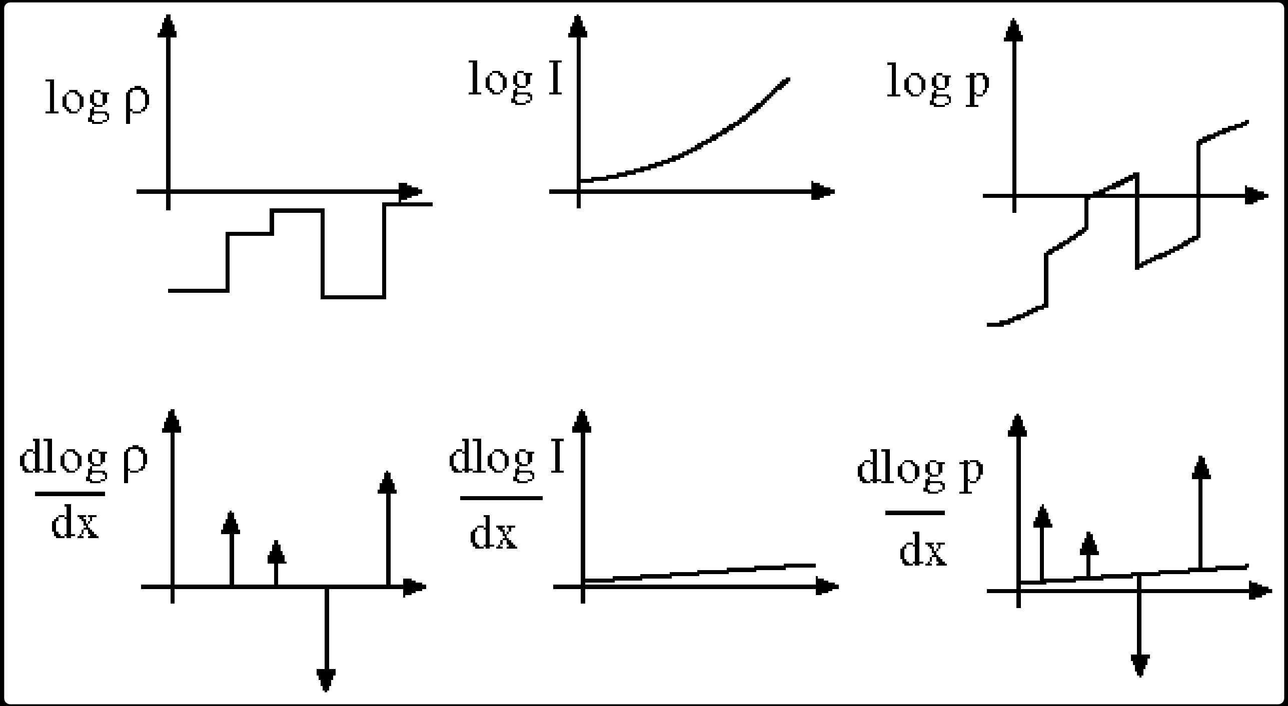
Land's Retinex Theory

- Goal: remove slow variations from the image
- Many approaches to this. One is:

$$L(x,y) = R(x,y) * E(x,y)$$
$$\log(L(x,y)) = \log(R(x,y)) + \log(E(x,y))$$

- Hi-pass filter (say with derivative)
- Threshold to remove small low-frequencies
- Then invert process; take integral, exponentiate

1-D Lightness "Retinex"

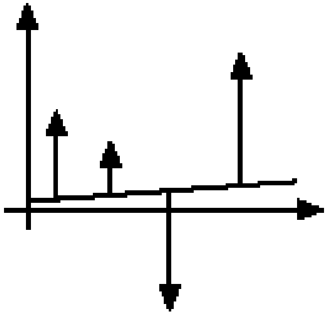


Threshold gradient image to find surface (patch) boundaries

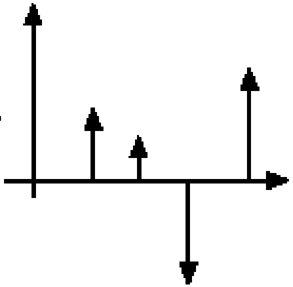
Figures courtesy D. Forsyth

1-D Lightness “Retinex”

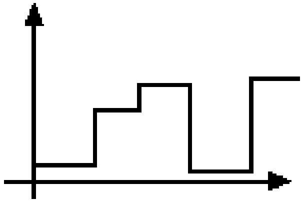
$$\frac{d \log p}{dx}$$



Threshold $\frac{d \log p}{dx}$

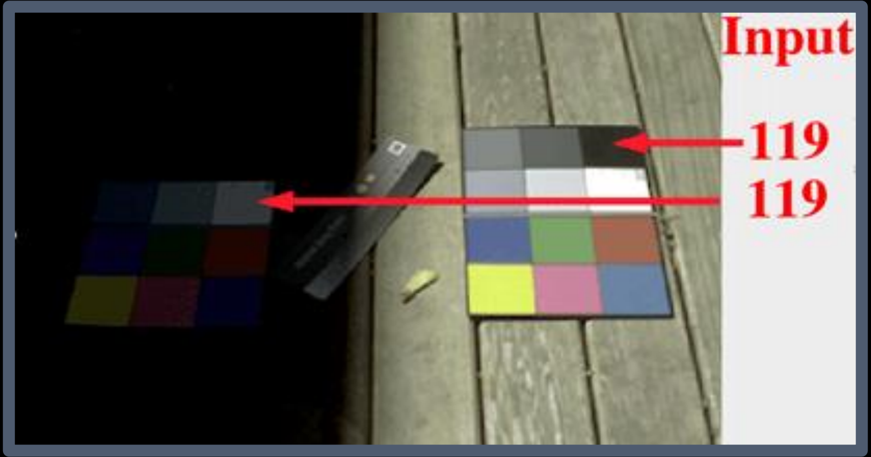


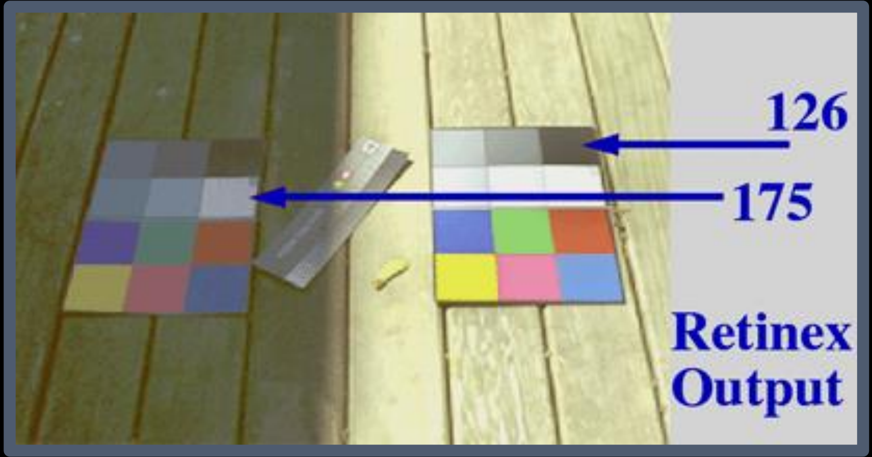
Integrate to recover albedo



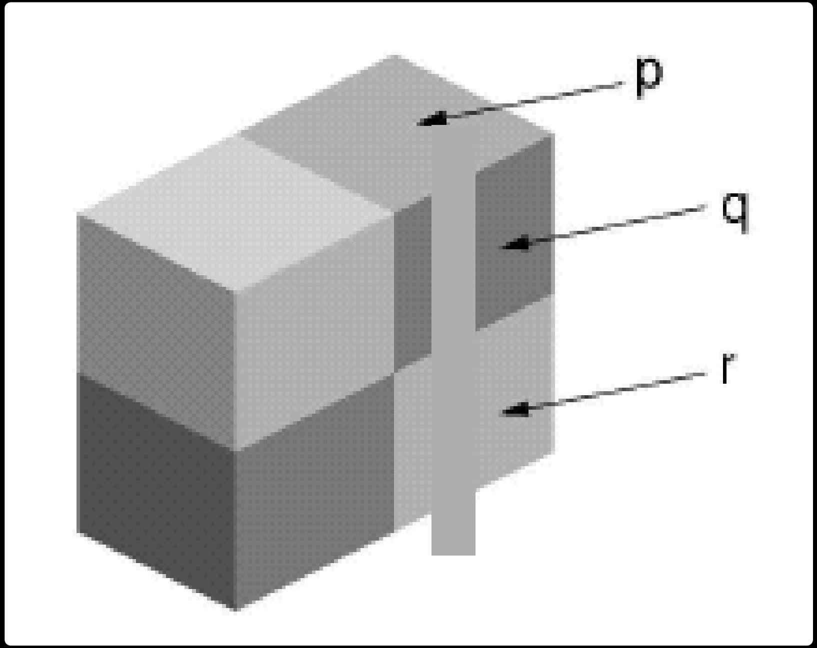
Integration to recover surface lightness (unknown constant)

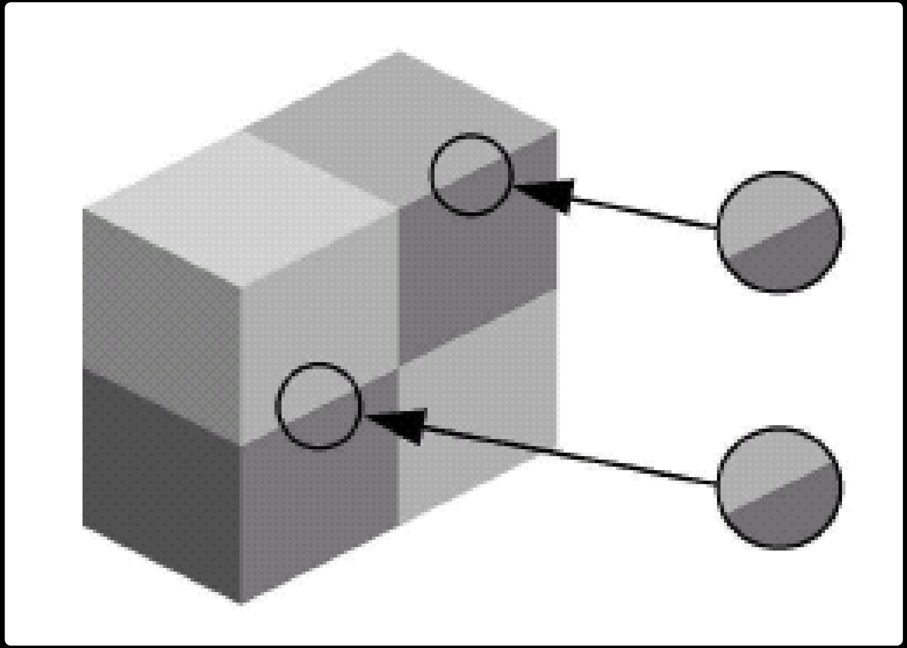
Color Retinex





Images courtesy John McCann





These approaches fail on 3D objects, where illuminance can change quickly as well

Human color and lightness constancy

- **Color constancy**: determine hue and saturation under different colors of lighting
- **Lightness constancy**: gray-level reflectance under differing intensity of lighting

Other approaches

- Average reflectance across scene is known (often fails) – e.g. measured using a standard *gray card*
- Brightest patch is white
- Gamut (set of all colors) falls within known range
  - Works quite well for correcting photographs for human observers, but not good enough for recognition
- Known reference color (color chart, skin color, …)

Current methods nowhere near adequate – lots to do!