Reflections, shadows, and visual perception

CS 48N, Winter 2011

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Reflection from diffuse surfaces

(Dorsey)

- rough surfaces reflect light uniformly in all directions
- appearance is independent of viewing direction
- if perfectly so, surface is called ideal diffuse (“Lambertian”)

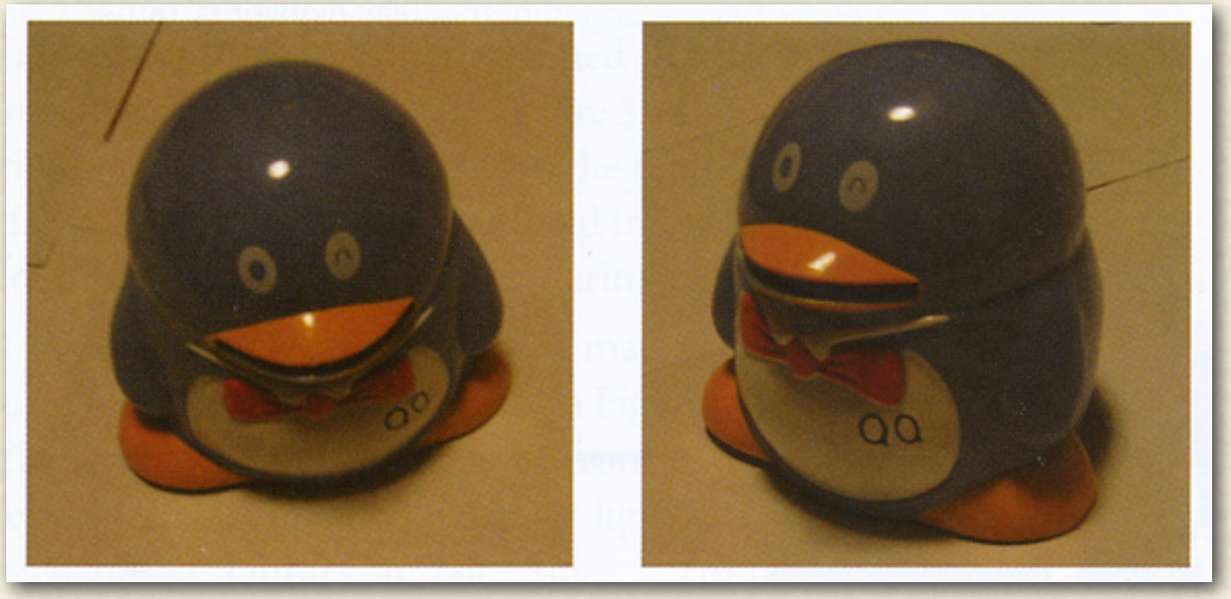
Albedo

- fraction of light reflected from a diffuse surface
- examples
  - clouds 80%
  - fresh snow 80%
  - old snow 40%
  - grass 30%
  - soil 15%
  - rivers 7%
  - ocean 3%

Bartolomeo Bettera, Still Life with Musical Instruments (1600s)

Bartolomeo Bettera, Still Life with Musical Instruments (1600s)

Reflection from shiny surfaces



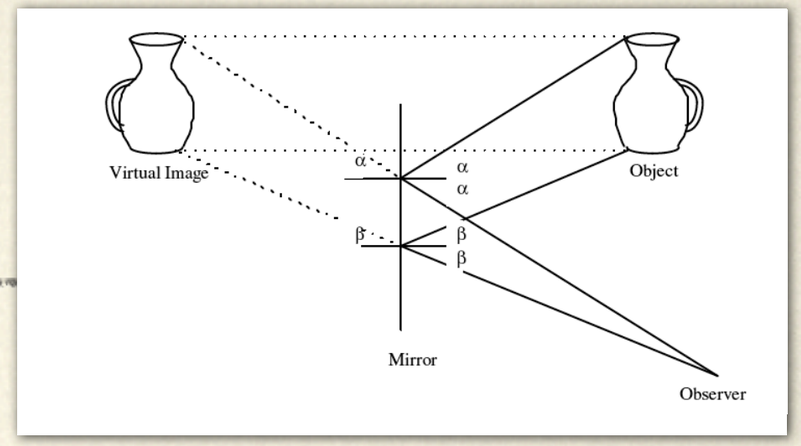
(Dorsey)

- the amount of variance in the orientation of surface microfacets determines whether a surface is diffuse or specular
- diffuse reflections look the same regardless of viewing direction
- specular reflections move when the light or observer moves

Mirror reflections

- scenes reflected in water are not copies of the scenes!

Mirror reflections



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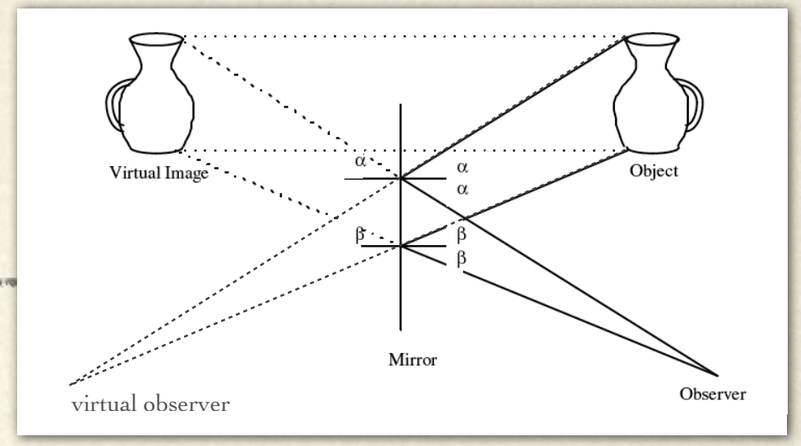

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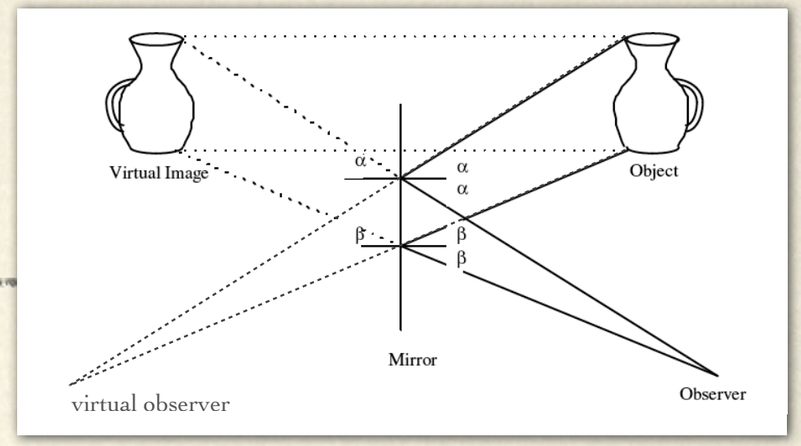
Mirror reflections



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Diego Velázquez, Venus at her Mirror (1647)

Fresnel reflectance

- a model of reflectance derived from physical optics (light as waves), not geometrical optics (light as rays)

$$R_s = \left[\frac{\sin(\theta_t - \theta_i)}{\sin(\theta_t + \theta_i)}\right]^2 = \left(\frac{n_1\cos\theta_i - n_2\cos\theta_t}{n_1\cos\theta_i + n_2\cos\theta_t}\right)^2 = \left[\frac{n_1\cos\theta_i - n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}{n_1\cos\theta_i + n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}\right]^2$$

$$R_p = \left[\frac{\tan(\theta_t - \theta_i)}{\tan(\theta_t + \theta_i)}\right]^2 = \left(\frac{n_1\cos\theta_t - n_2\cos\theta_i}{n_1\cos\theta_t + n_2\cos\theta_i}\right)^2 = \left[\frac{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} - n_2\cos\theta_i}{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} + n_2\cos\theta_i}\right]^2$$

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- conductors (metals) - specular highlight is color of metal
- non-conductors (dielectrics) - specular highlight is color of light
- specular highlight becomes color of light at grazing angles
- even diffuse surfaces become specular at grazing angles

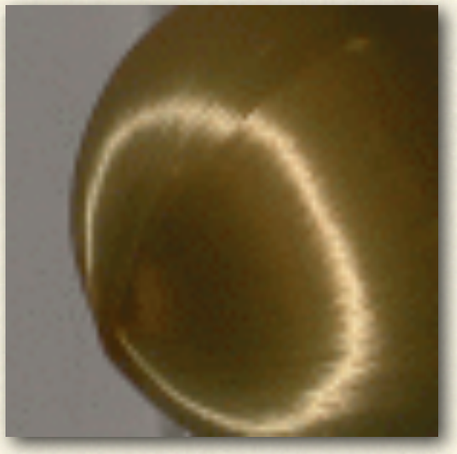
Why is rock dust white?

(even if the rock is black)

(Gary Meyer)

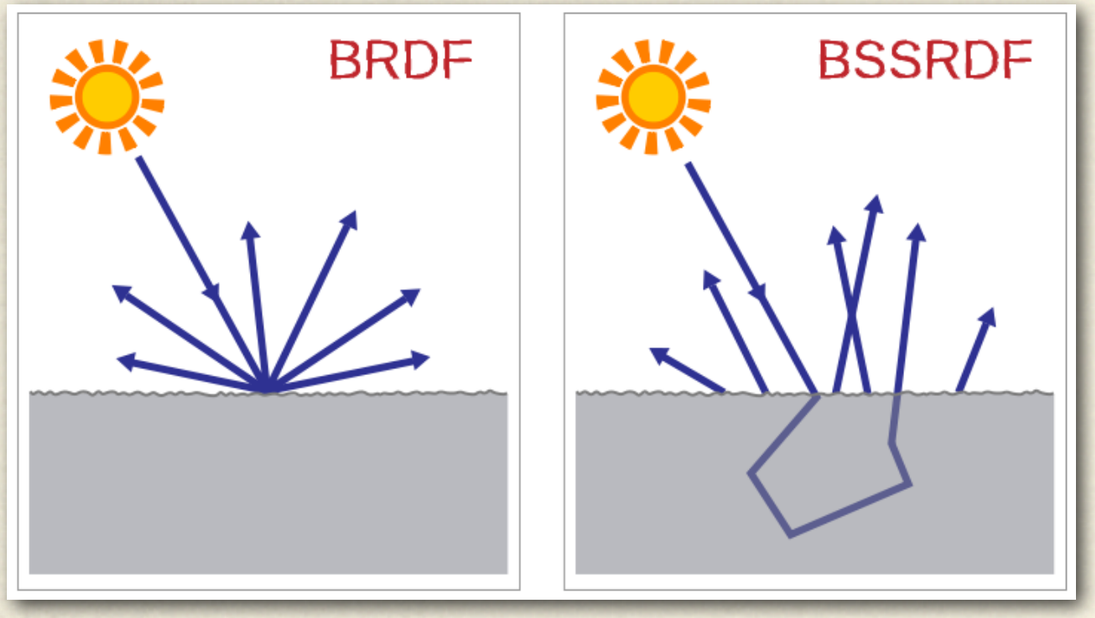
Anisotropic reflections

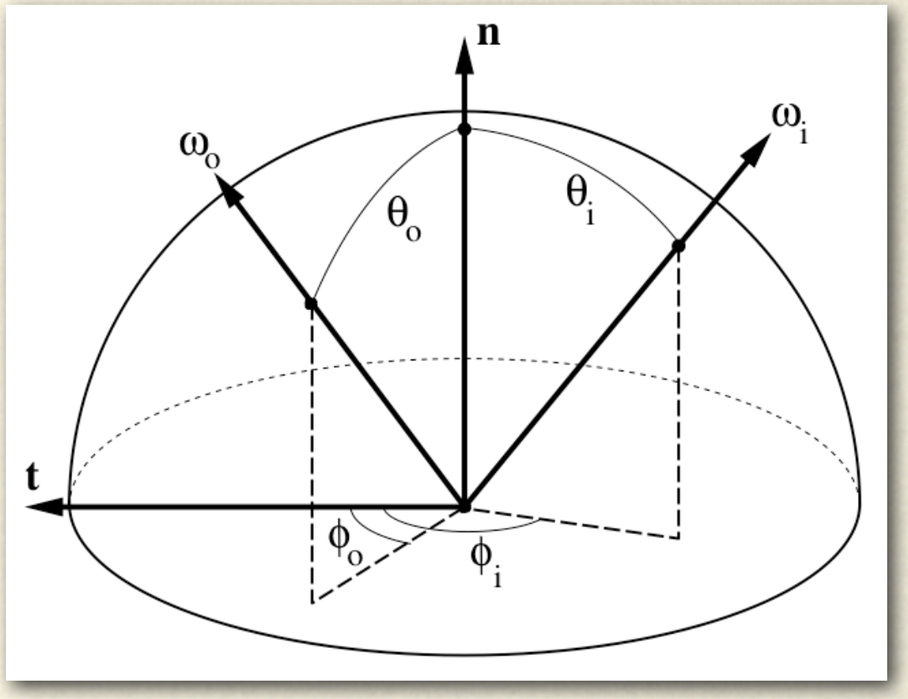
Anisotropic reflections



- highlight not radially symmetric around mirror direction
- highlight may depend on light direction and viewer direction (horse), or only on the difference between them (pot and Xmas tree ornament)
- produced by grooved or directionally textured materials

BRDFs and BSSRDFs





- Bidirectional Reflectance Distribution Function (4D function)

$$f_r(\theta_i, \phi_i, \theta_r, \phi_r)$$

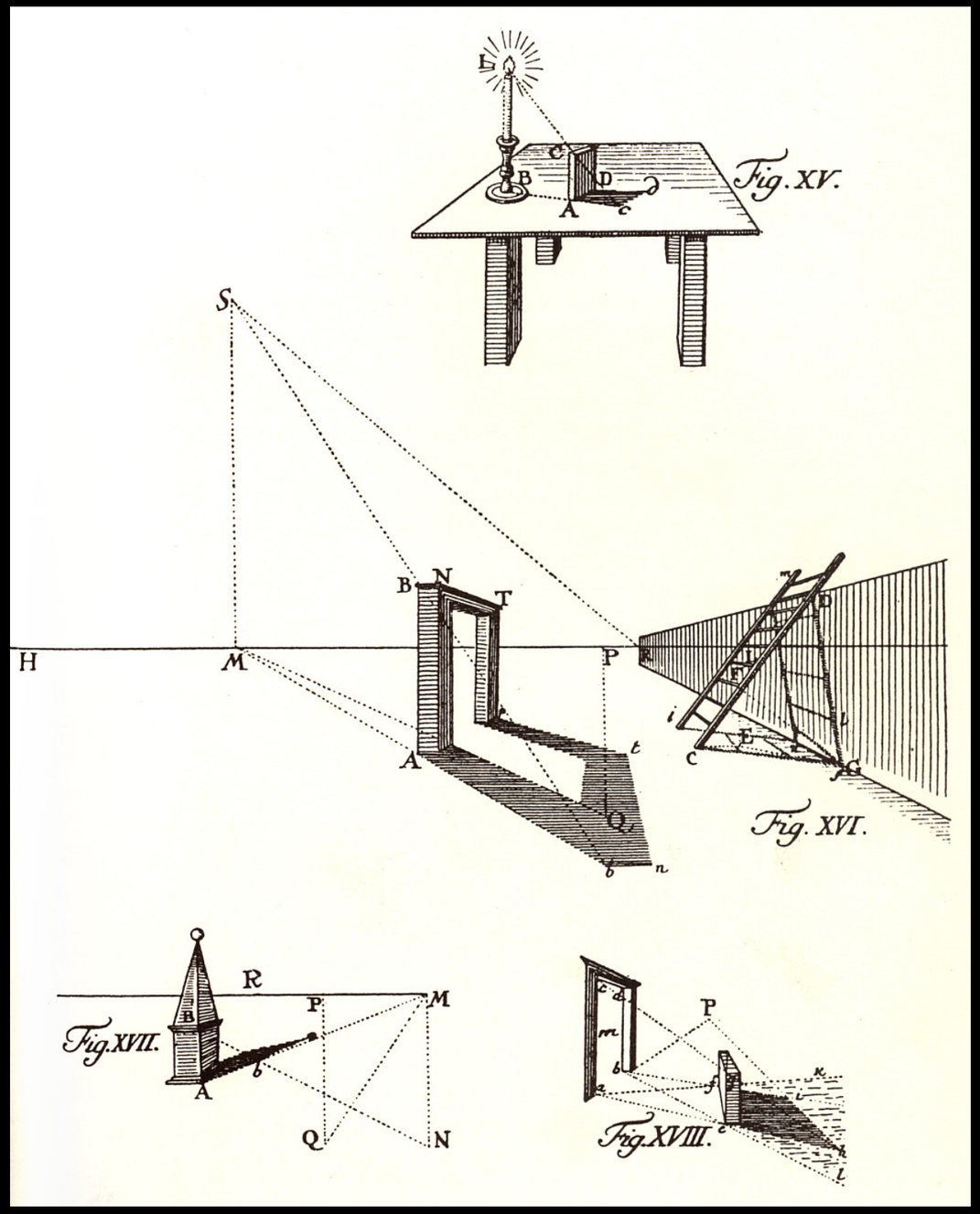
- Bidirectional Surface Scattering Reflectance Distribution Function (8D function)

$$\rho(x_i, y_i, \theta_i, \phi_i, x_r, y_r, \theta_r, \phi_r)$$

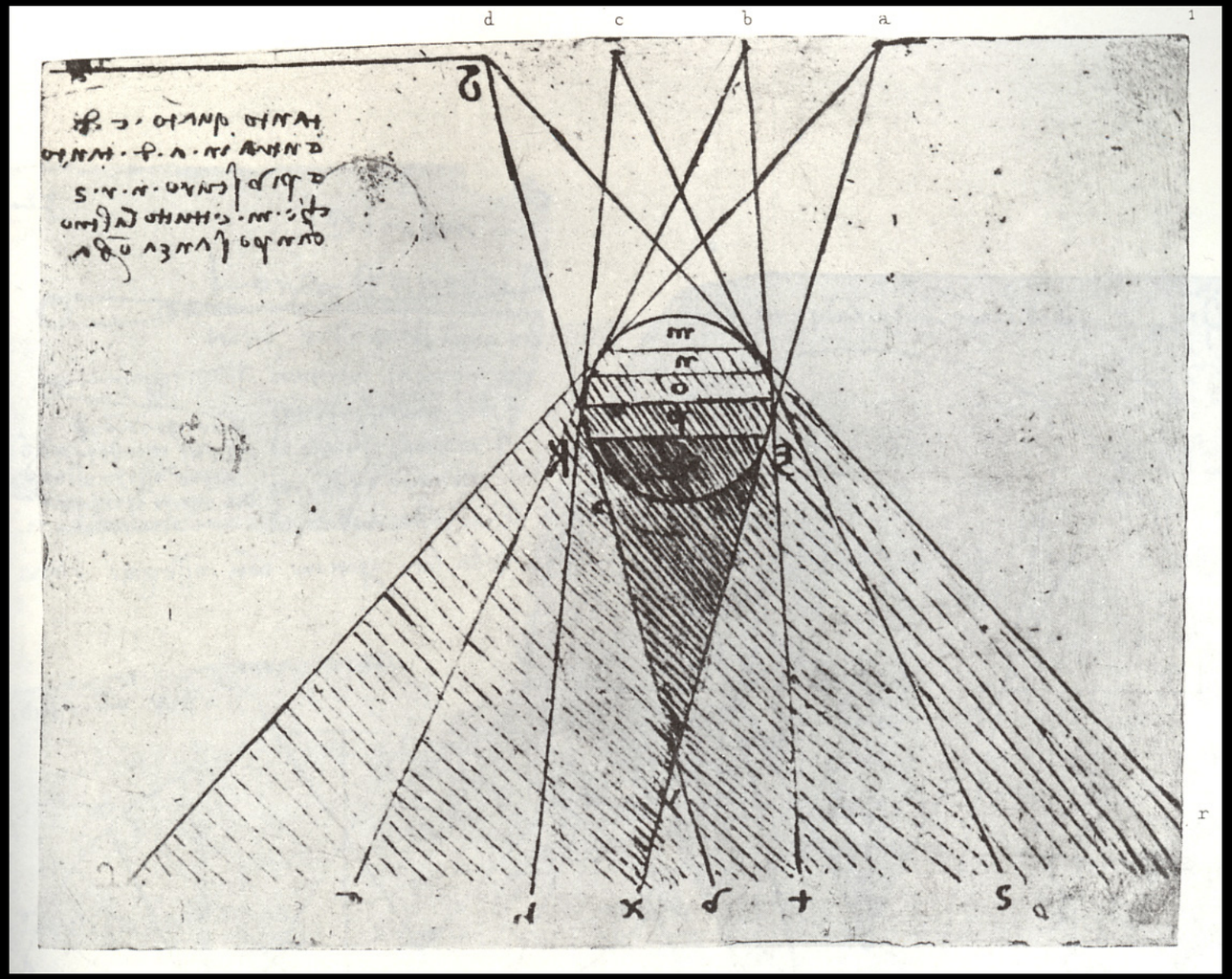
(Jensen)

without subsurface scattering

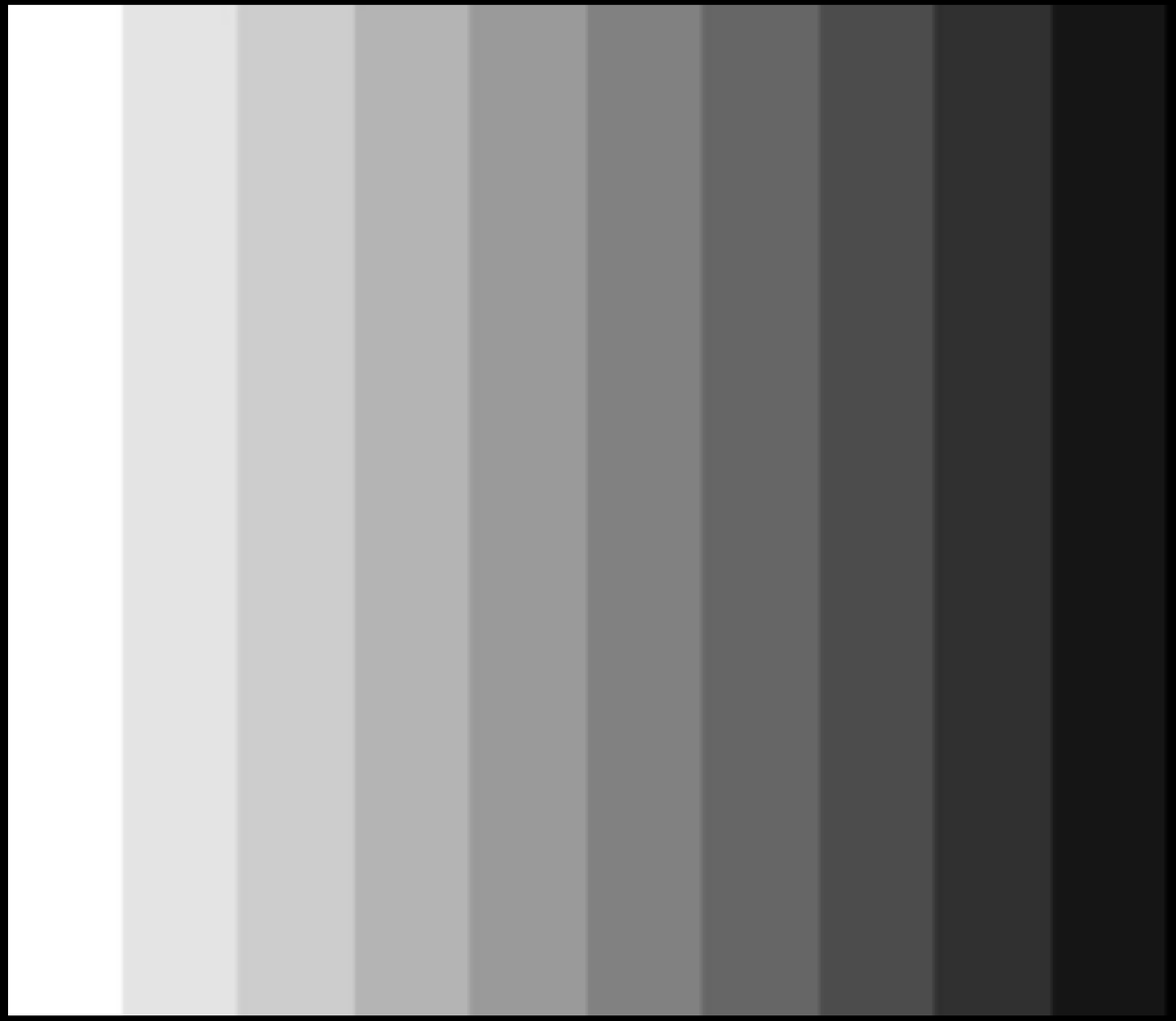
with subsurface scattering



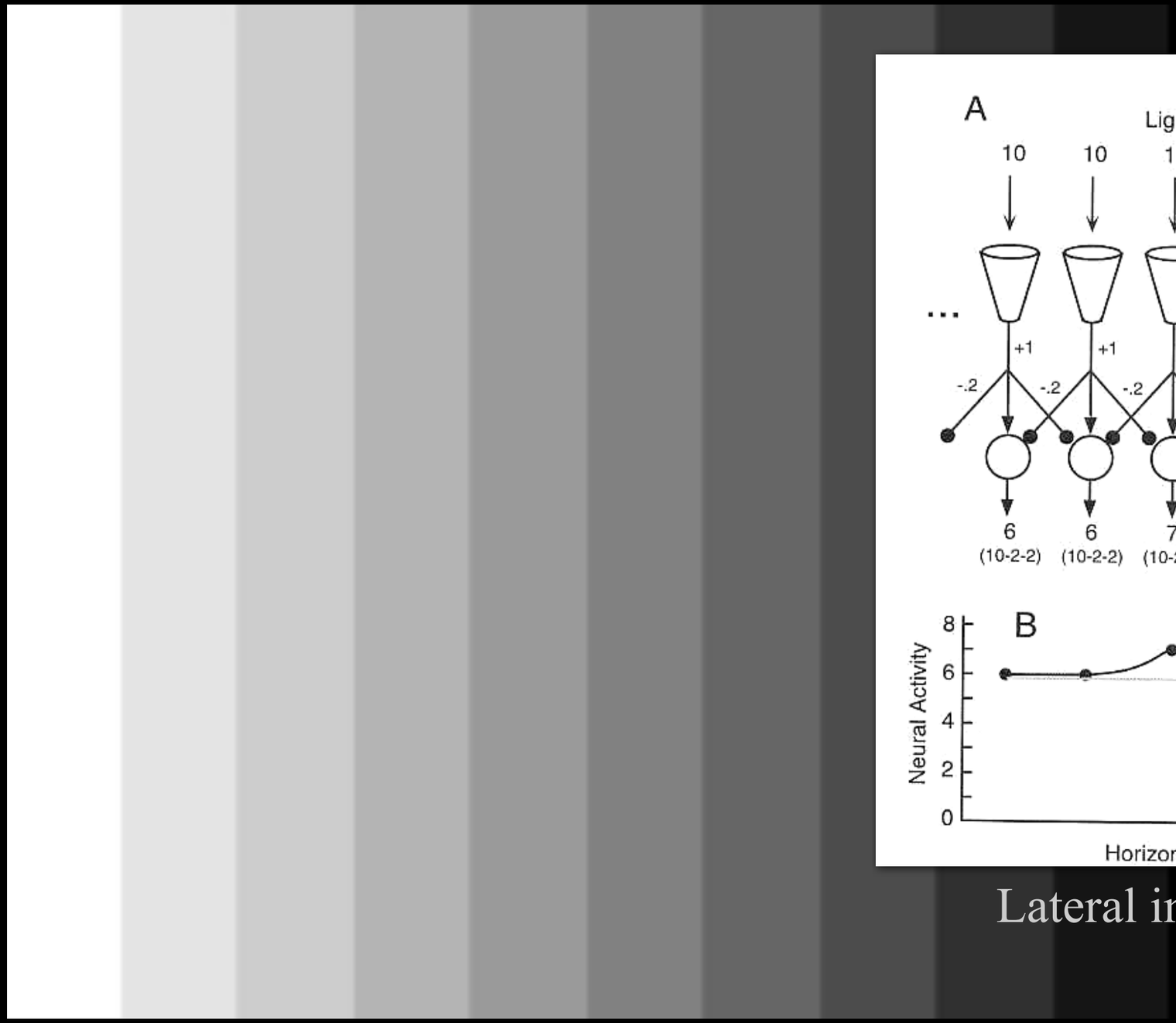
Lambert, studies of shadows (1759)



Leonardo, umbra and penumbra



Mach bands



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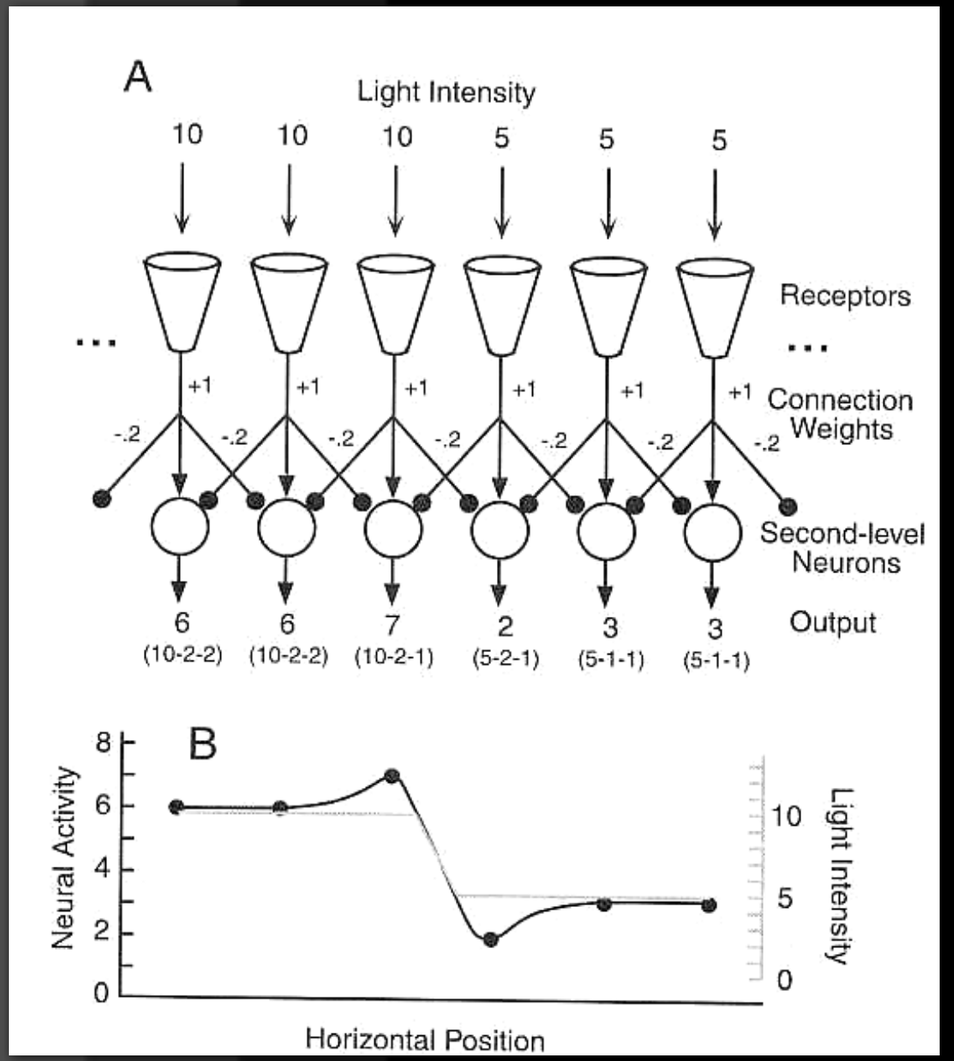
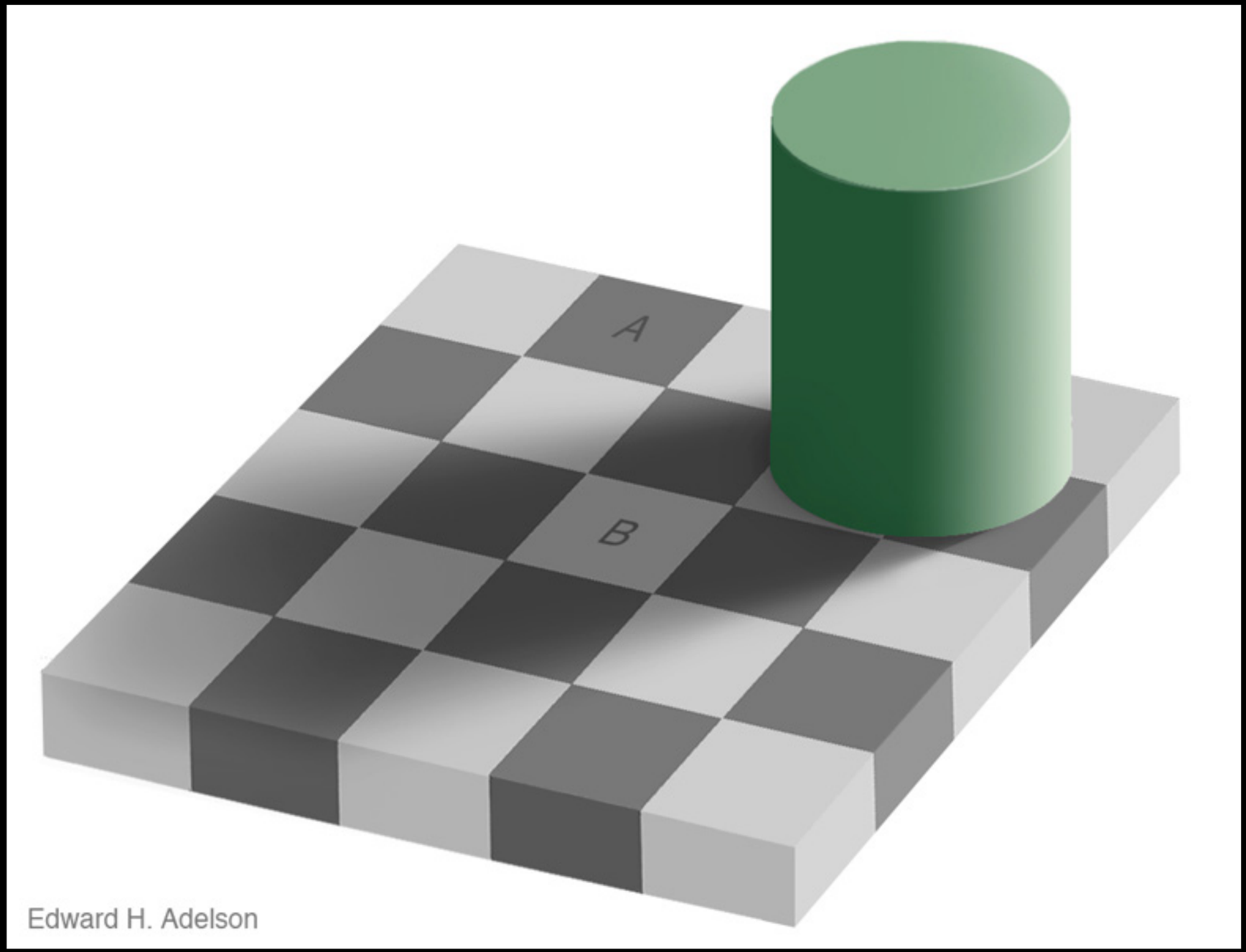
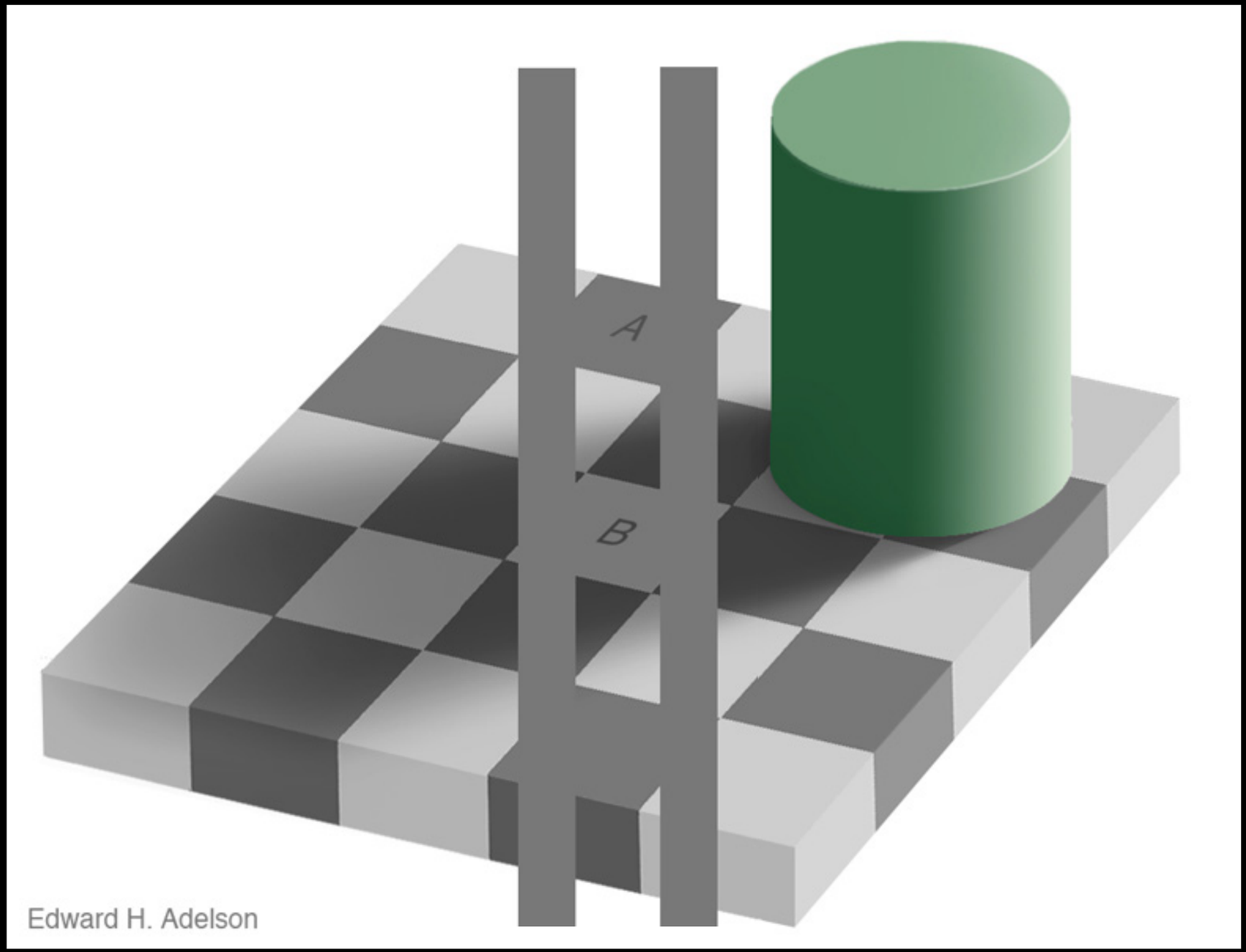


Lateral inhibition in the retina



The importance of local contrast

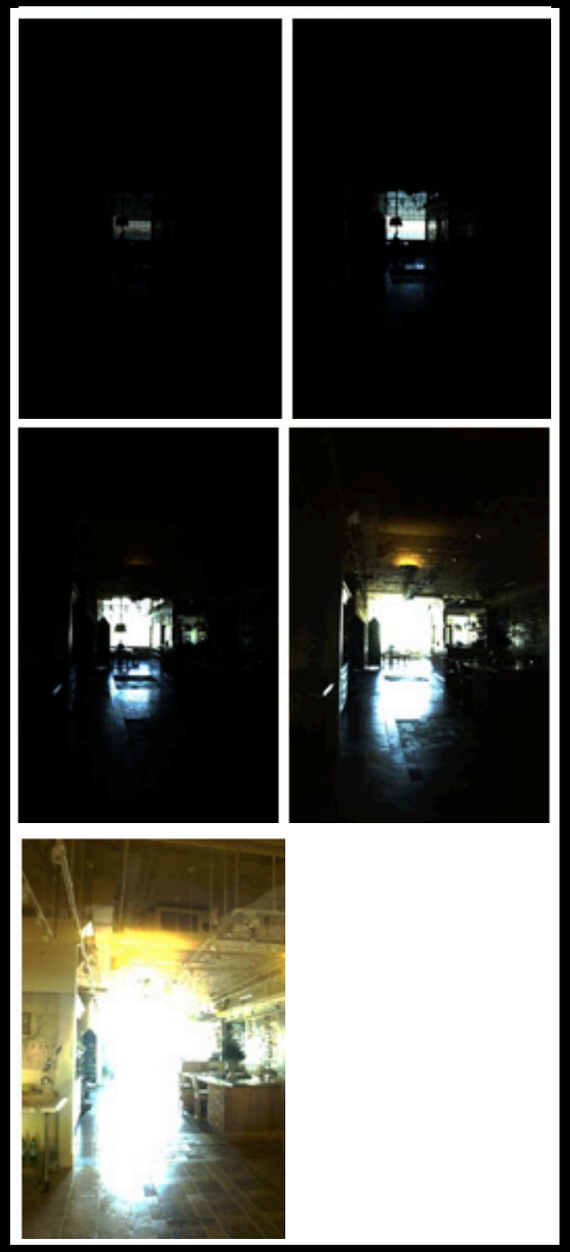


The importance of local contrast

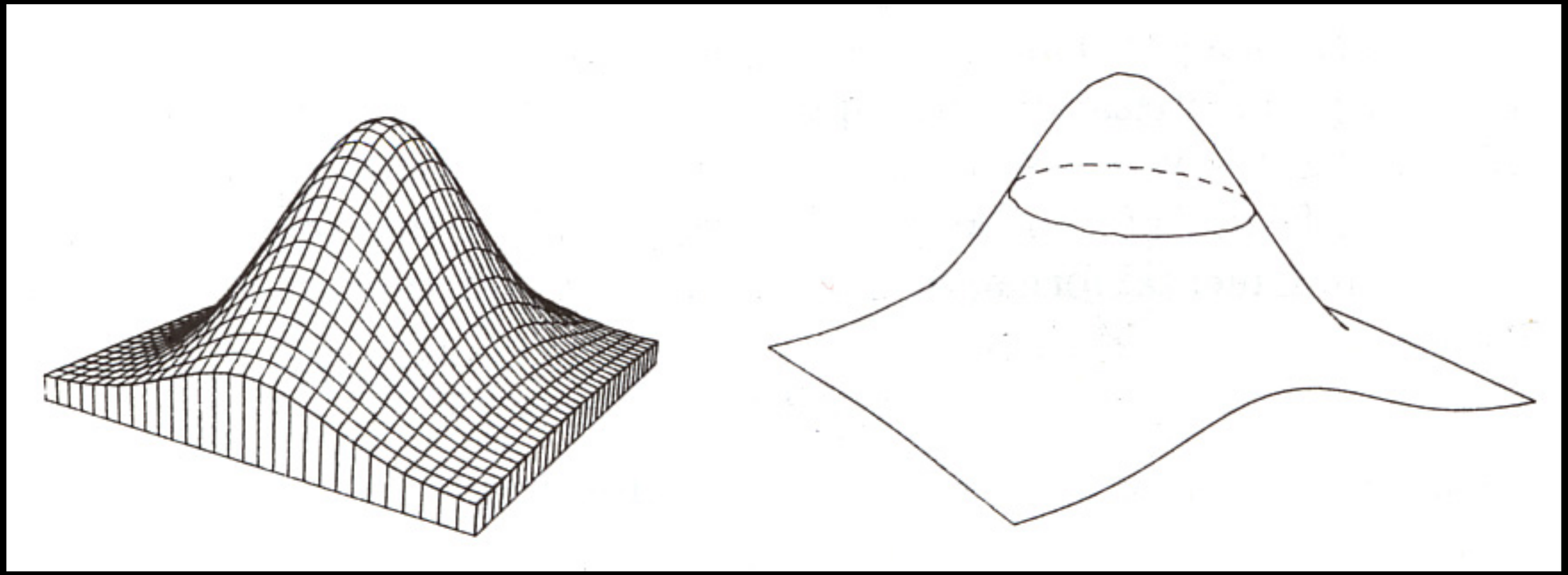
Georges Seurat, La Grande Jatte (1884)

Tone mapping using bilateral filters

[Durand and Dorsey SIGGRAPH 2002]



(Koenderink)



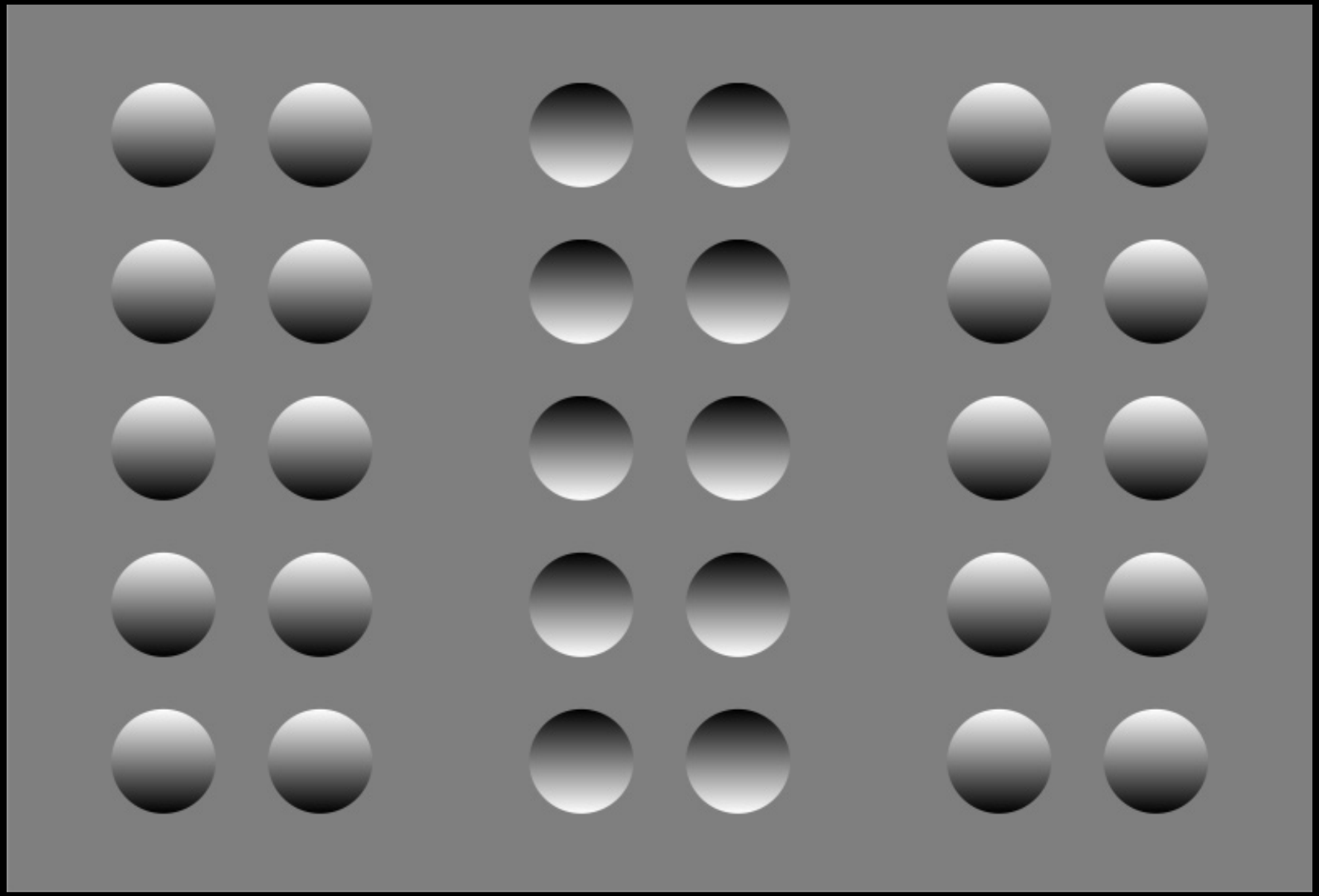
The parabolic line on a Gaussian bump

Roman copy of lost
Greek original

(Koenderink)

Modern copy, as a bust

Parabolic lines on the Apollo Belvedere, after a concept by Felix Klein



V. S. Ramachandran, Eggshell Illusion

How is this sculpture lit?

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The bas-relief ambiguity

[Belhumeur CVPR 1997]

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[Belhumeur CVPR 1997]