Image Processing

Introduction

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Class 01: Introduction to Image Processing

Overview

- Today:
  - Course Presentation;
  - The history of Image Processing;
  - Applications;
  - Fundamentals of the Human Visual System.

Course Presentation

Professora Adjunta
Departamento de Engenharia Elétrica
Universidade de Brasília (UnB)
Campus Universitário Darcy Ribeiro
70919-970 Brasília - DF, Brazil
Email: mylene@unb.br

- B.Sc. in Electrical Engineering (UFPE), M.Sc. in Electrical Engineering (Unicamp) e Ph.D. in Electrical Engineering (University of California Santa Barbara).
- Research Area: Image and Video Processing
- More information: www.ene.unb.br/mylene

Course Presentation

- All course material, including class notes, lists of exercises, references, etc. will be posted at
  - `www.ene.unb.br/mylene/PI.html`.

Course Presentation

- All course material, including class notes, lists of exercises, references, etc. will be posted at
  - `www.ene.unb.br/mylene/PI.html`.
- Classes:
  - Tuesdays, 14:00-15:50
  - Thursdays, 14:00-15:50

Overview

Topics:

- Introductions to Image Processing and Fundamentals of the Human Visual System;
- Transforms and operators (e.g. filters);
- Image Processing at pixel and frequency domain;
- Image Enhancement
- Image Restoration
- Colors
- Morphology and Image Segmentations;
- Etc.

Methodology

- Theoretical classes;
- 2 (two) exams;
- Bi-weekly List of Exercises;
- A final project (C, C++, Java, or Matlab) – 1 to 2 persons;
  - For a suggestion on possible project topics: see course homepage;
  - The topic of the project must be chosen before the 1st exam;
  - The project includes: presentation, code, and report.

Final Grade:

The final grade (NF) is calculated in the following way:

$$\text{NF} = P_1 \cdot 0,25 + P_2 \cdot 0,25 + Le \cdot 0,2 + Pj \cdot 0,3$$

where P_1 = grade of exam 1, P_2 = grade of exam 2, Le = average of grades of the lists of exercises, and Pj = final project grade.

Timeline

Calendário:

- Exam 1: 20/04 - 13h-16h;
- Exam 2: 20/06 - 13h-16h;
- Oral Presentation of Projects: 23 and 27/06, 13-15:50h;
- Final deadline for report and code: 29/06;

Final Grades

The final grade is calculated using the following table:

Nota Final	**Menção Final**
$9,0 \leq NF \leq 10,0$	SS (A)
$7,0 \leq NF < 9,0$	MS (B)
$5,0 \leq NF < 7,0$	MM (C)
$3,0 \leq NF < 5,0$	MI (D)
$0 < NF < 3,0$	II
Over 25% of absence (or $NF = 0,0$)	SR (F)

Bibliography

- Gonzalez, Rafael C. e Woods, Richard E., Digital Image Processing, 3o ed, 2008, Addison Wesley (Livro Texto)
- Parker, J. R., Algorithms for Image Processing and Computer Vision, 1997, John Wiley & Sons.
- Al Bovik, Handbook of Image and Video Processing, Academic Press.
- Castleman, Kenneth R., Digital Image Processing, Prentice-Hall, 1995.
- Jain, Anil K., Fundamentals of Digital Image Processing, Prentice-Hall, 1988.
- Sonka, M., Hlavac, V. e Boyle, R., Image Processing Analysis and Machine Vision, Chapman & Hall, 1993.

First Digital Images

- What is an image?

First Digital Images

- What is an image?
  - A visual representation of a function $f(x, y)$ (f is related to intensity (or color) at posisiton (x, y));
  - Images are represented in a rectangular format;
  - Continuous time and space ...

Figura: Albrecht Drer

Digital Images

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

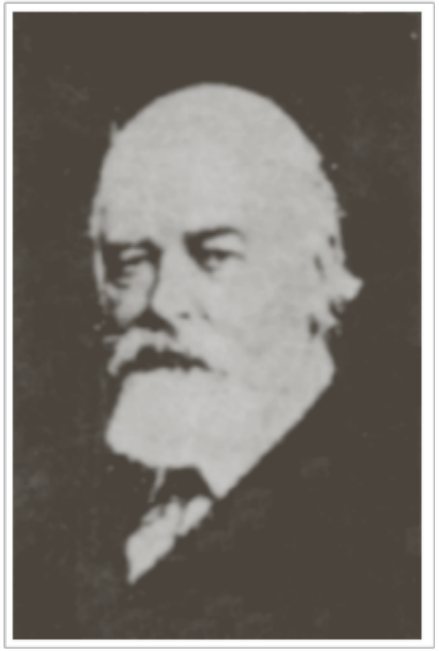


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

FIGURE 1.3 Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

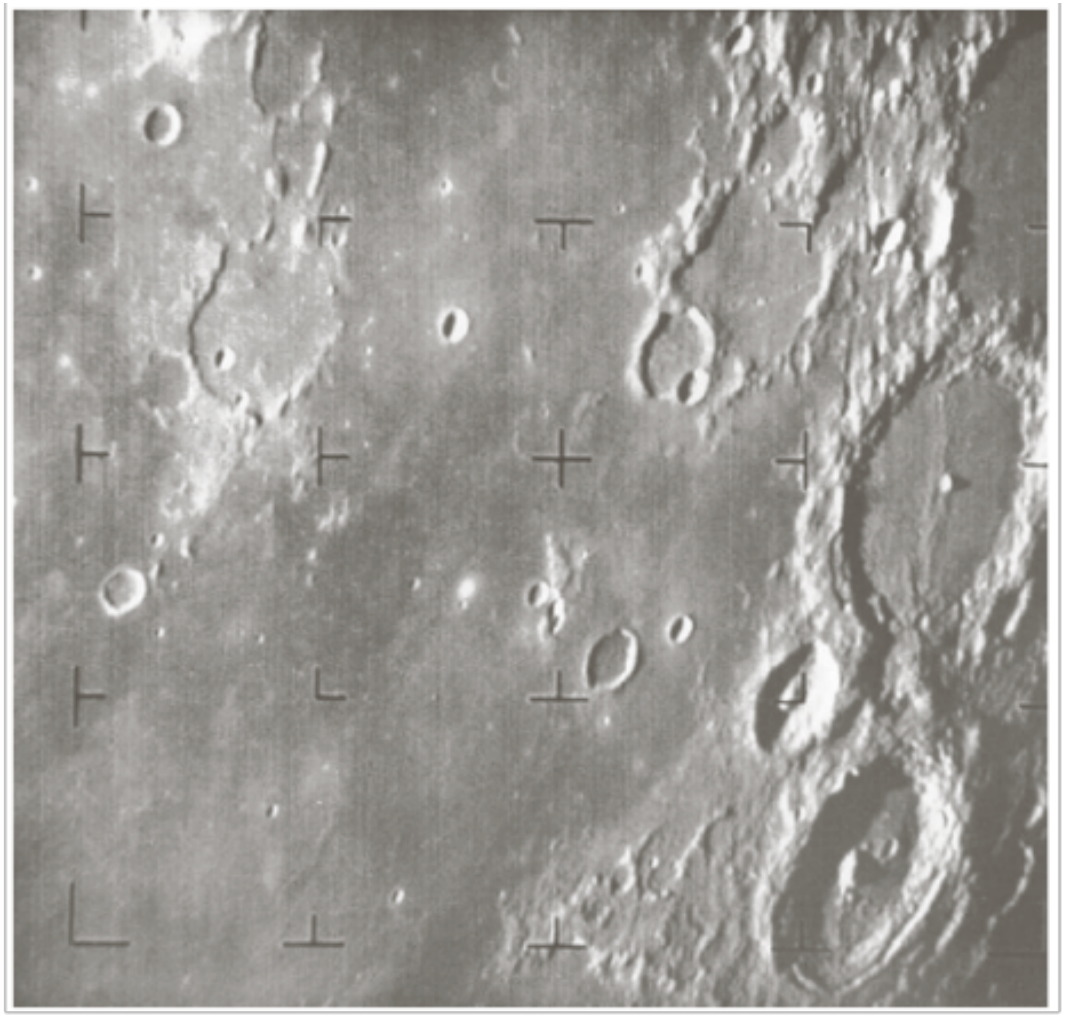


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

Jet Propulsion Lab (Pasadena, CA, EUA)

The SEAC Scanner
with control console in background

Figura: R.B. Thomas is operating the SEAC Scanner, the control console is in the background.

Figura: 1957, R.A.Kirsch produziu a primeira foto digital (his son).

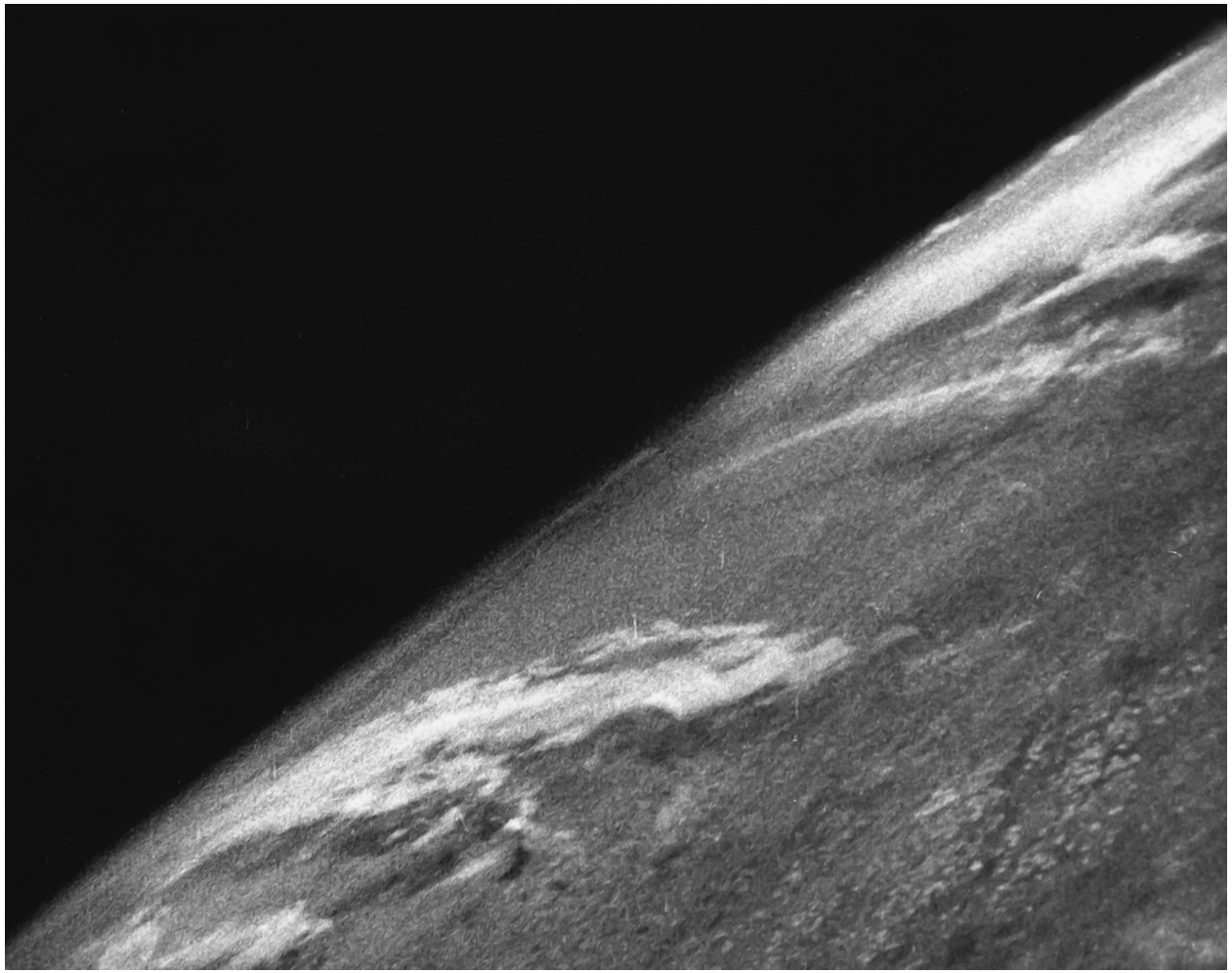
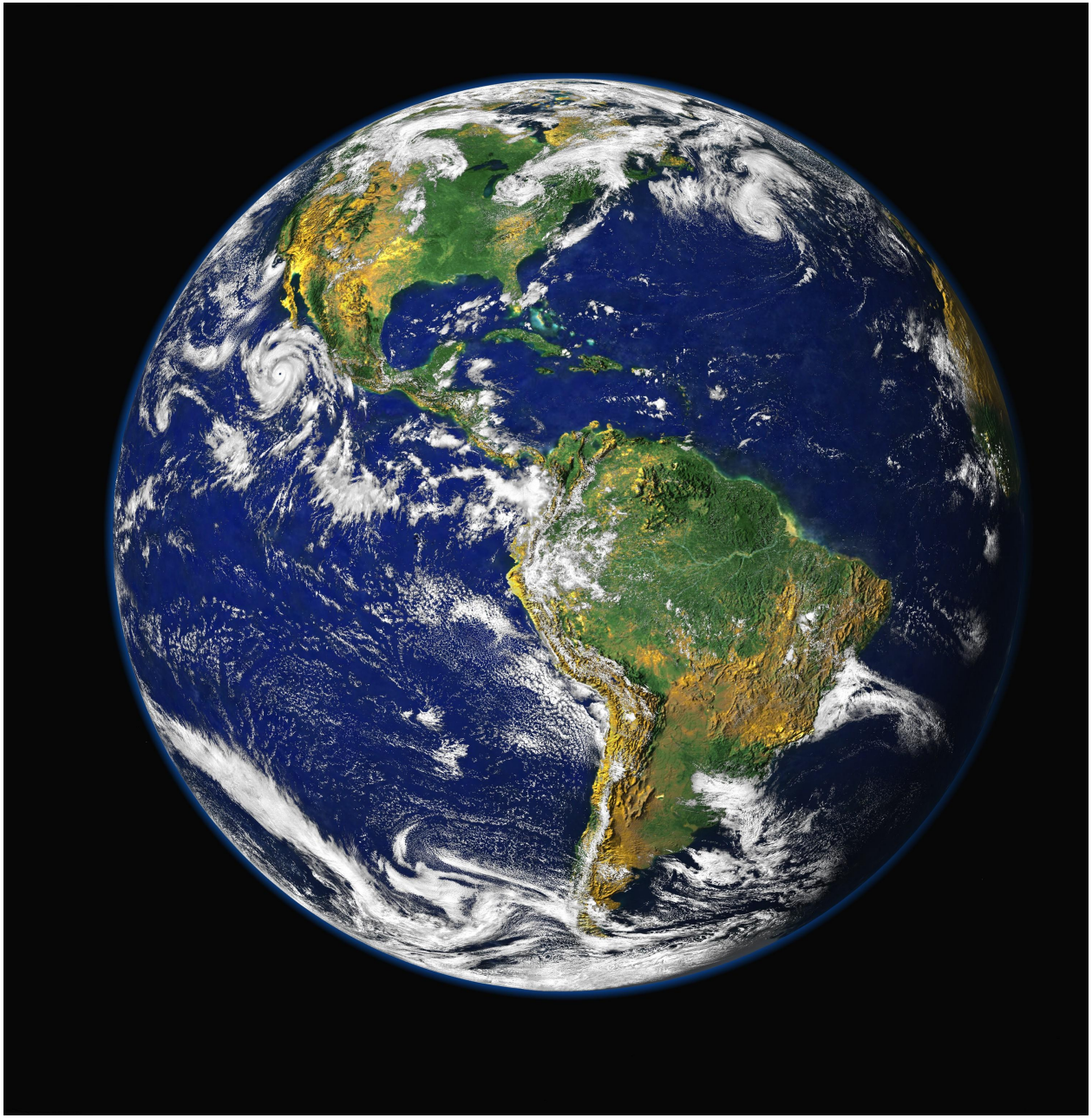


Figura: The first images from space were taken on the sub-orbital V-2 rocket flight launched by the U.S. on October 24, 1946.

Figura: October 2013, NASAs Juno spacecraft.

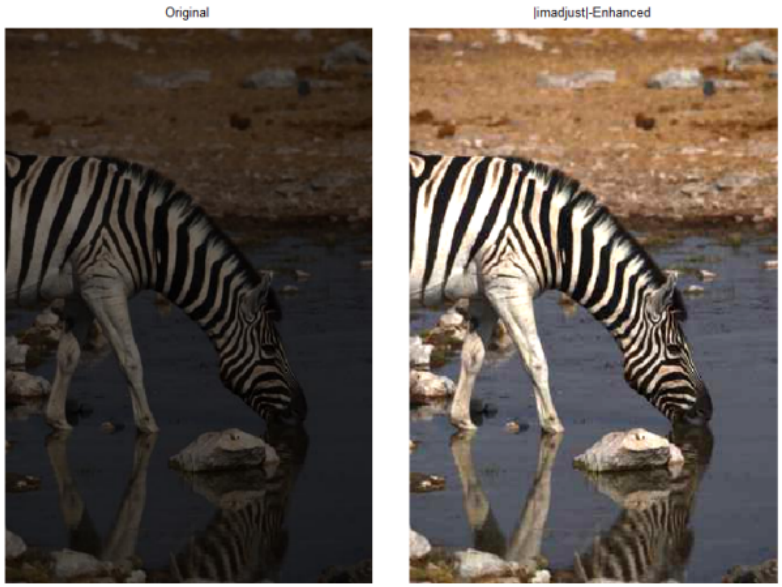


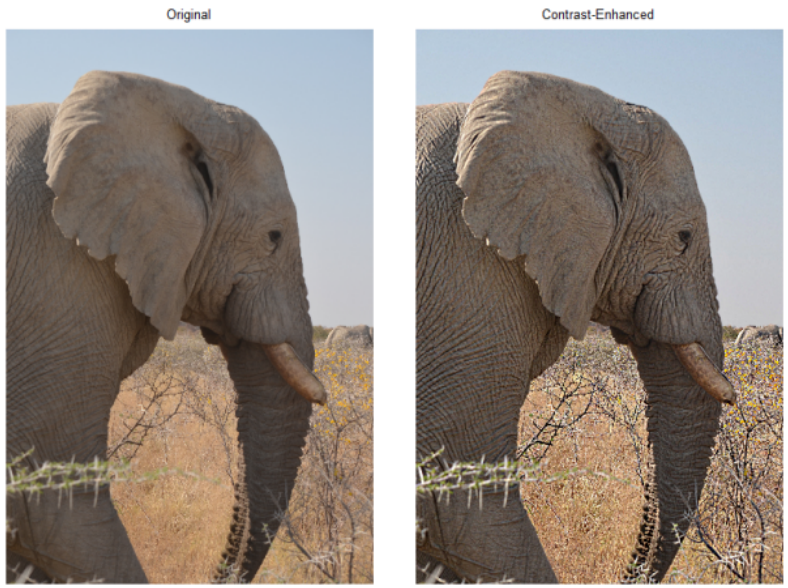
How do we process an image (digital)?

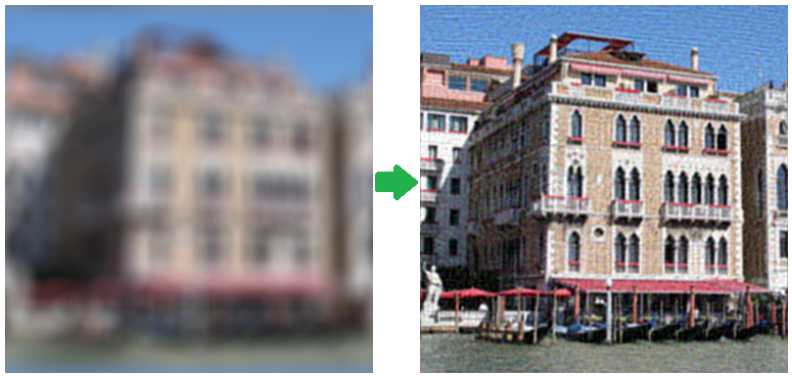
- Enhance or restore images:
  - Remove old films scratches;
  - Improve the visibility of objects in medical images;
- Extract semantics (information) about the image (description)
  - Read the zipcode in a letter;
  - Measure the water polution using aerial images;
- Produce beautiful (?) images;
- Etc...

Image Enhancement and Restoration

Image Enhancement and Restoration



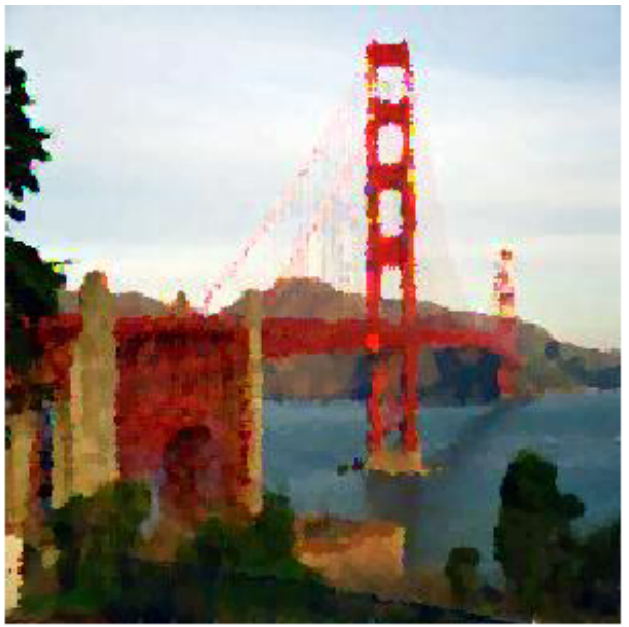




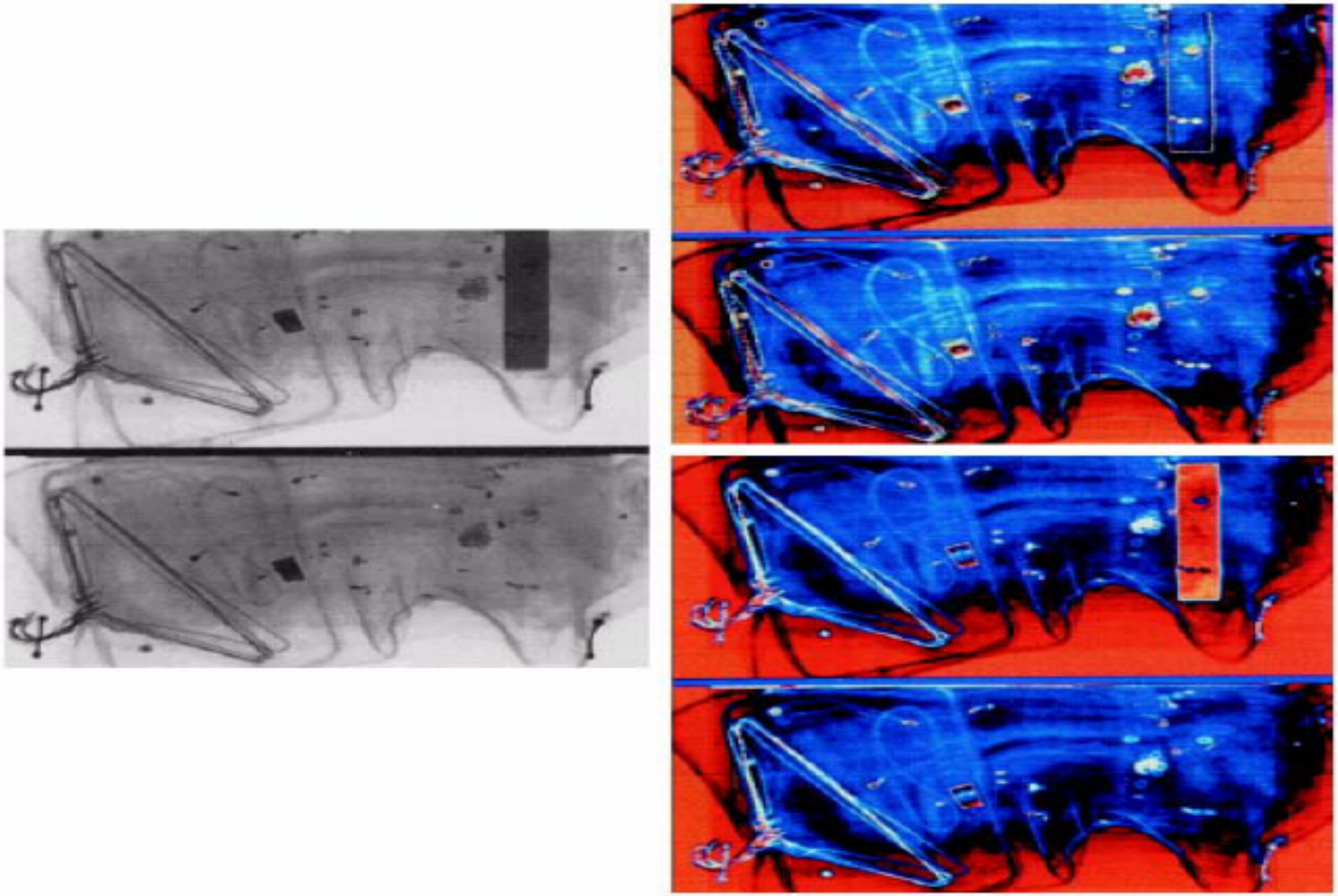
Dithering

Art

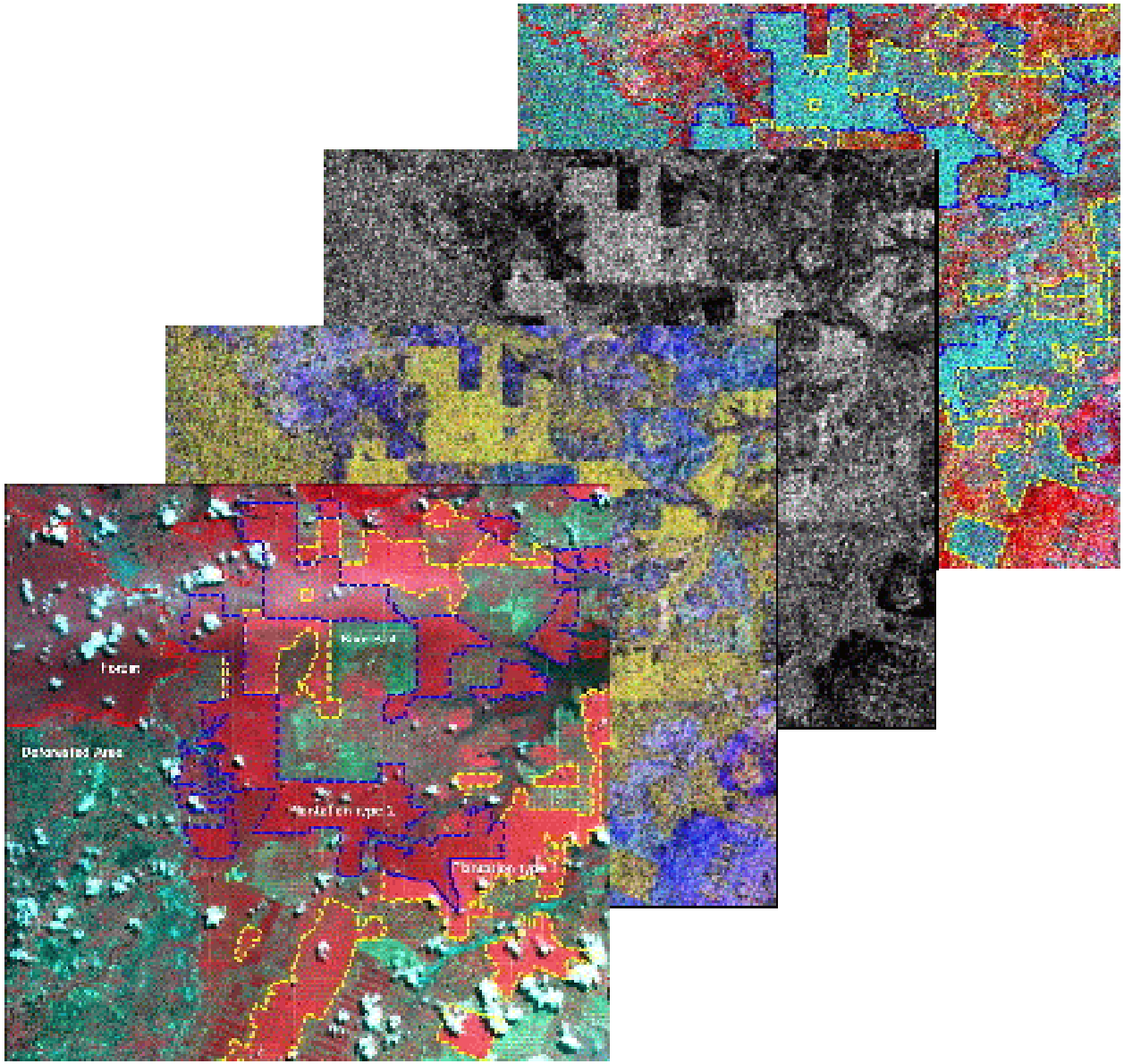




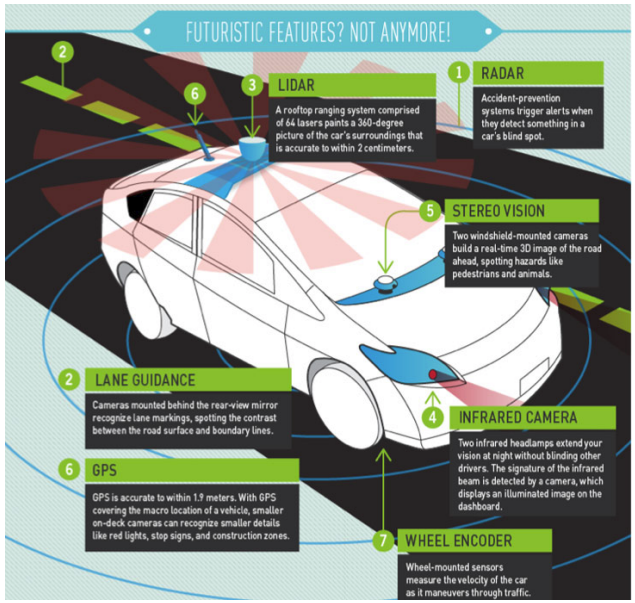
Security

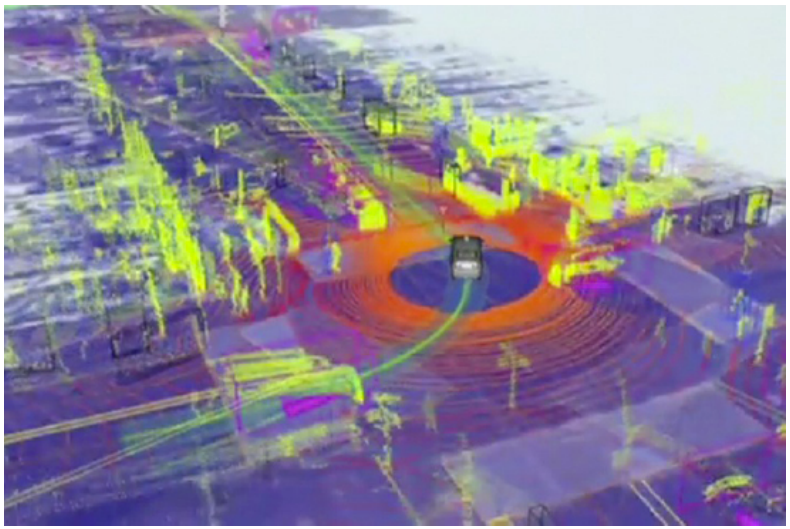


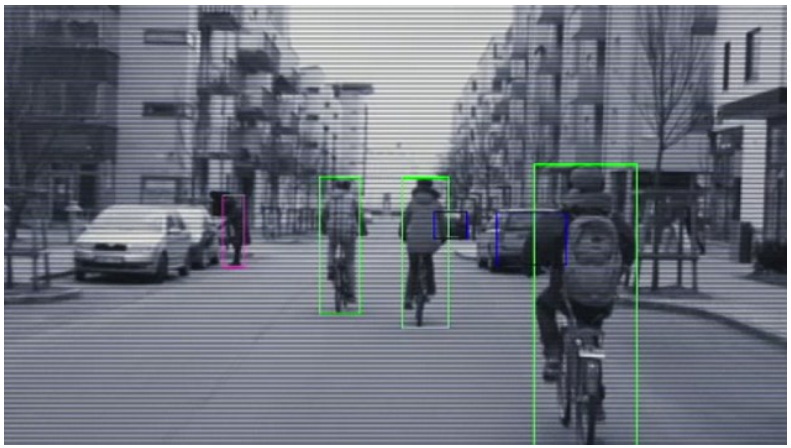
Geology and Geography



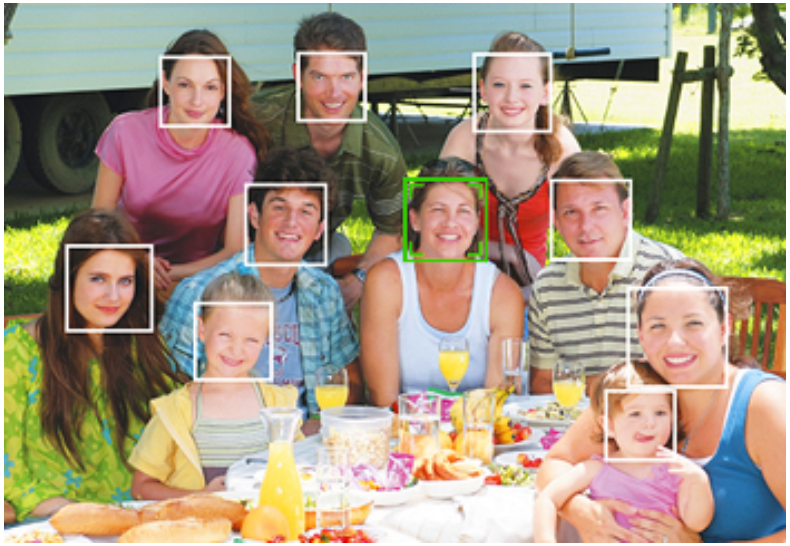
Autonomous Vehicles

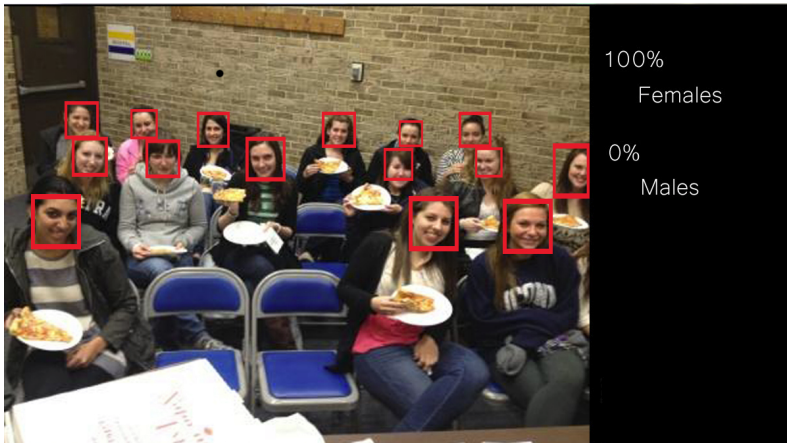


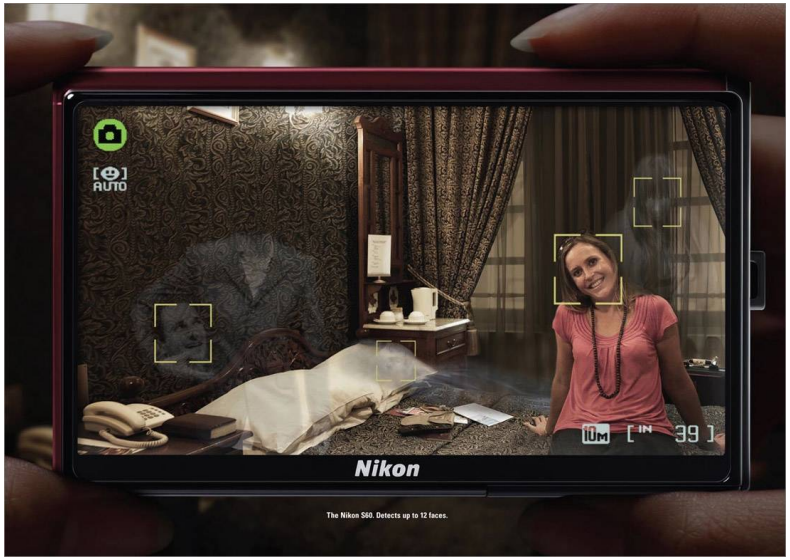


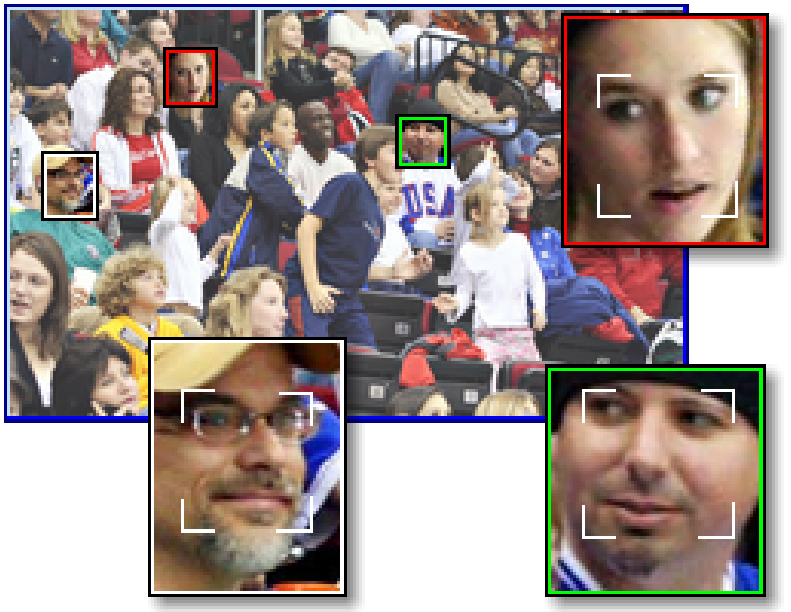


Face Detection









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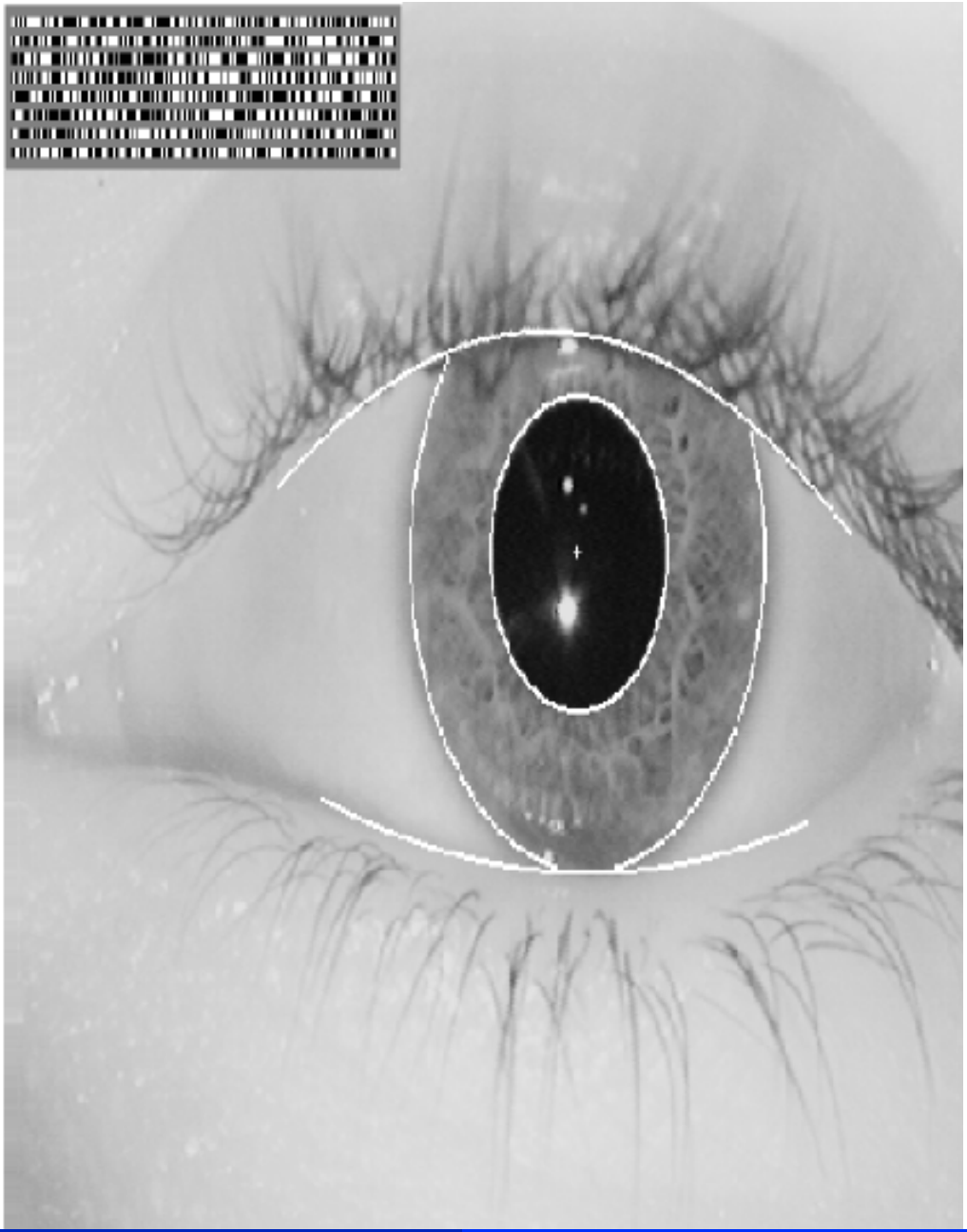
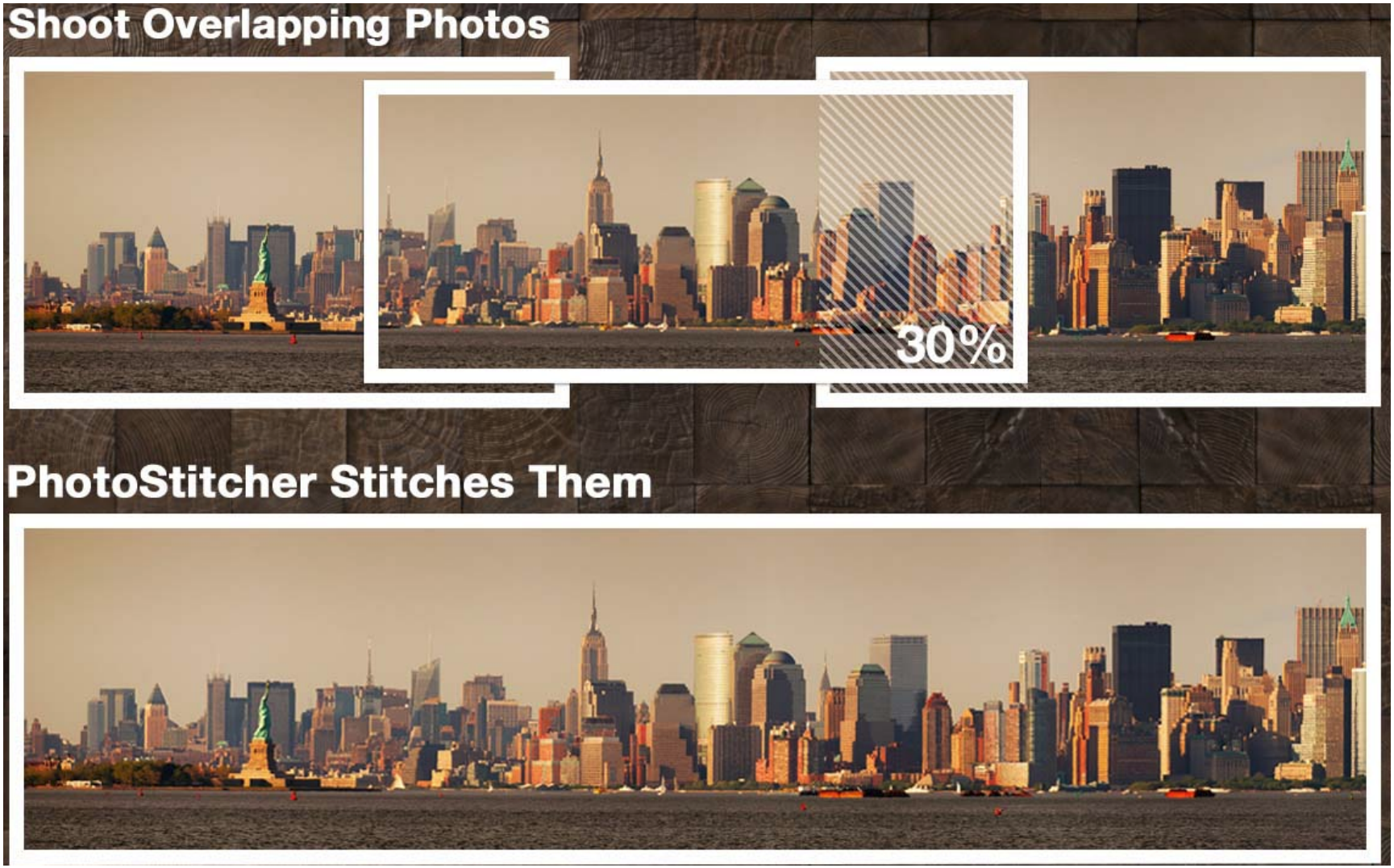
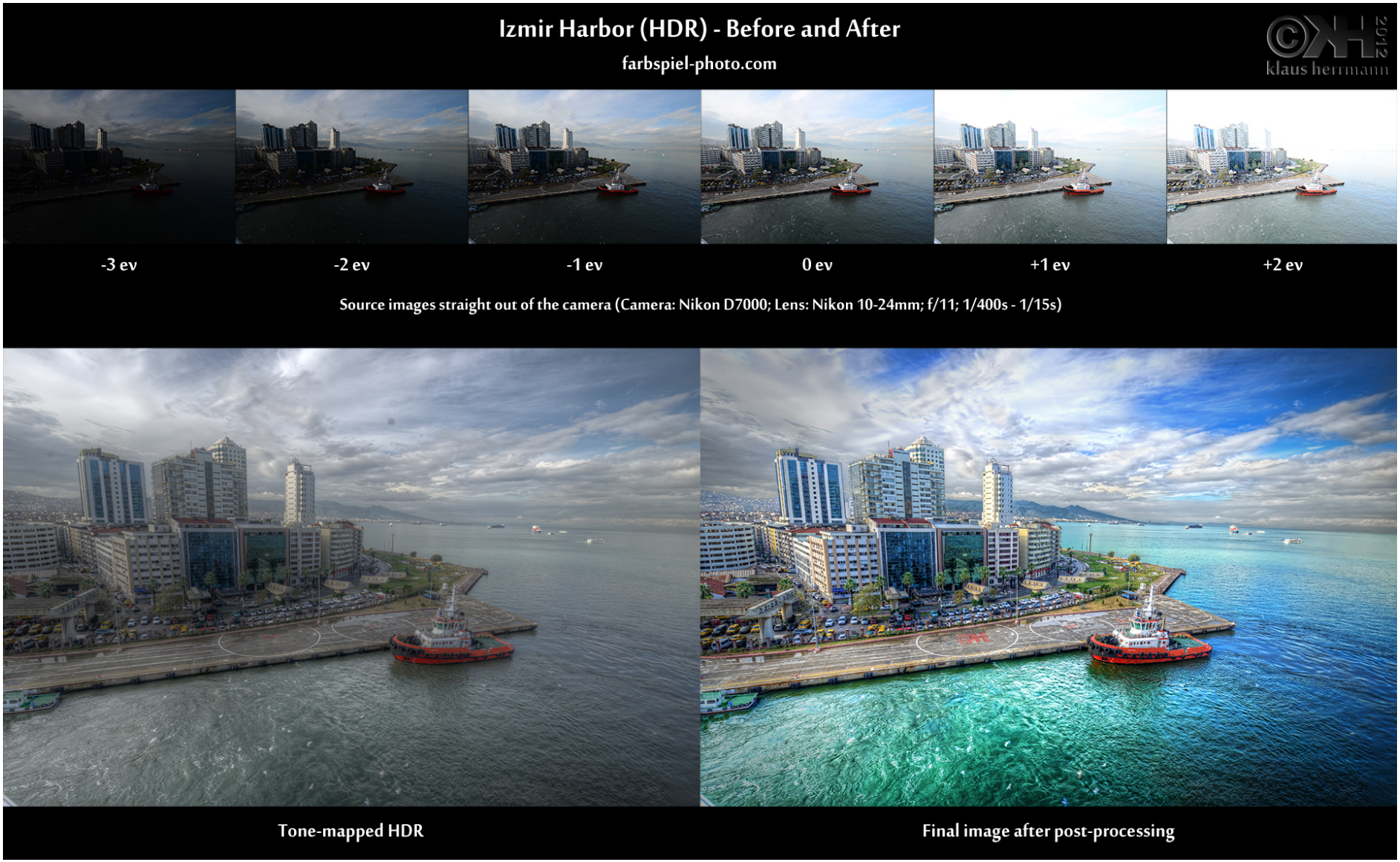



Shoot Overlapping Photos
30%
PhotoStitcher Stitches Them

original

marcada

mensagem


Izmir Harbor (HDR) - Before and After
farbspiel-photo.com
klaus herrmann
-3 ev
-2 ev
-1 ev
0 ev
+1 ev
+2 ev
Source images straight out of the camera (Camera: Nikon D7000; Lens: Nikon 10-24mm; f/11; 1/400s - 1/15s)
Tone-mapped HDR
Final image after post-processing


Rosánou Abbey (HDR) - Before and After
farbspiel-photo.com
klaus herrmann
-3 ev
-2 ev
-1 ev
0 ev
+1 ev
+2 ev
Source images straight out of the camera (Camera: Nikon D7000; Lens: Nikon 10-24mm@10mm; f/8; ISO200; 1/2000s - 1/50s)
Tone-mapped HDR
Final image after post-processing

Cap. 2

Fundamentals of the Human Visual System (HVS)

Perception

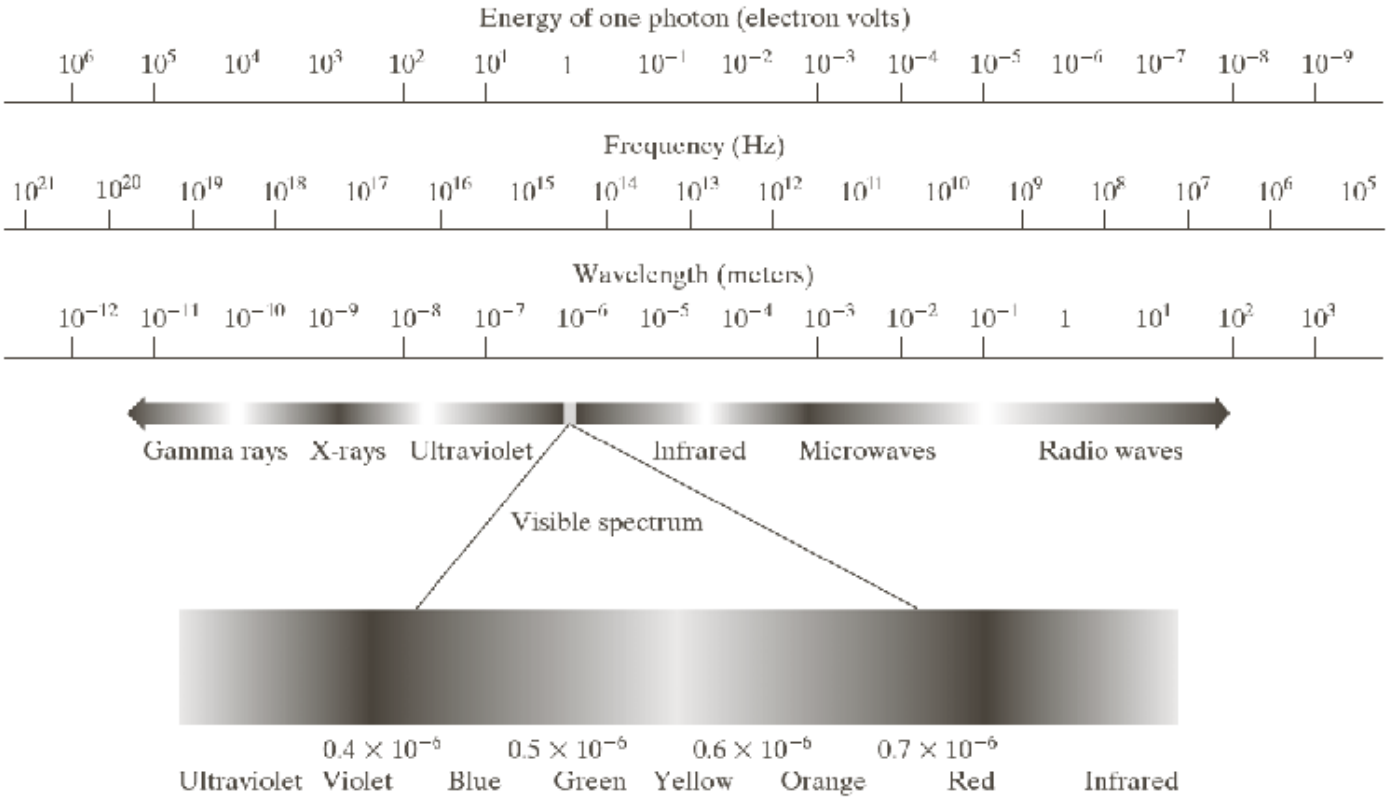
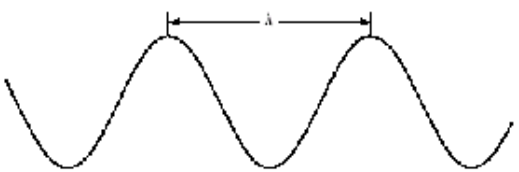


FIGURE 2.11
Graphical representation of one wavelength.



The human eye

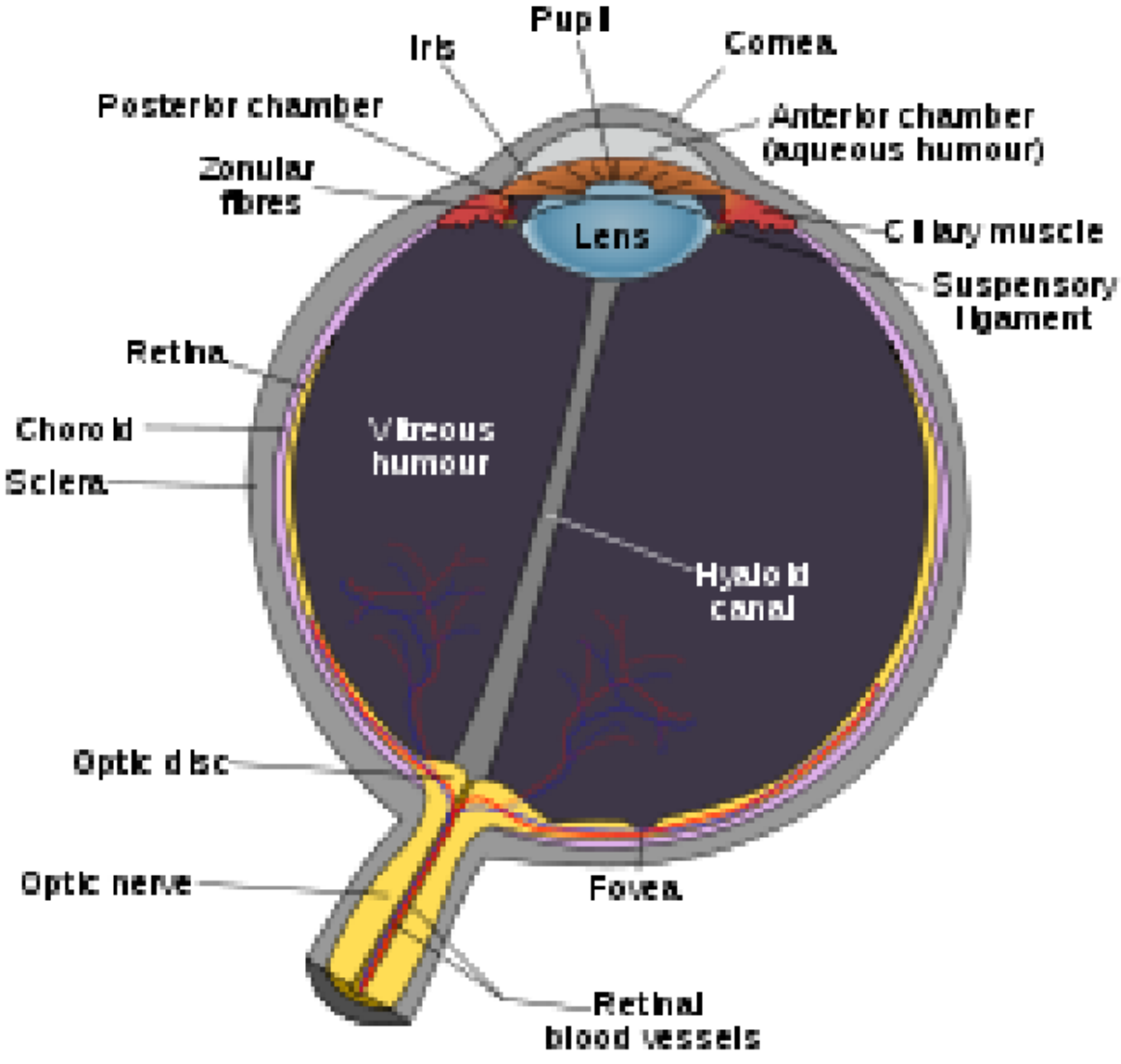
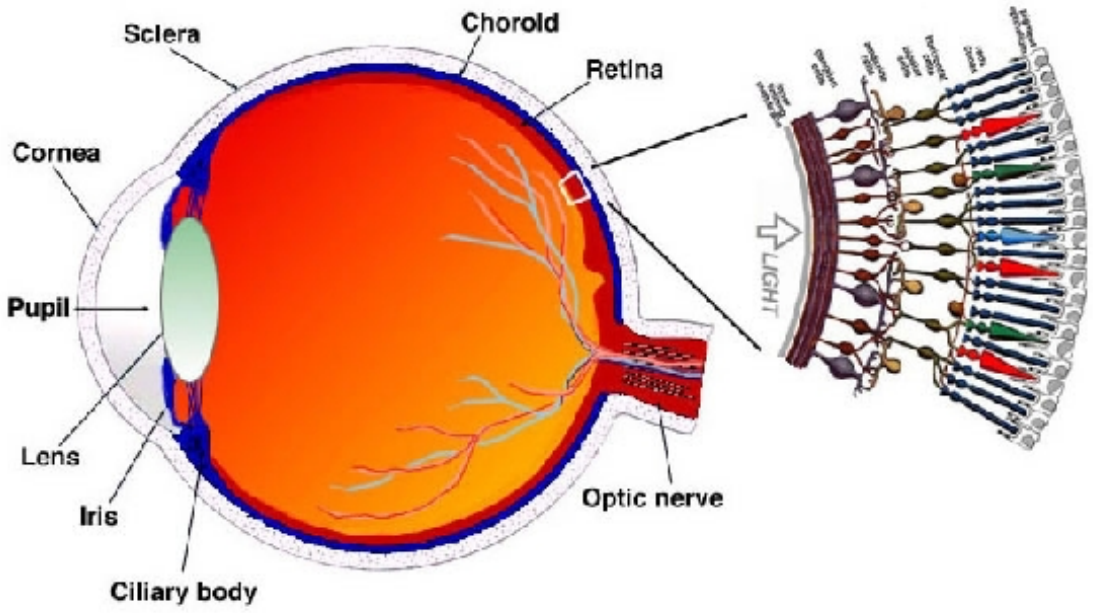
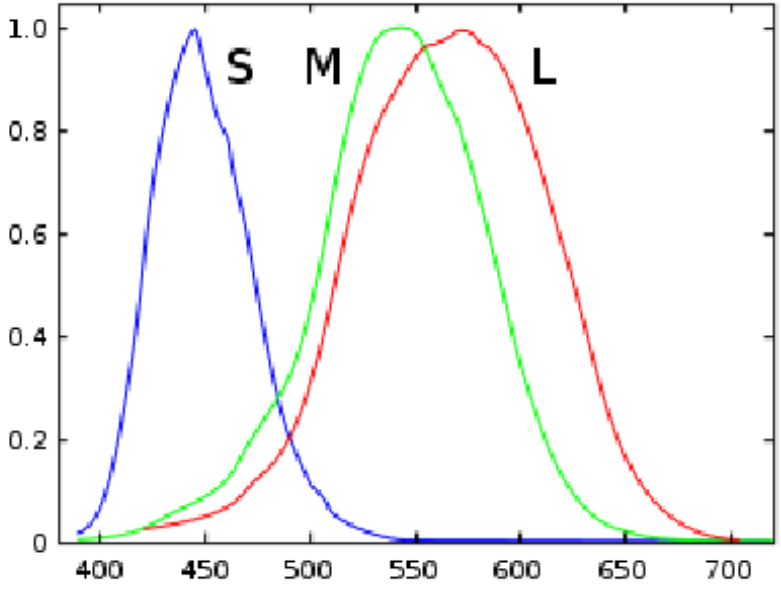


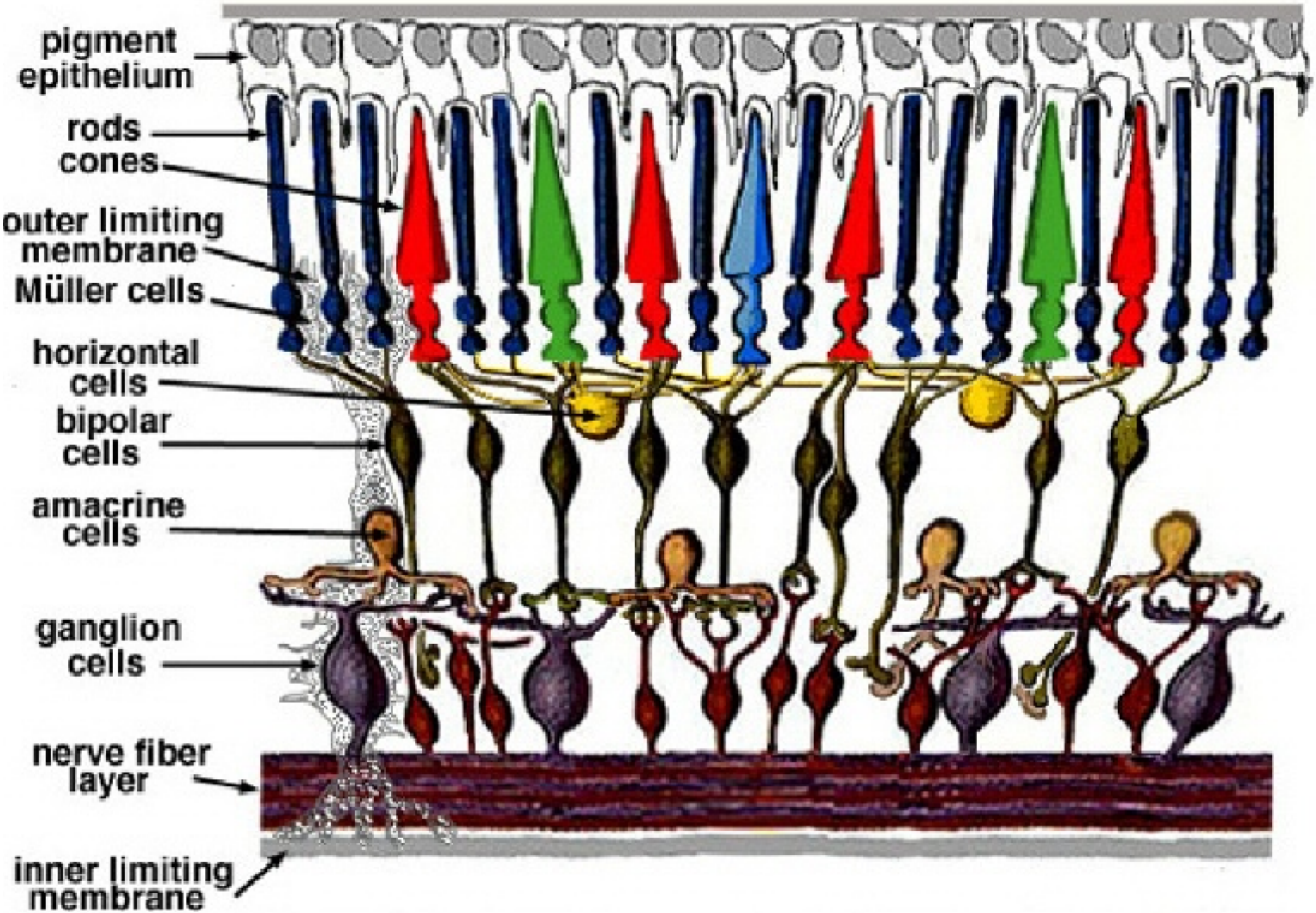
Photo-receptors



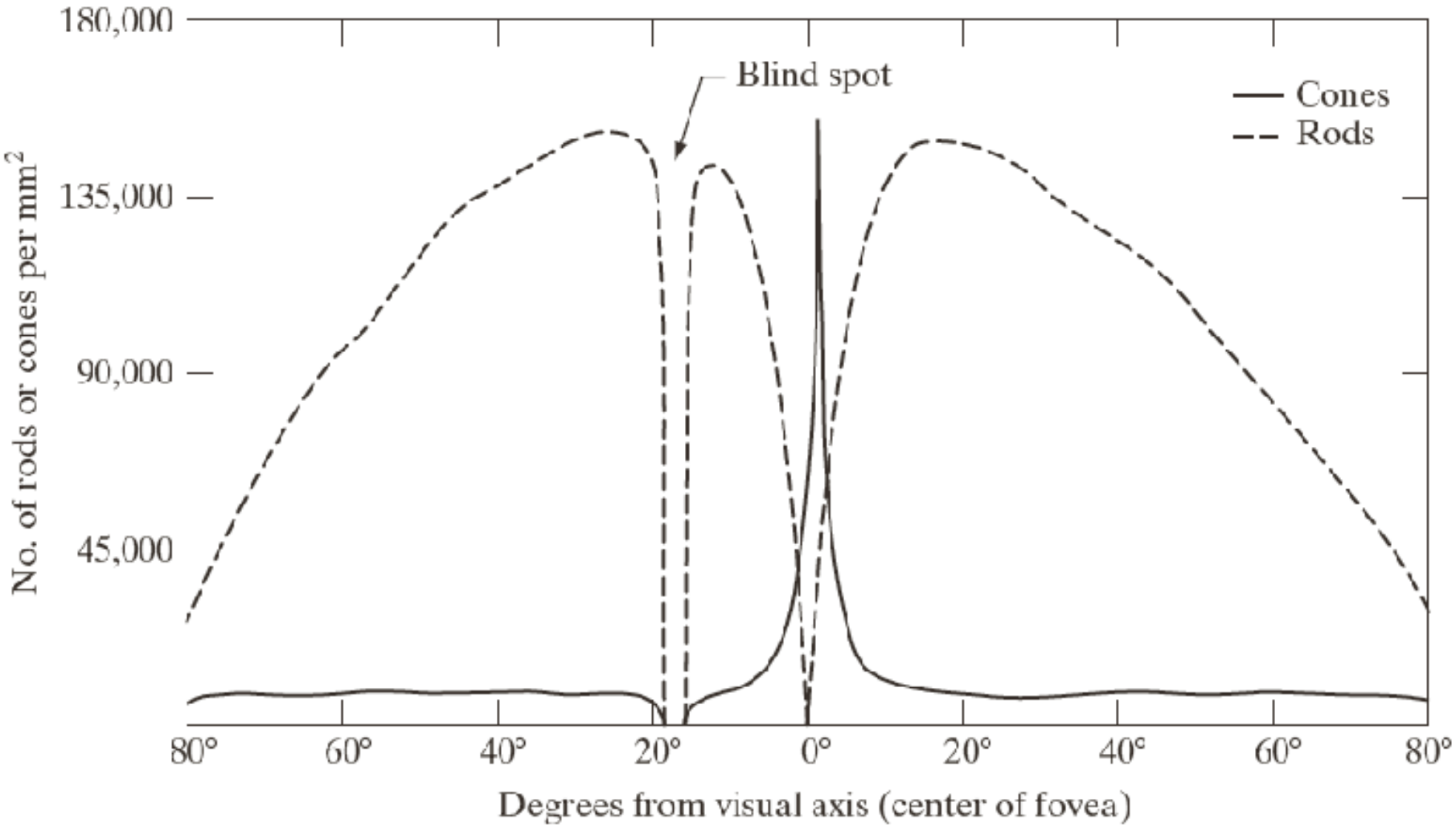
Cones e bastonetes (rods)

- Cones: (S, M, L) – 5 milhões
  - níveis “normais” de luz,
  - permitem a percepção de luz
  - localizados no centro da retina (detalhes da imagem)
- Bastonetes – 100 milhões
  - distribuídos na retina
  - níveis baixos de luz

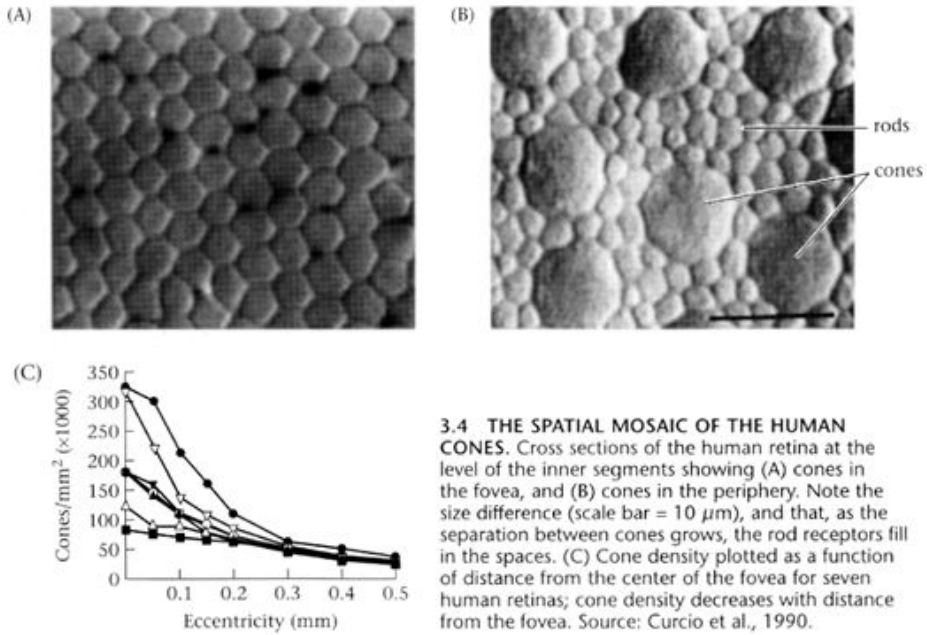



pigment epithelium
rods
cones
outer limiting membrane
Müller cells
horizontal cells
bipolar cells
amacrine cells
ganglion cells
nerve fiber layer
inner limiting membrane

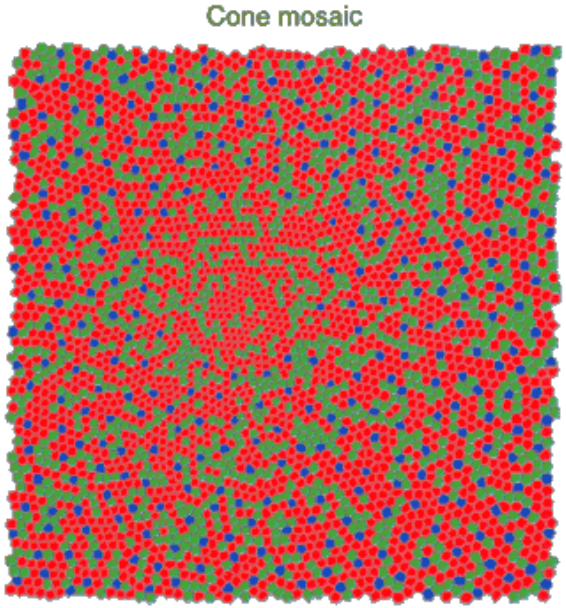
Distribution of Photo-Receptors

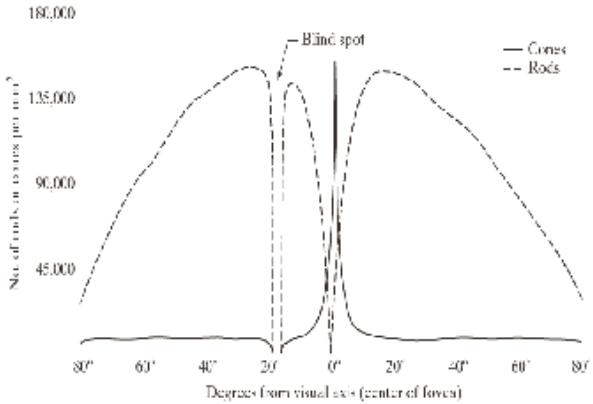


Distribution of Photo-Receptors

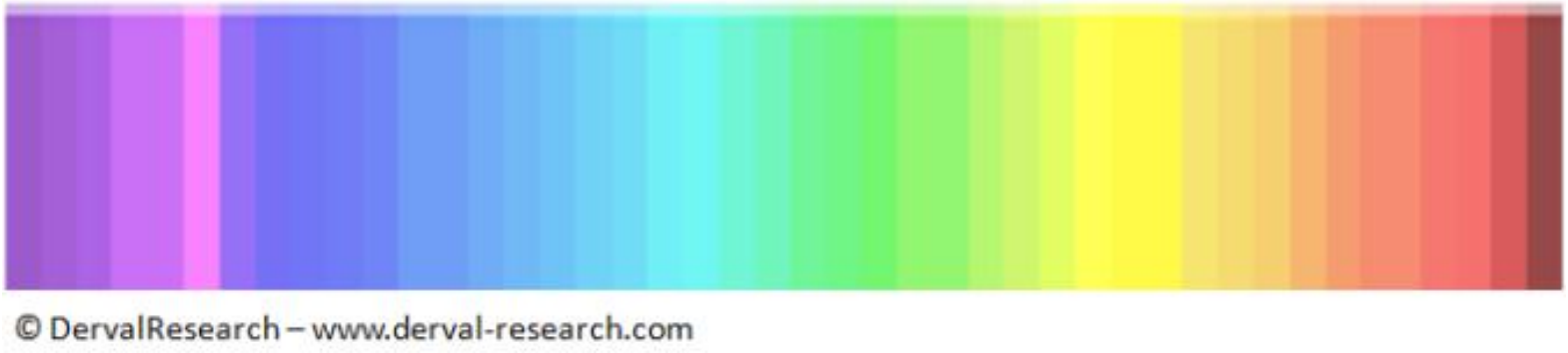


3.4 THE SPATIAL MOSAIC OF THE HUMAN CONES. Cross sections of the human retina at the level of the inner segments showing (A) cones in the fovea, and (B) cones in the periphery. Note the size difference (scale bar = 10 μm), and that, as the separation between cones grows, the rod receptors fill in the spaces. (C) Cone density plotted as a function of distance from the center of the fovea for seven human retinas; cone density decreases with distance from the fovea. Source: Curcio et al., 1990.

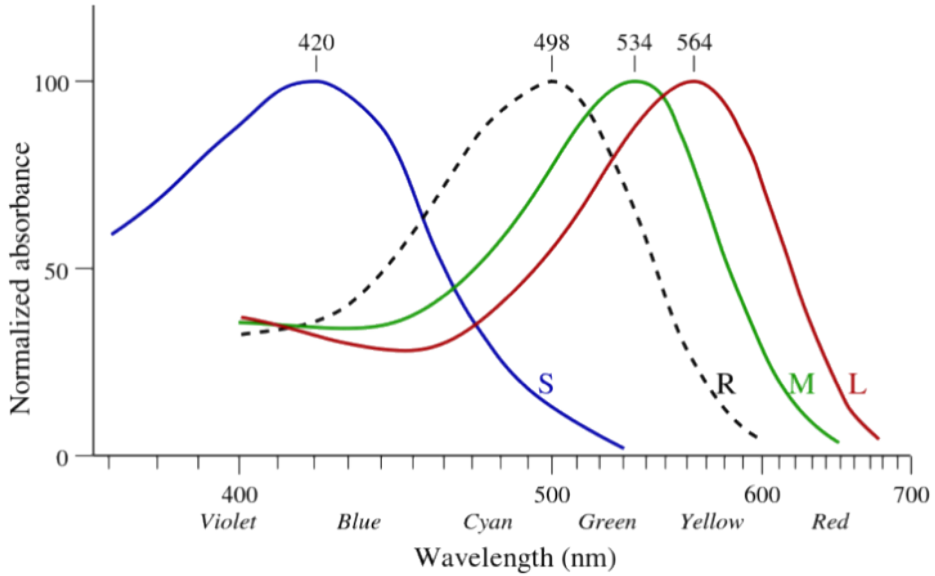




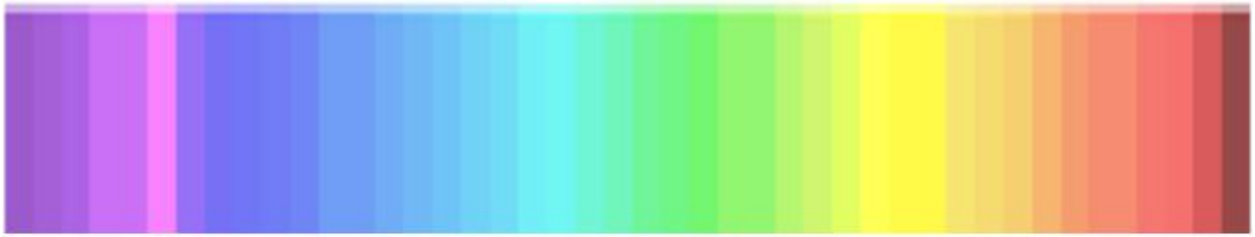
Distribution of Photo-Receptors



- less than 20 bars $\Longrightarrow$ 2 types of cones (25% of the population)
- from 20 to 32 bars $\Longrightarrow$ 3 types of cones (50% of the population)
- from 33 to 39 bars $\Longrightarrow$ 4 types of cones (25% of the population)



Distribution of Photo-Receptors



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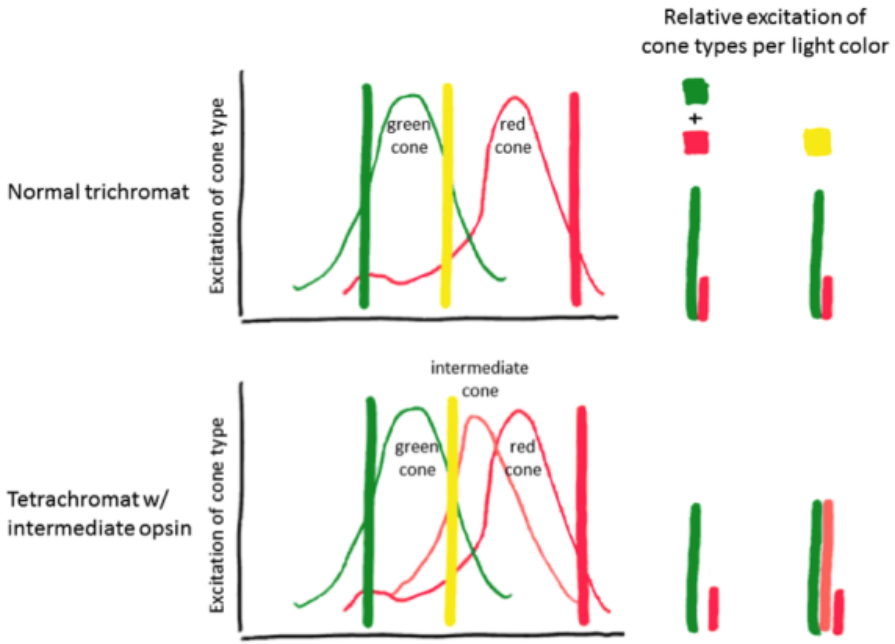
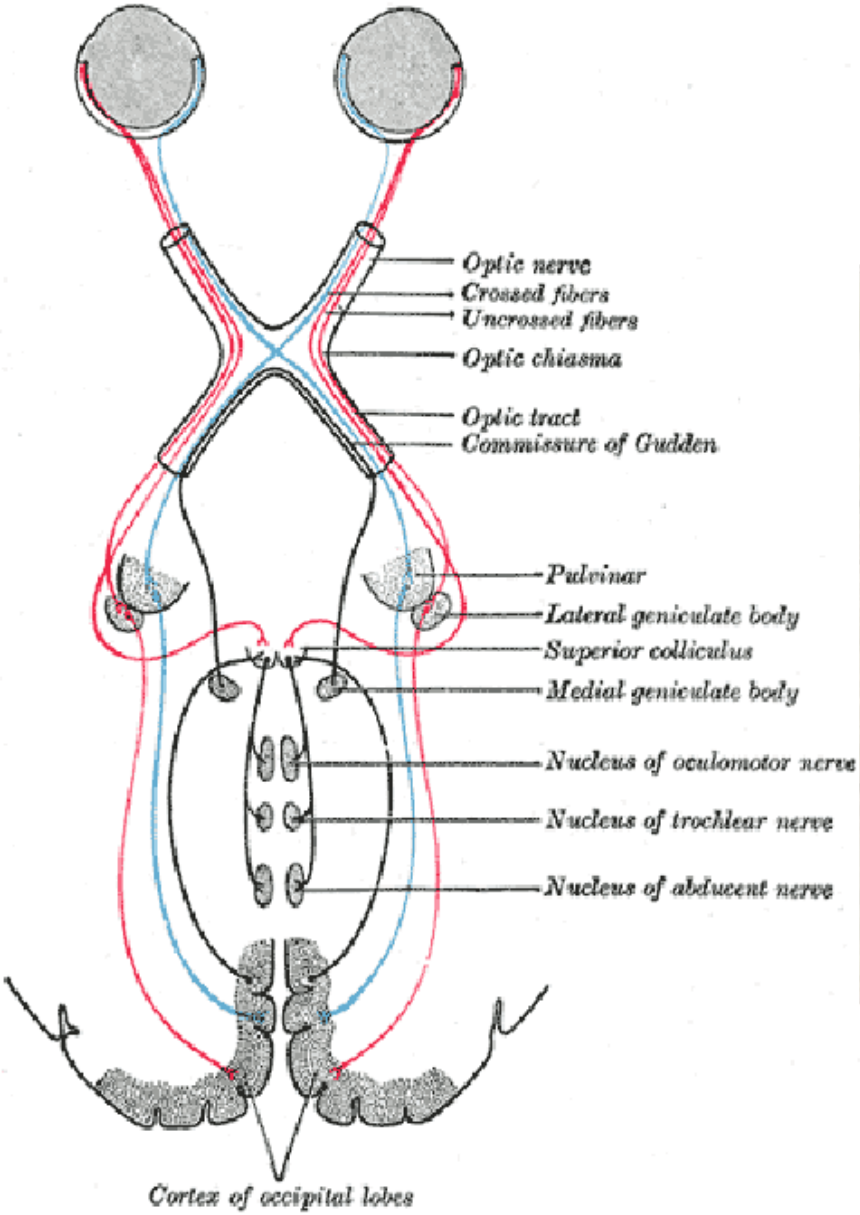
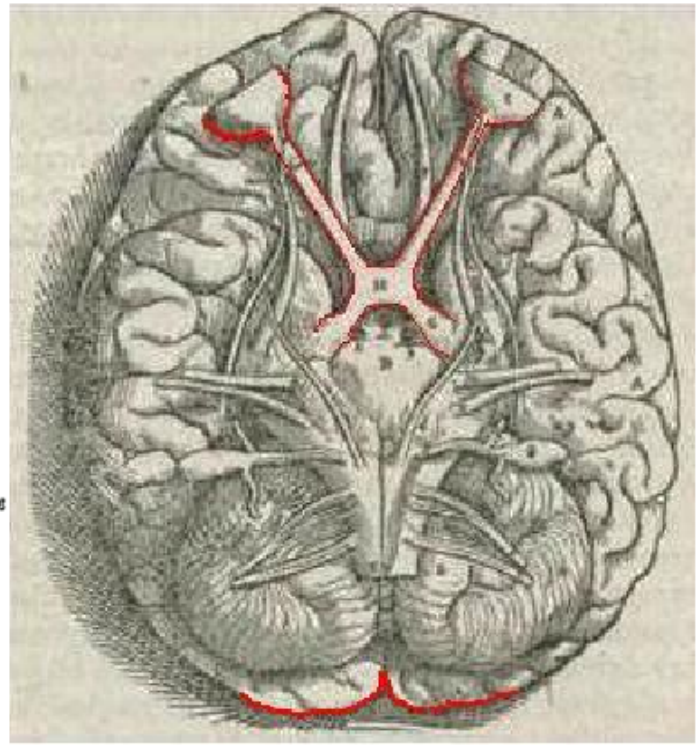


Distribution of Photo-Receptors

Figura: Color Blindness red-gree and normal vision.

The Eye


Optic nerve
Crossed fibers
Uncrossed fibers
Optic chiasma
Optic tract
Commissure of Gudden
Pulvinar
Lateral geniculate body
Superior colliculus
Medial geniculate body
Nucleus of oculomotor nerve
Nucleus of trochlear nerve
Nucleus of abducent nerve
Cortex of occipital lobes



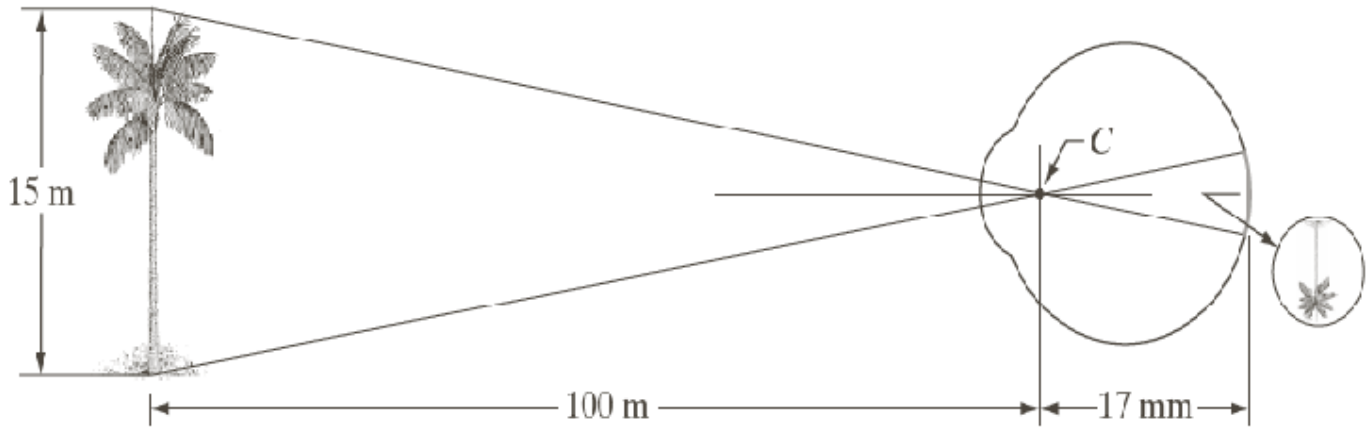


FIGURE 2.3
Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

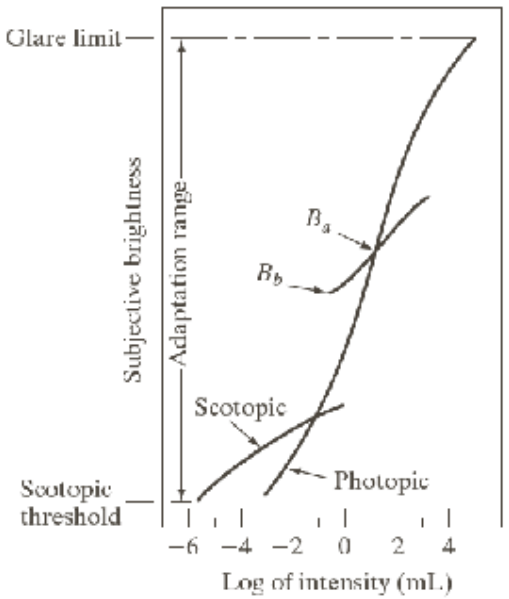


FIGURE 2.4
Range of subjective brightness sensations showing a particular adaptation level.

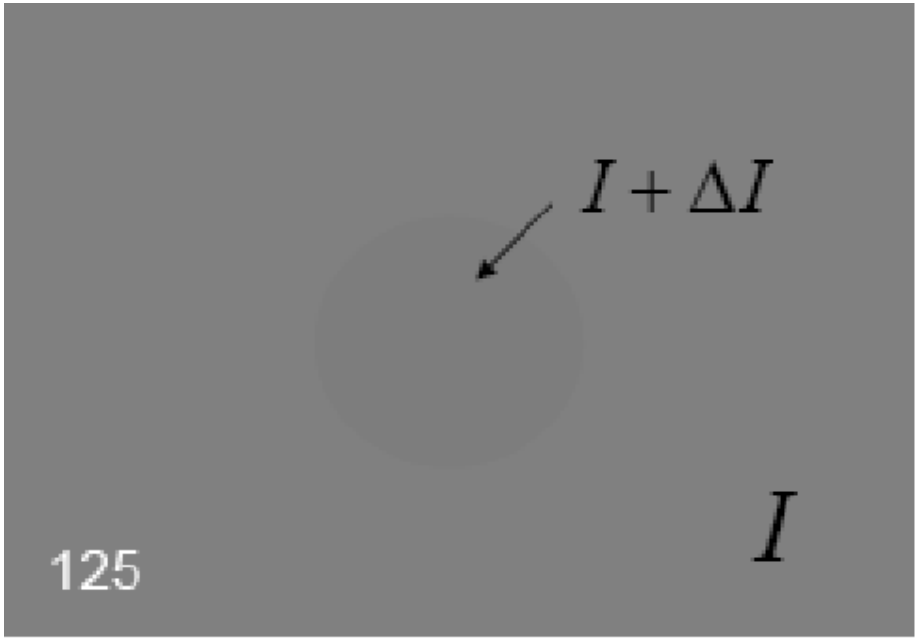
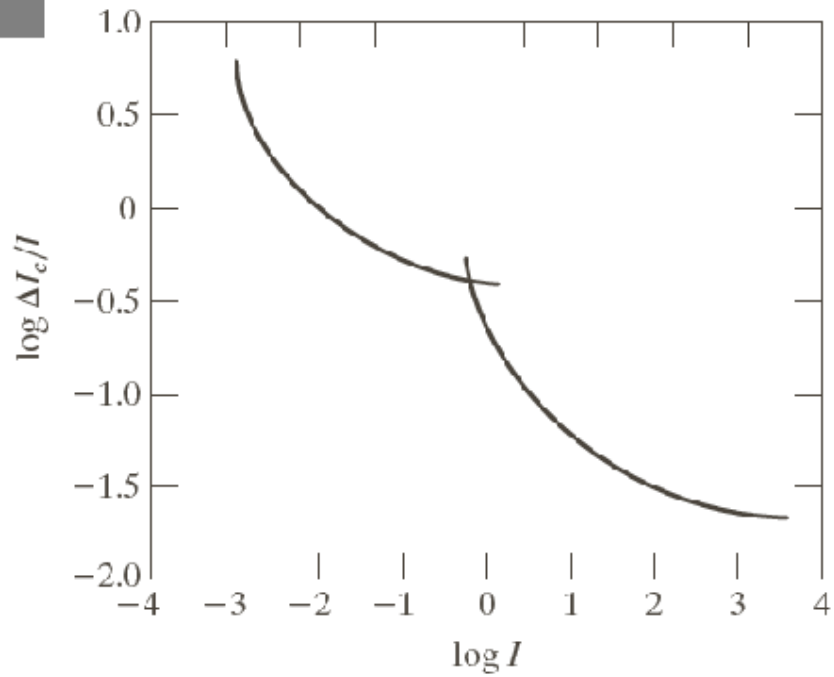


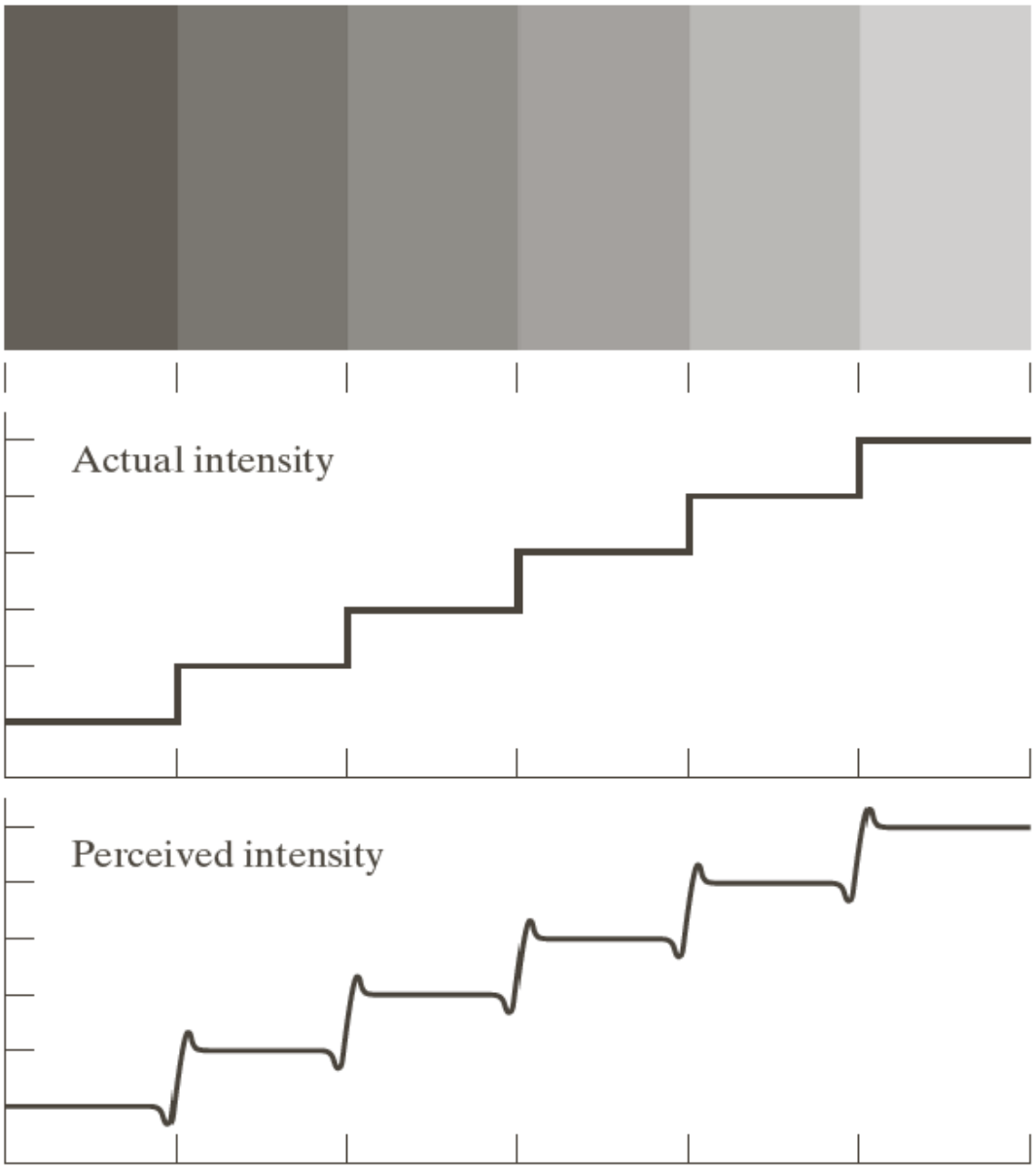
FIGURE 2.5 Basic experimental setup used to characterize brightness discrimination.

FIGURE 2.6 Typical Weber ratio as a function of intensity.



Discriminação é pobre (razão de weber é Alta) para níveis baixos de iluminação.

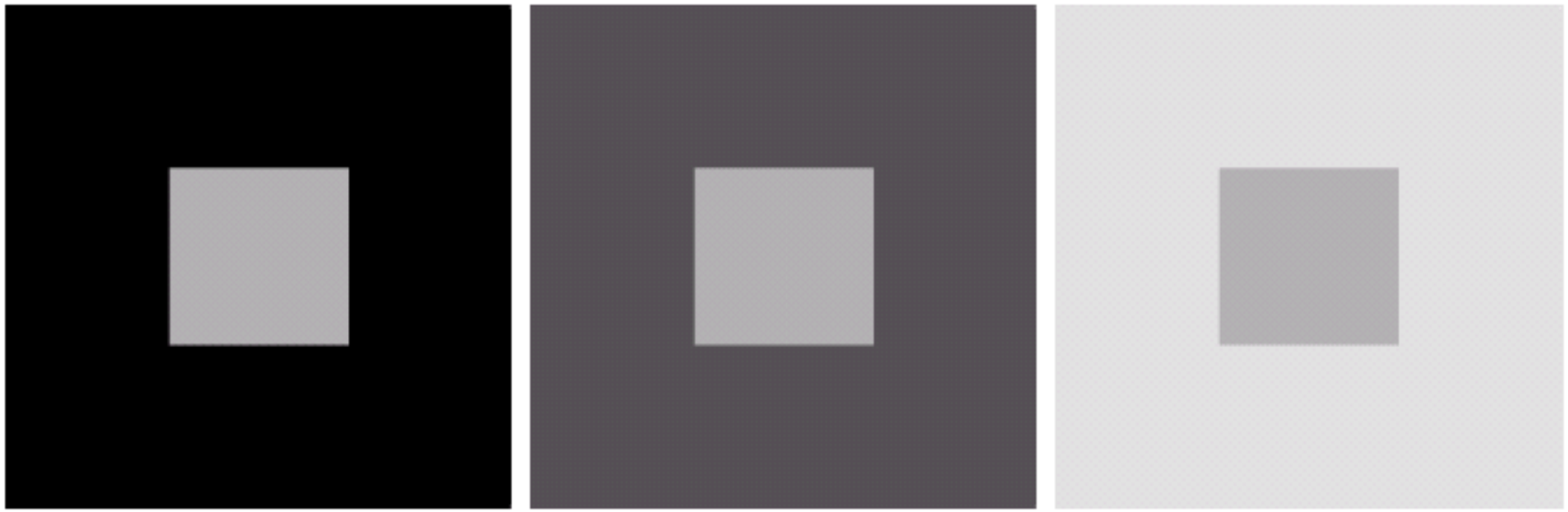
Intensity



a
b
c

FIGURE 2.7
Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.

Contrast



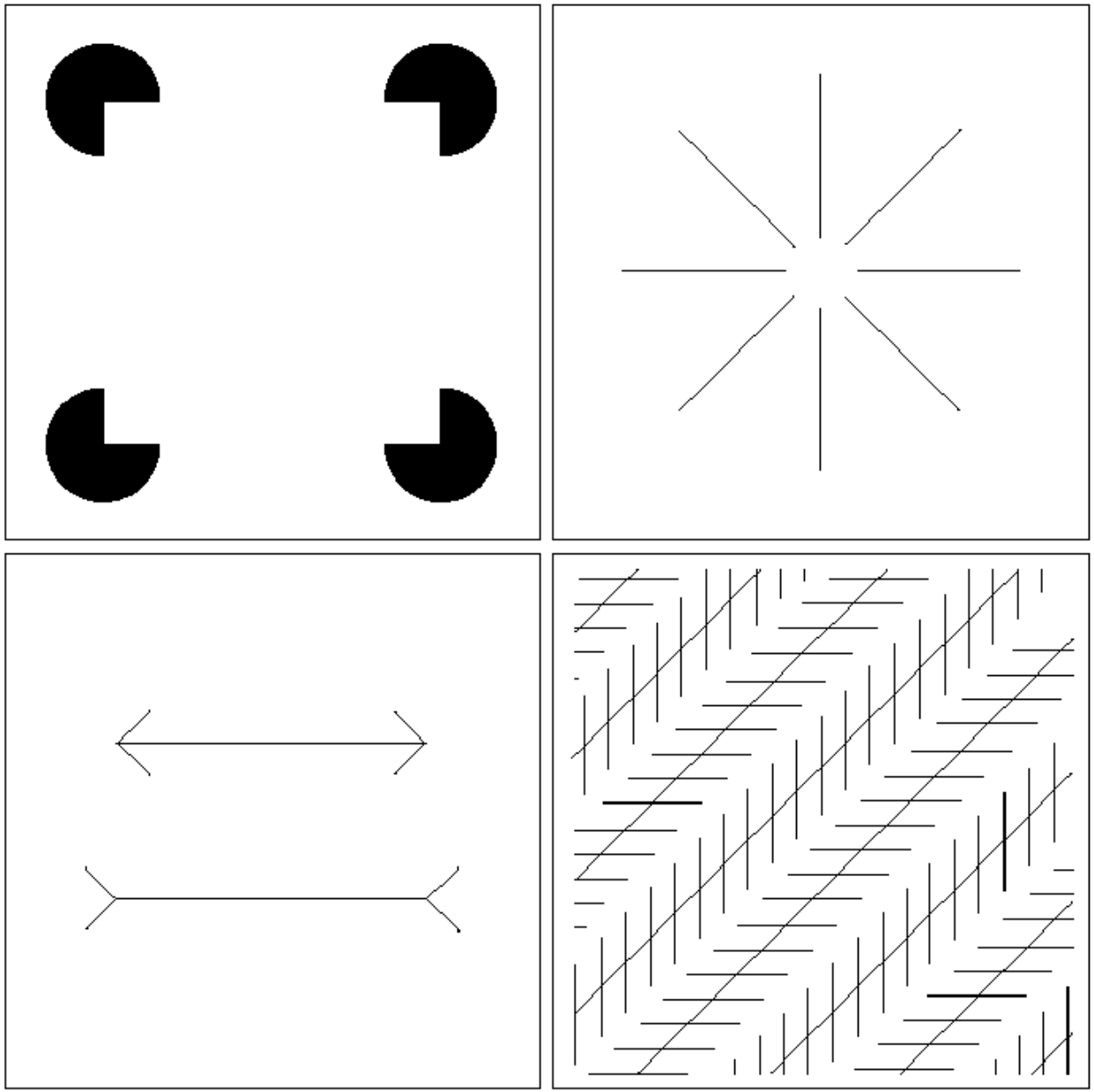
a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Illusions

a b
c d

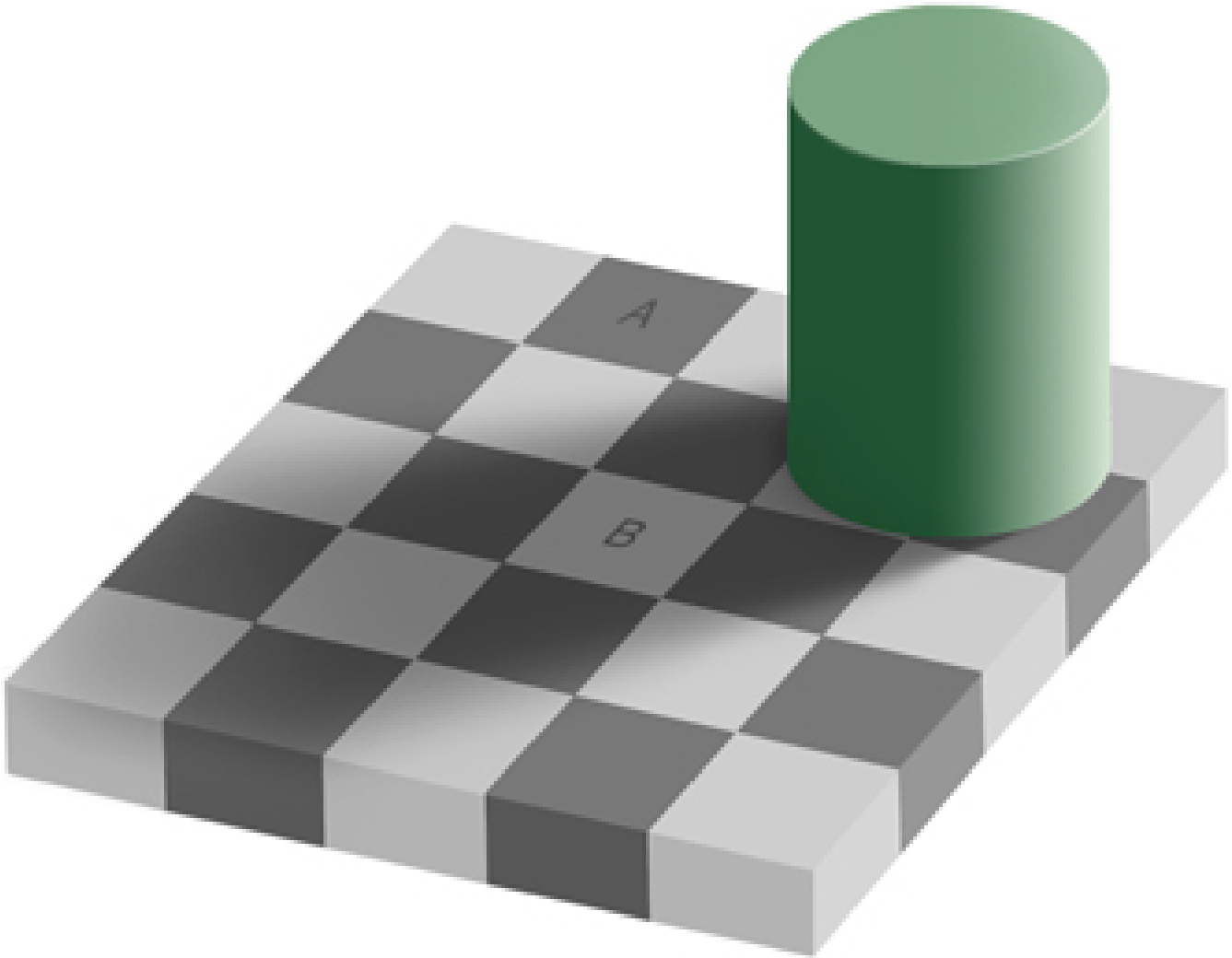
FIGURE 2.9 Some well-known optical illusions.



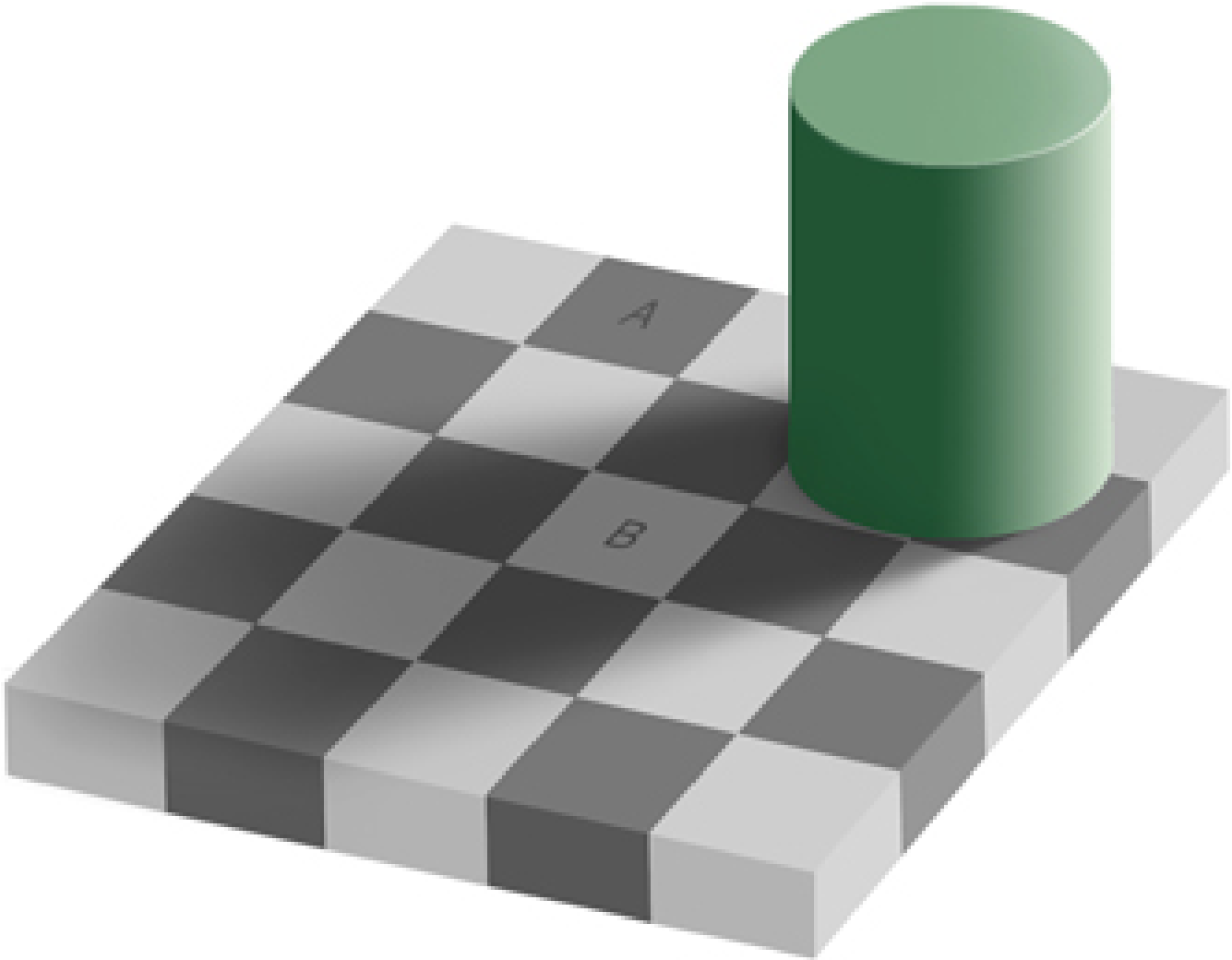
Illusions

The dress is white-gold or blue-black?

Illusions

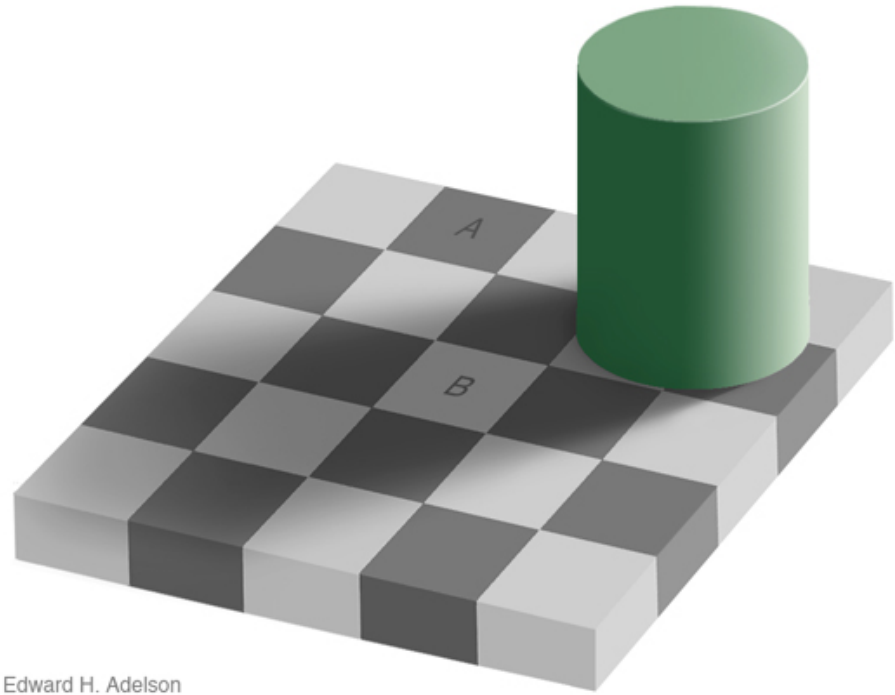


Illusions

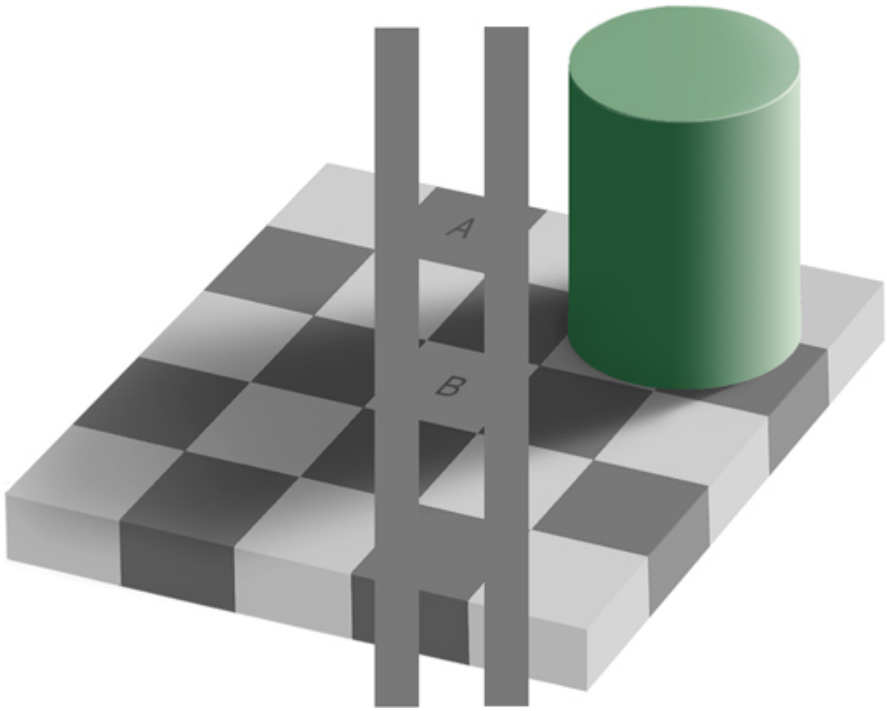


Edward Adelson's checkerboard: The squares marked A and B are the same shade of gray.

Illusions



Edward H. Adelson



Illusions

Why do some people see TheDress as blue and black, and some as gold and white?

Illusions

white with a blue light or *blue* with a white light?