ISEL
INSTITUTO SUPERIOR
DE ENGENHARIA DE LISBOA

PROCESSAMENTO DE IMAGEM E BIOMETRIA

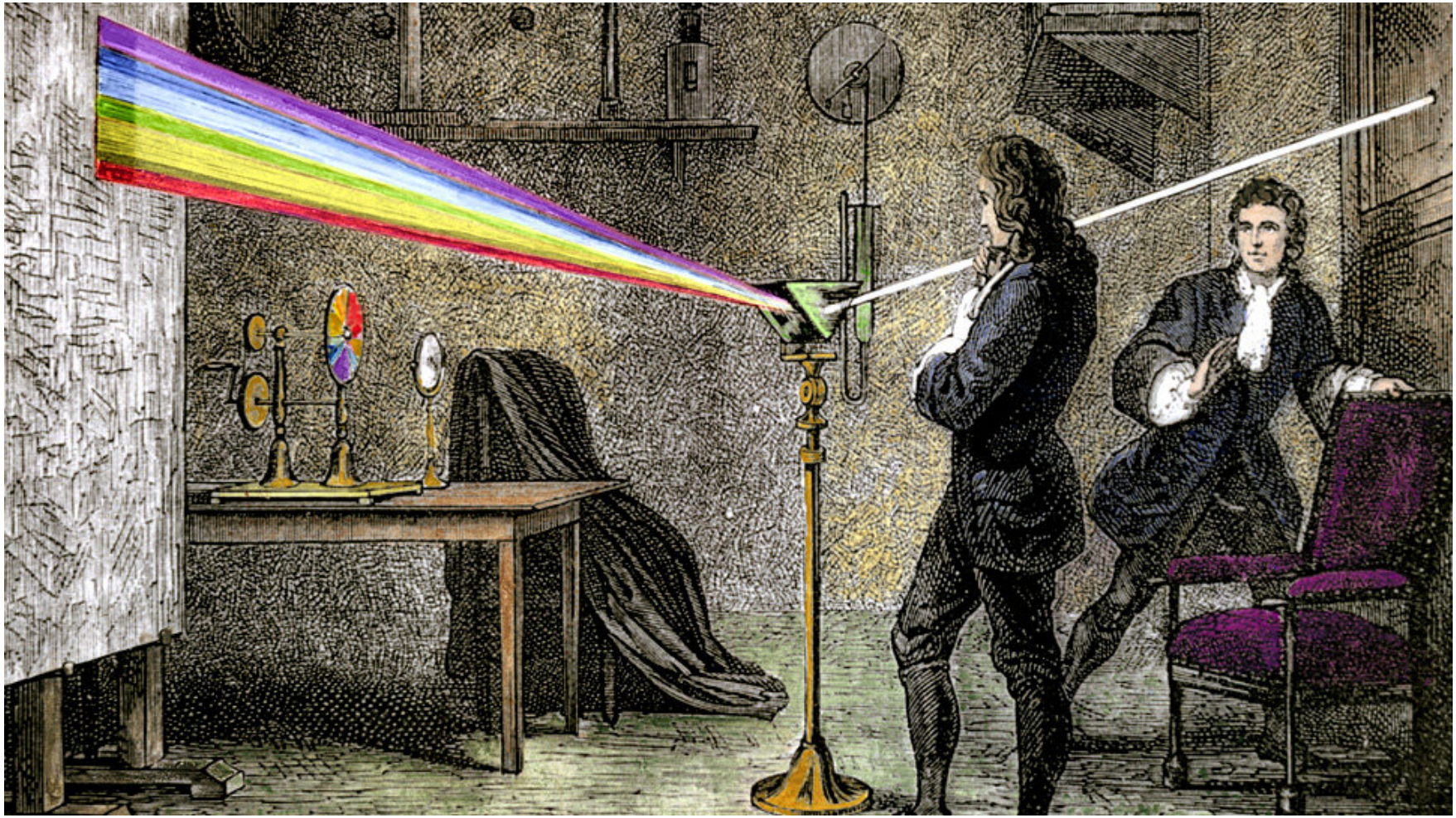
IMAGE PROCESSING AND BIOMETRICS

7. **COLOR IMAGE PROCESSING (part 1)**

Summary (part 1)

- Basics about color
- Human perception of color – the human visual system
- Pseudo-coloring techniques
  - Intensity Slicing
  - Intensity Transformation
- MATLAB functions
- Exercises

Basics about color (1)



Isaac Newton prism experiment

Basics about color (2)

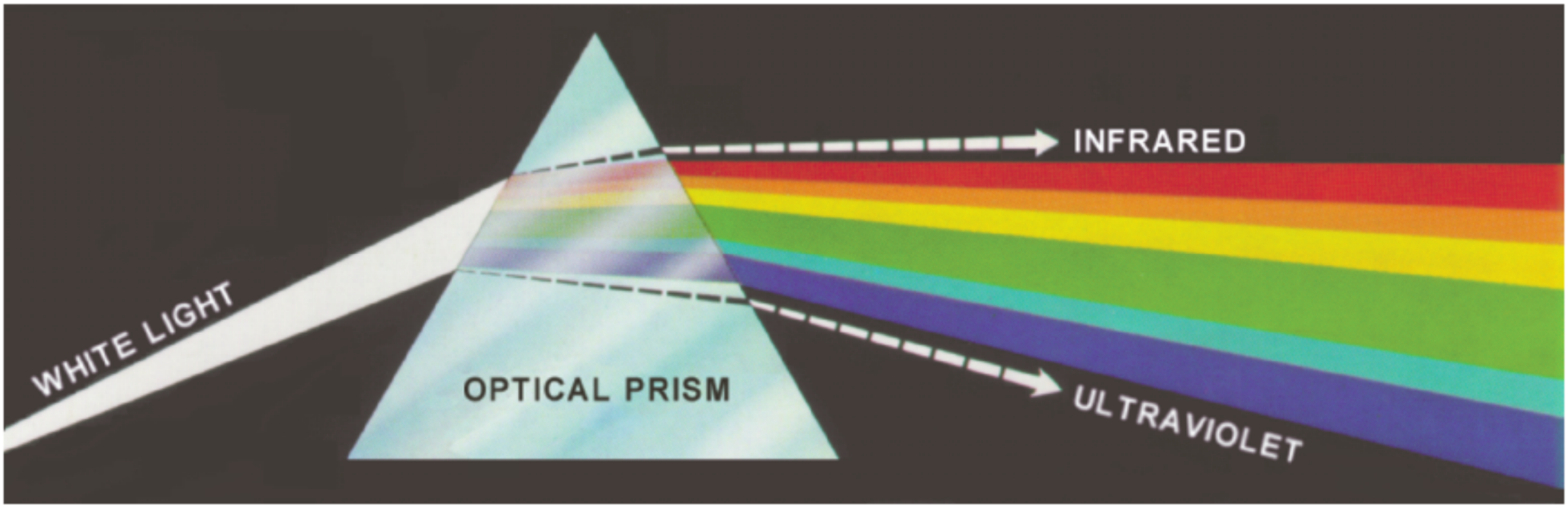
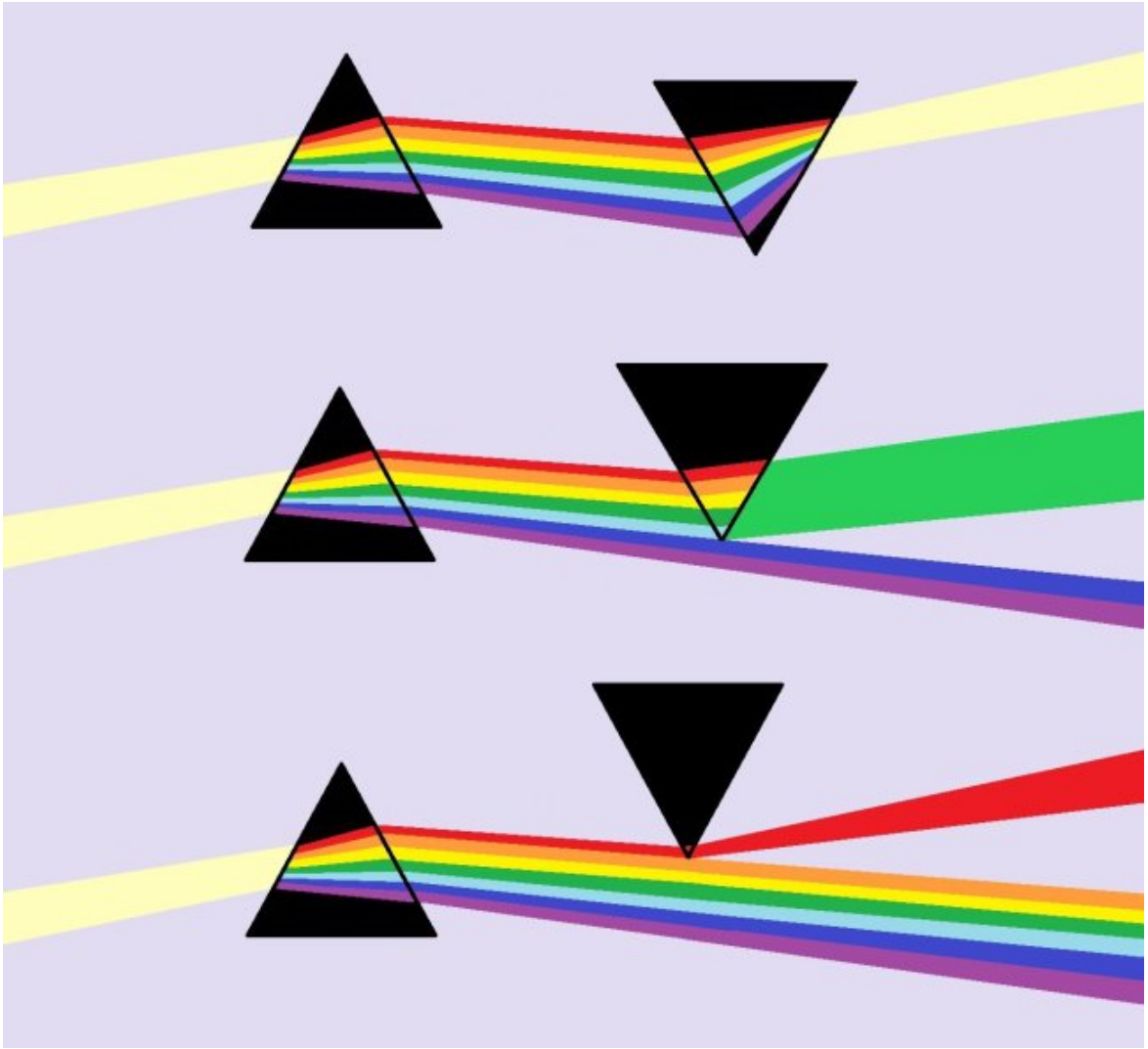


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

Basics about color (3)



http://www.thestargarden.co.uk/Newtons-theory-of-light.html

Basics about color (4)

https://en.wikipedia.org/wiki/Rainbow

Basics about color (5)

https://en.wikipedia.org/wiki/Rainbow

https://spaceplace.nasa.gov/blue-sky/en/

Basics about color (6)

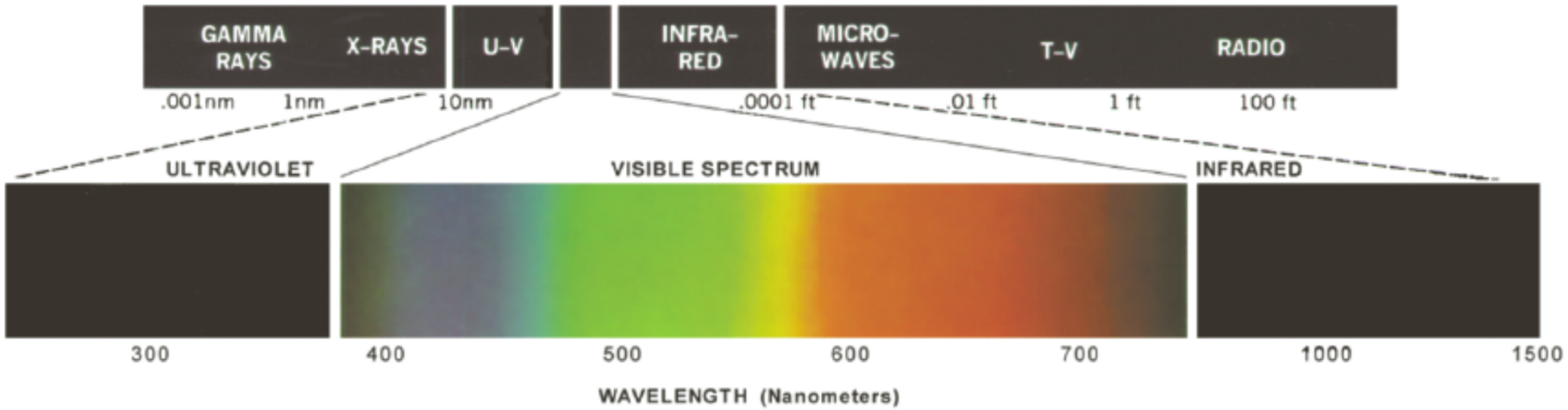
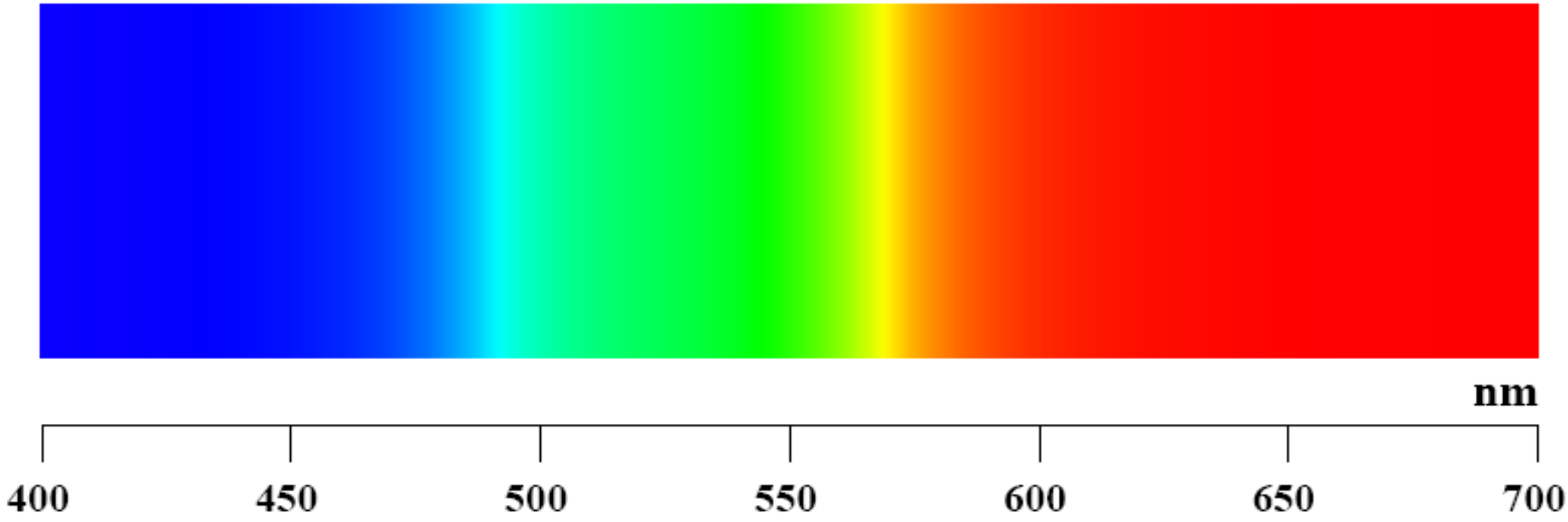
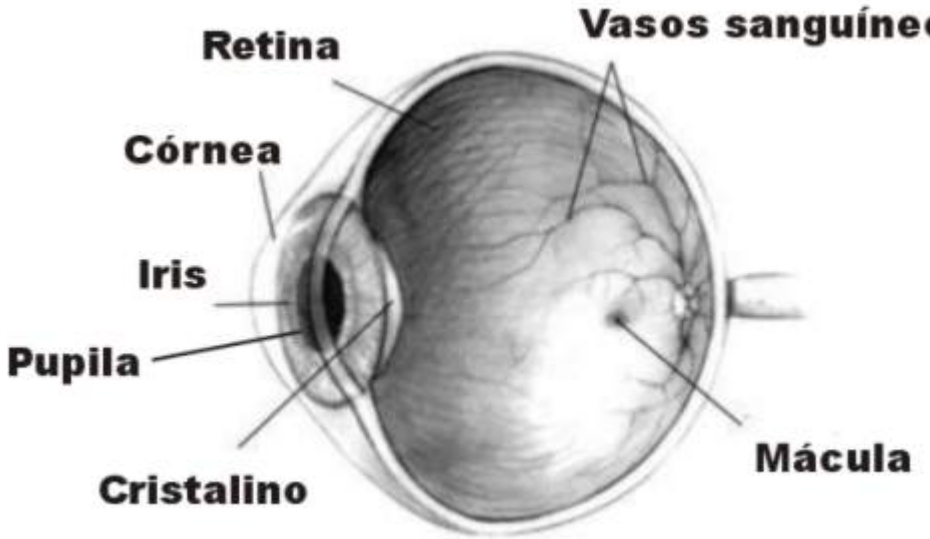


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

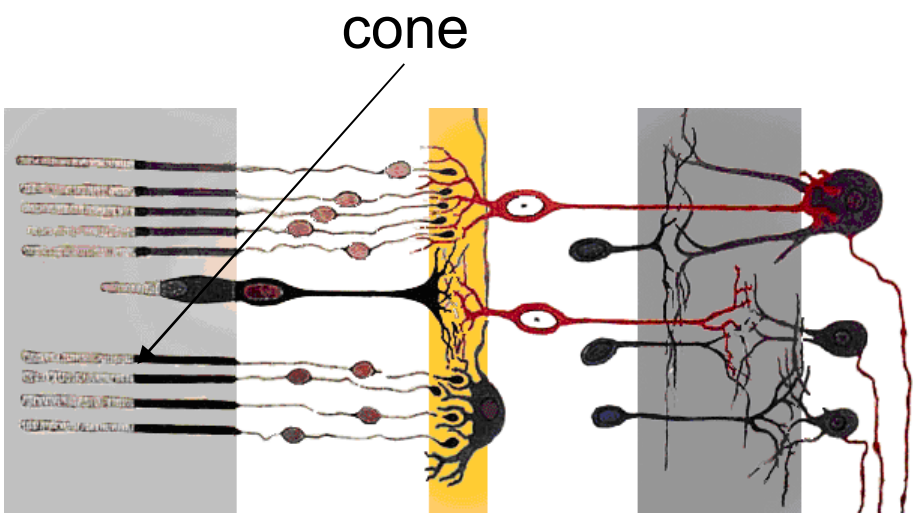
Basics about color (7)



Human Visual System (1)



[wikipedia.org]



Rods
(bastonetes)

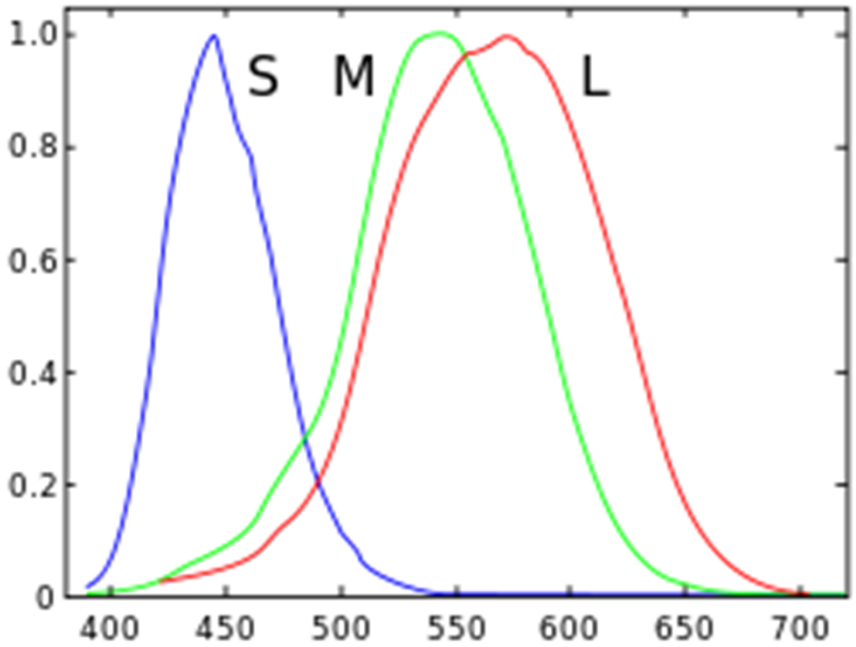
Optical Nerve

Human Visual System (2)

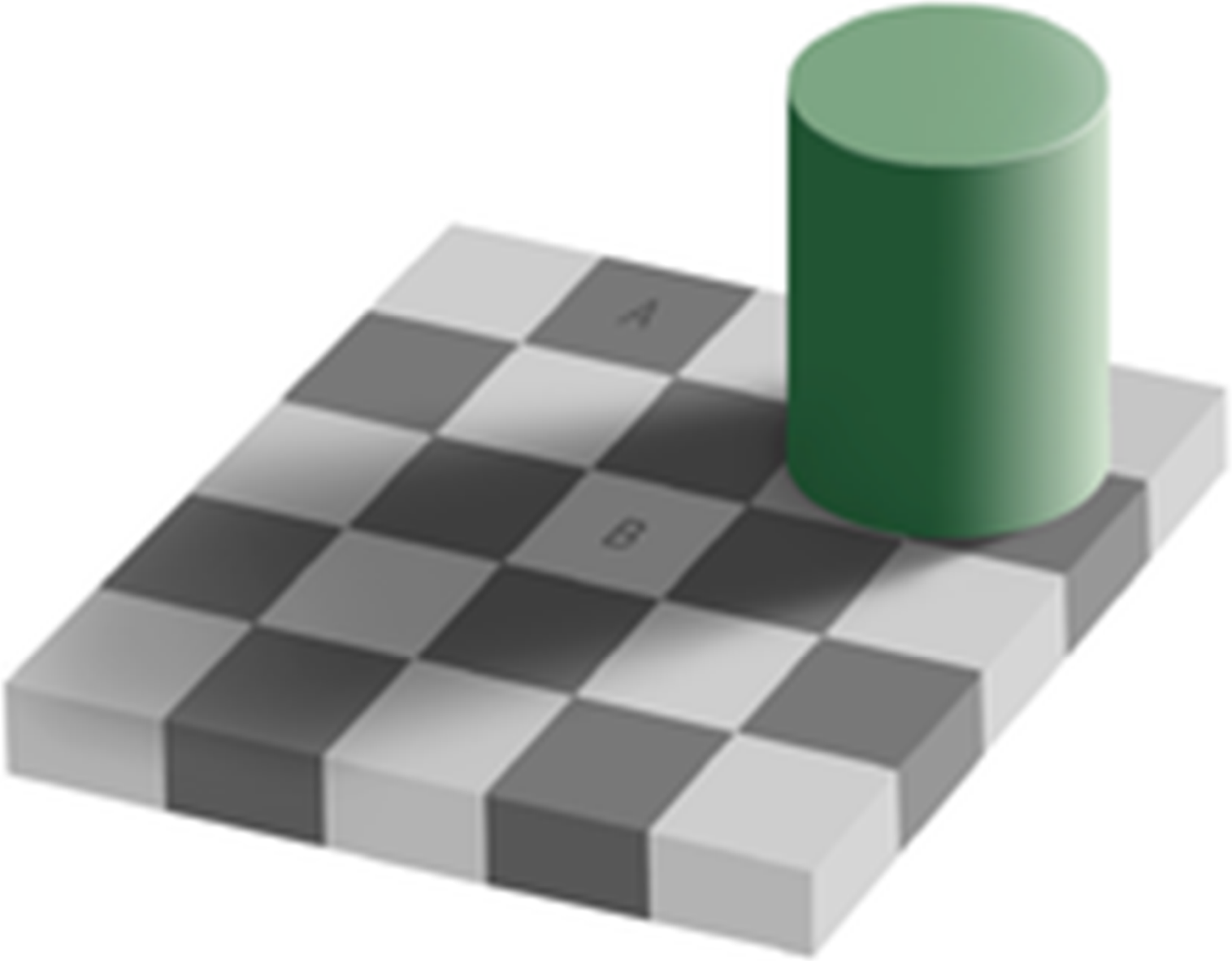
On the retina, we have about:

- 6 million cones, sensitive to color **(red, green, blue) RGB**
- 100 million of rods, sensitive to light

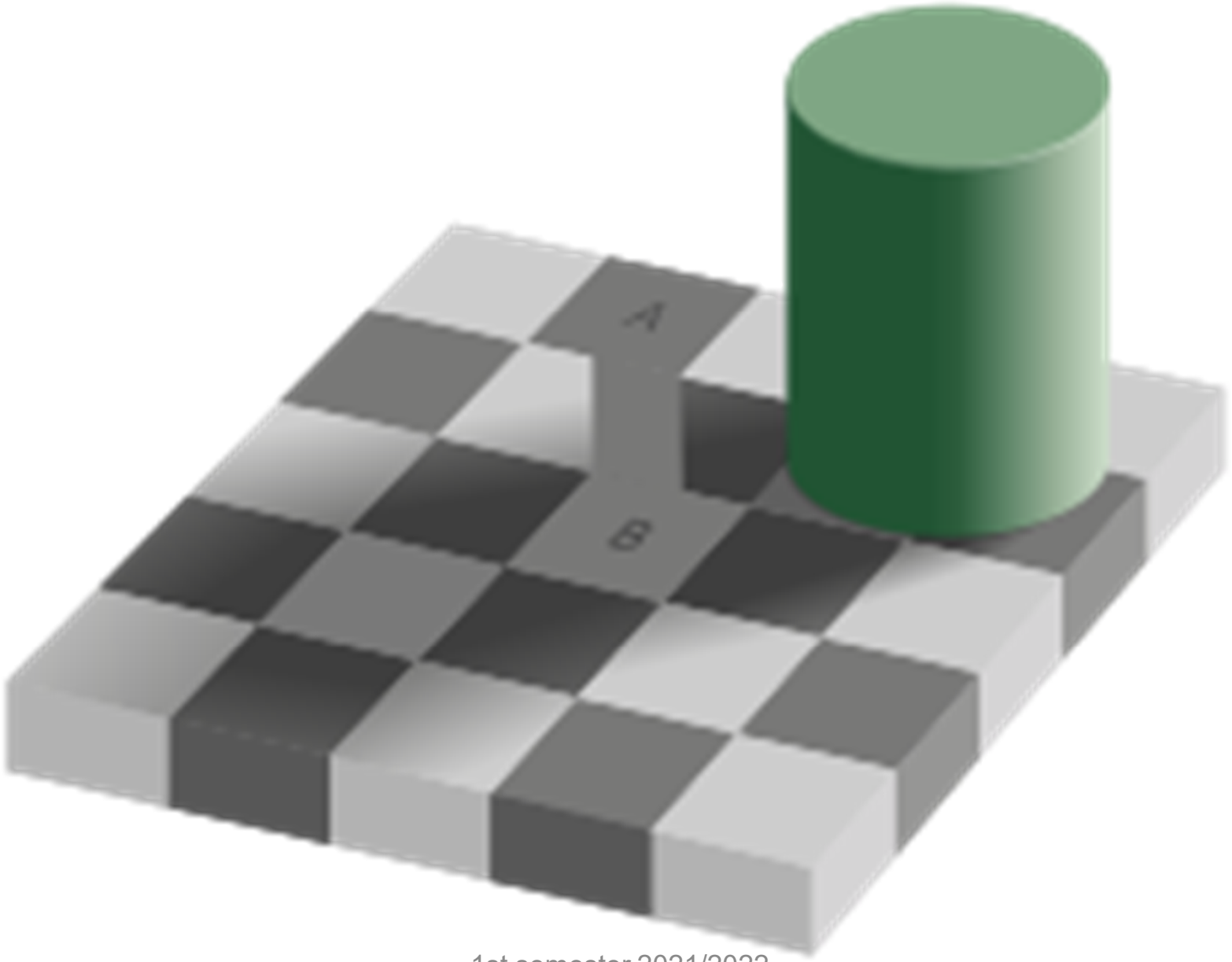
https://en.wikipedia.org/wiki/Rod_cell
https://en.wikipedia.org/wiki/Cone_cell



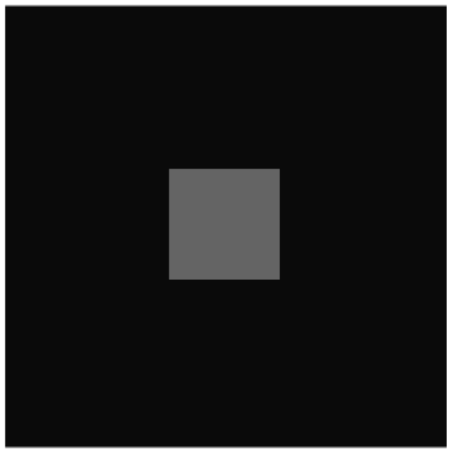
Human Perception (1)

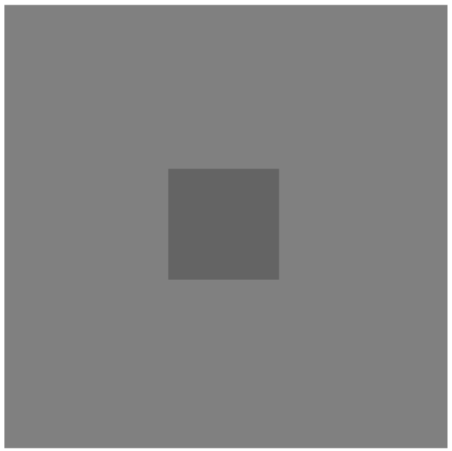


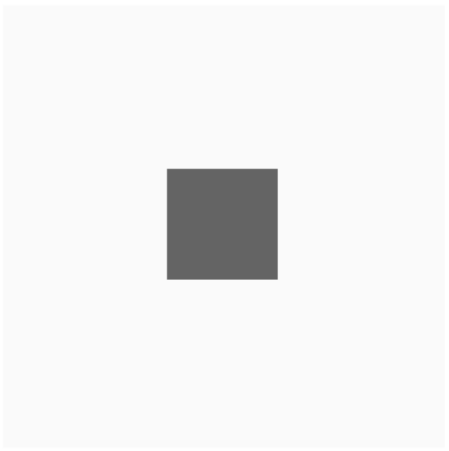
Human Perception (2)



Human Perception (3)

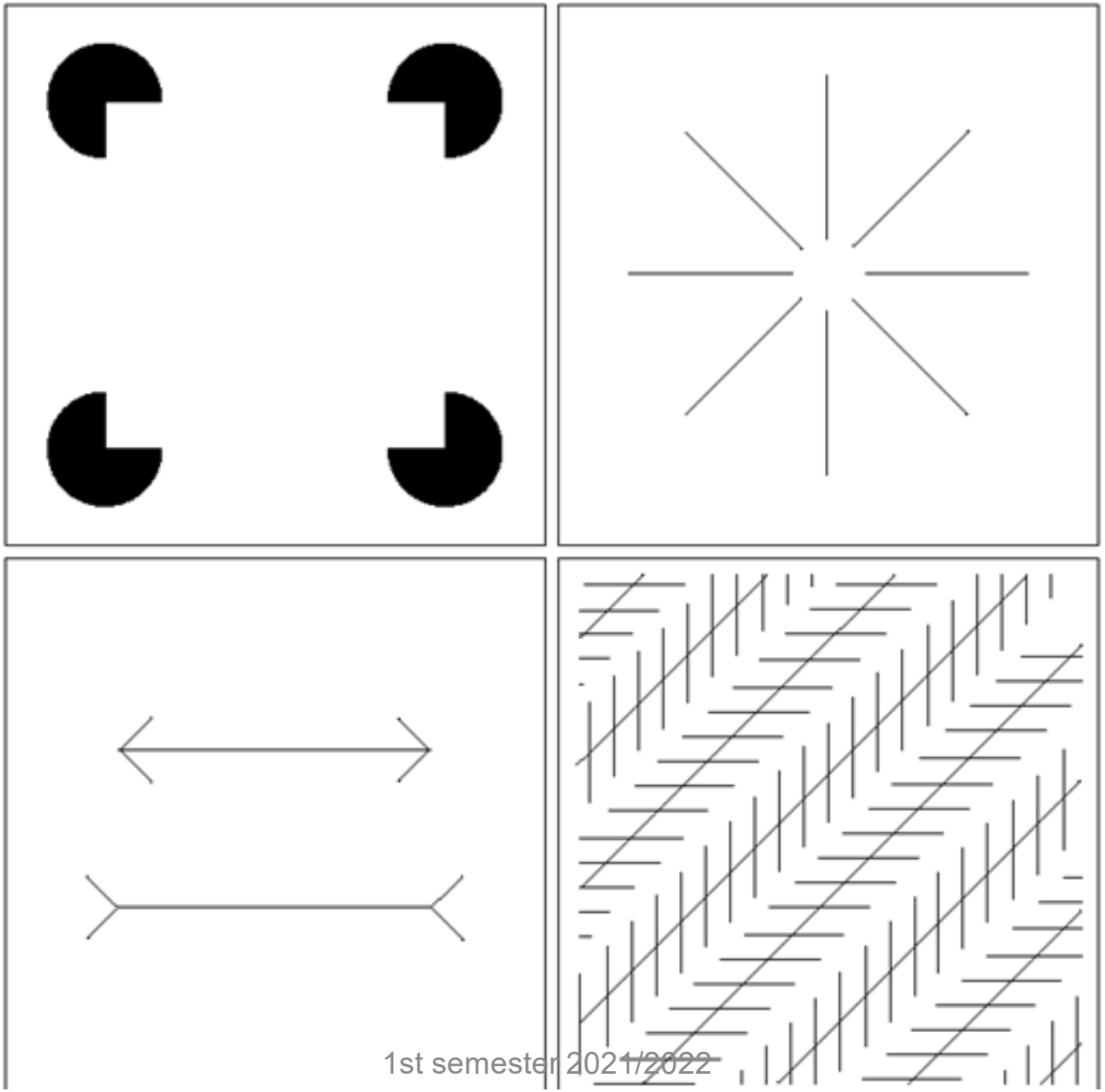




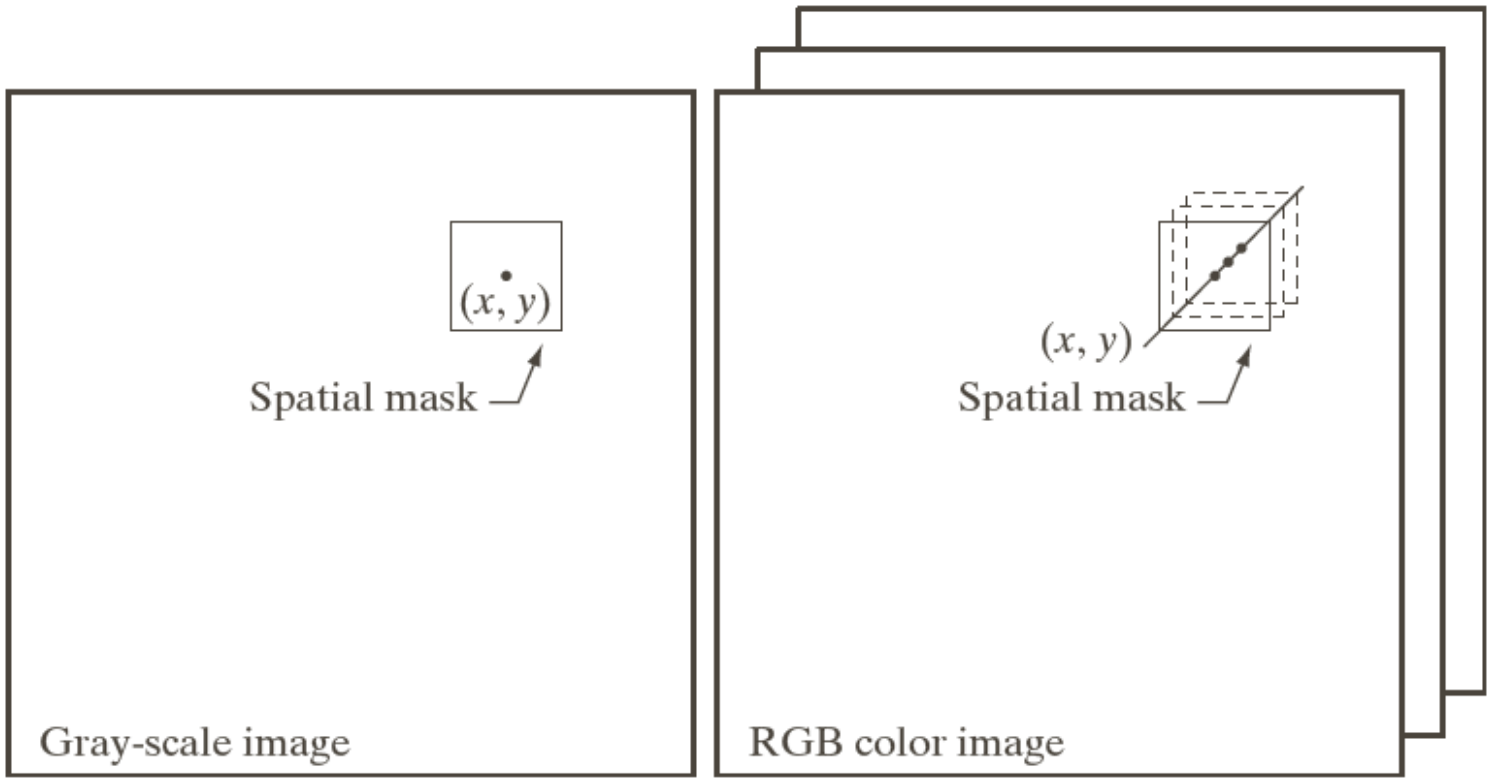


Pixel info: (X, Y) Pixel Value

Human Perception (4)



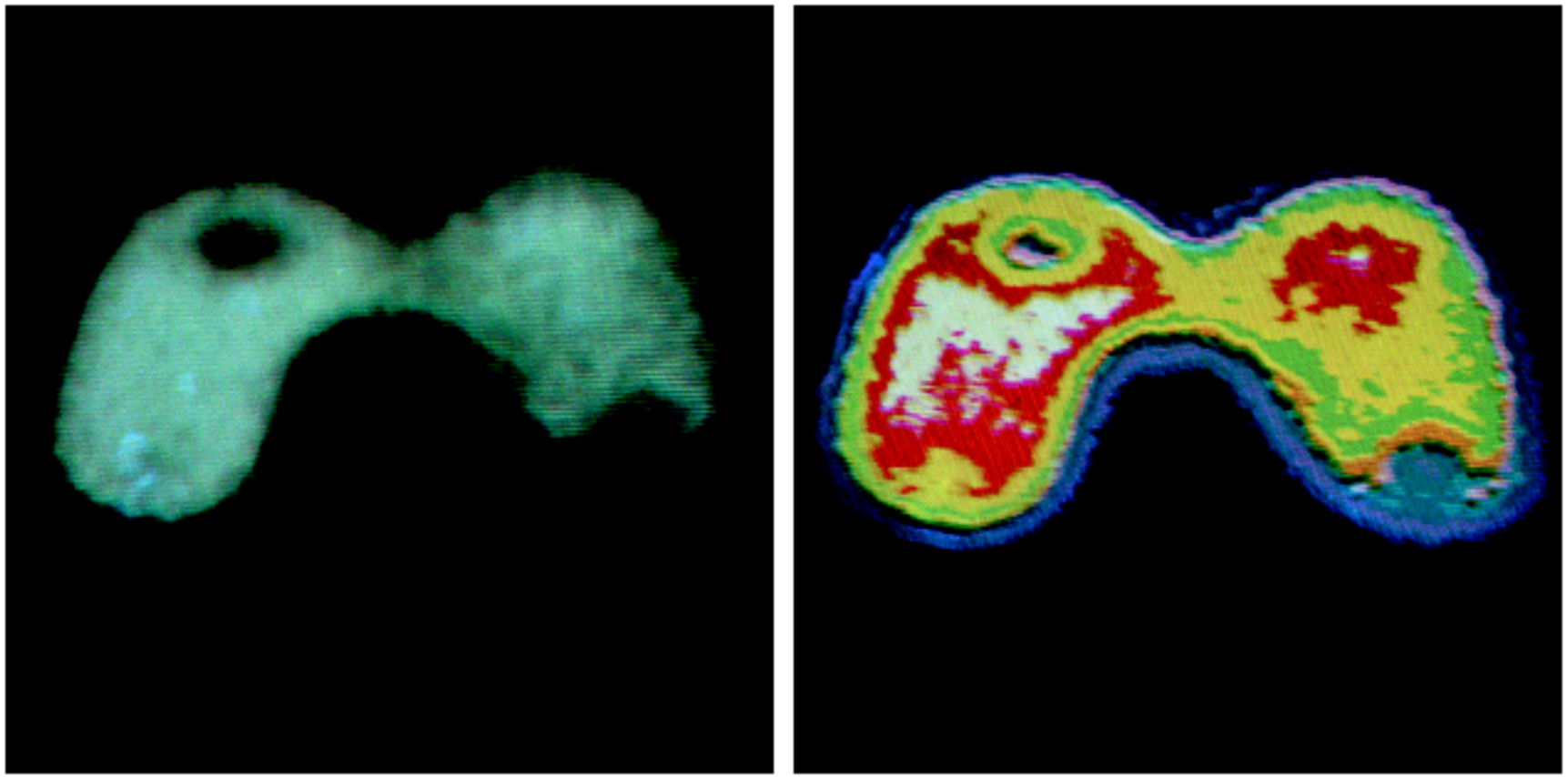
Monochrome and color images



a b

FIGURE 6.29
Spatial masks for gray-scale and RGB color images.

Pseudo-color - intensity slicing (1)



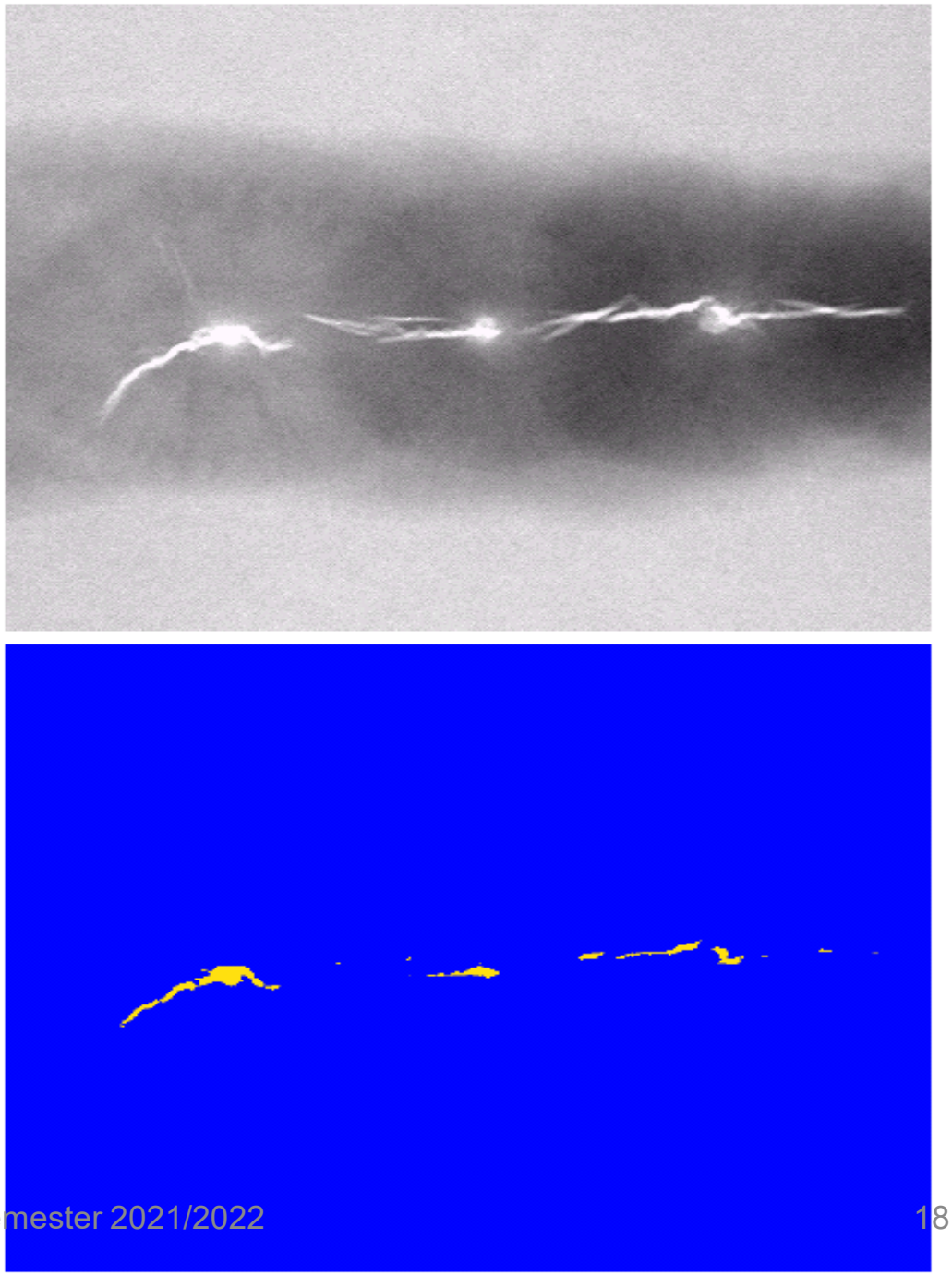
a b

FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

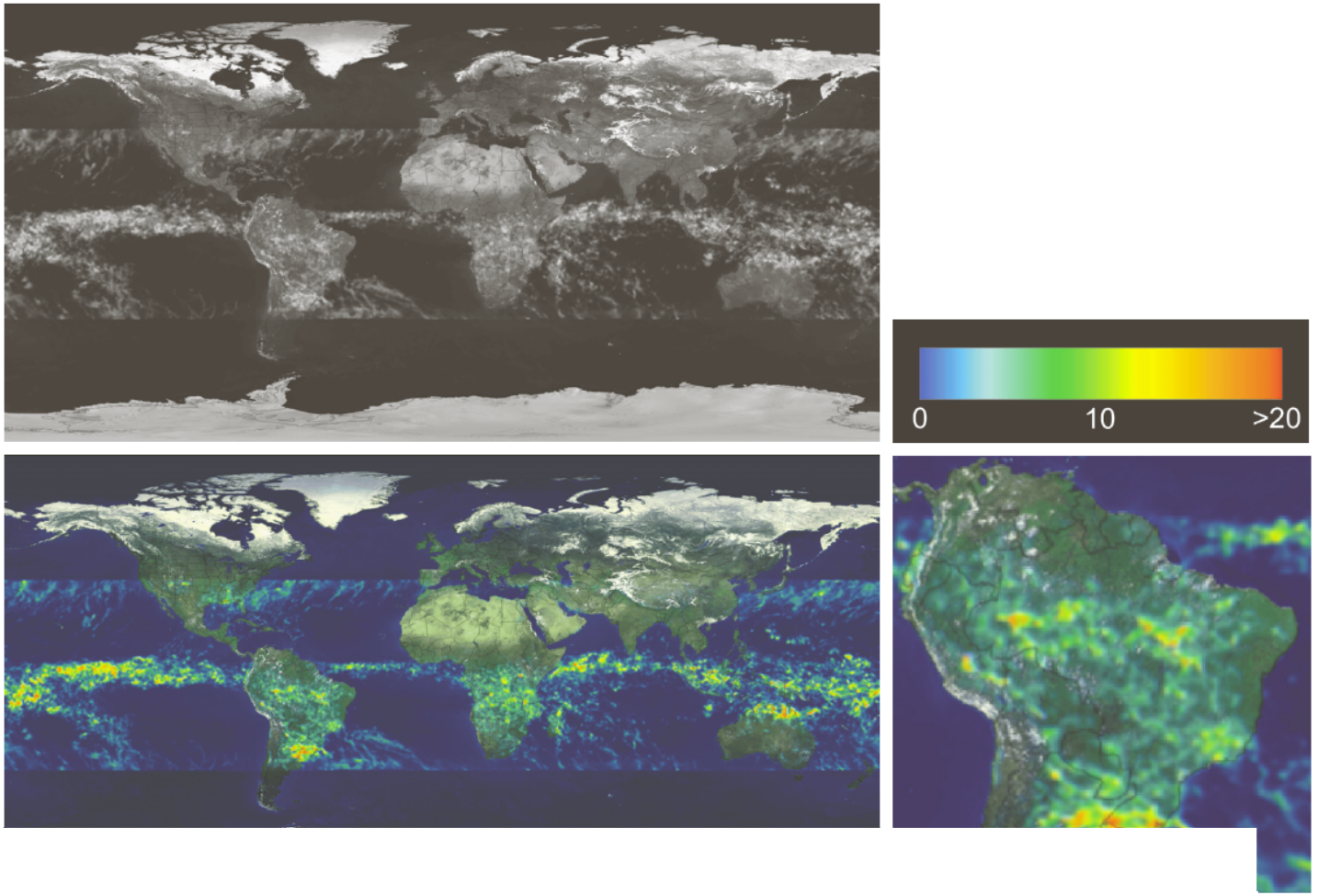
Pseudo-color - intensity slicing (2)

a
b

FIGURE 6.21
(a) Monochrome X-ray image of a weld. (b) Result of color coding. (Original image courtesy of X-TEK Systems, Ltd.)



Pseudo-color - intensity slicing (3)



a b
c d

FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South American region. (Courtesy of NASA.)

Pseudo-color - intensity slicing (4)

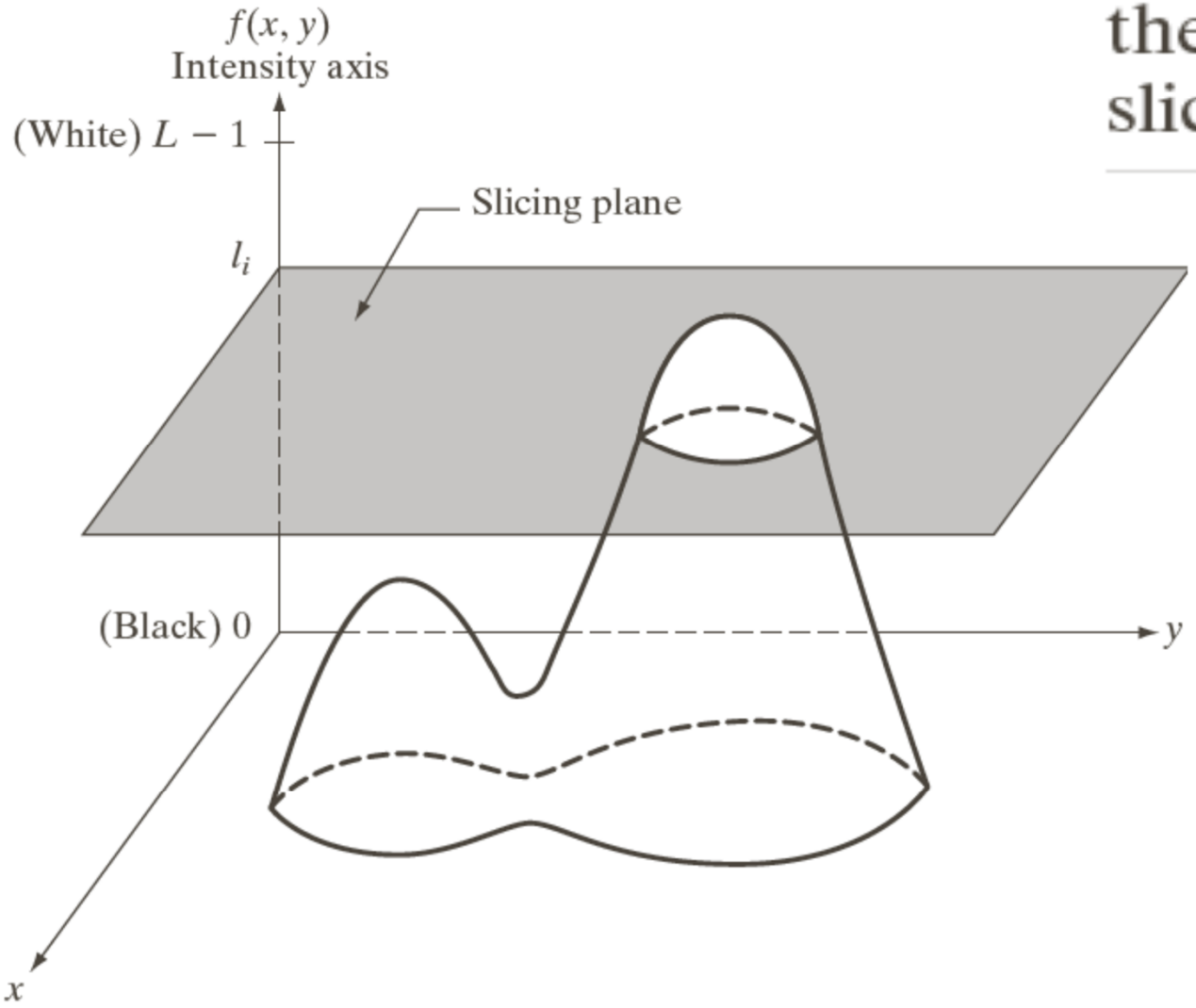


FIGURE 6.18 Geometric interpretation of the intensity-slicing technique.

Pseudo-color - intensity slicing (5)

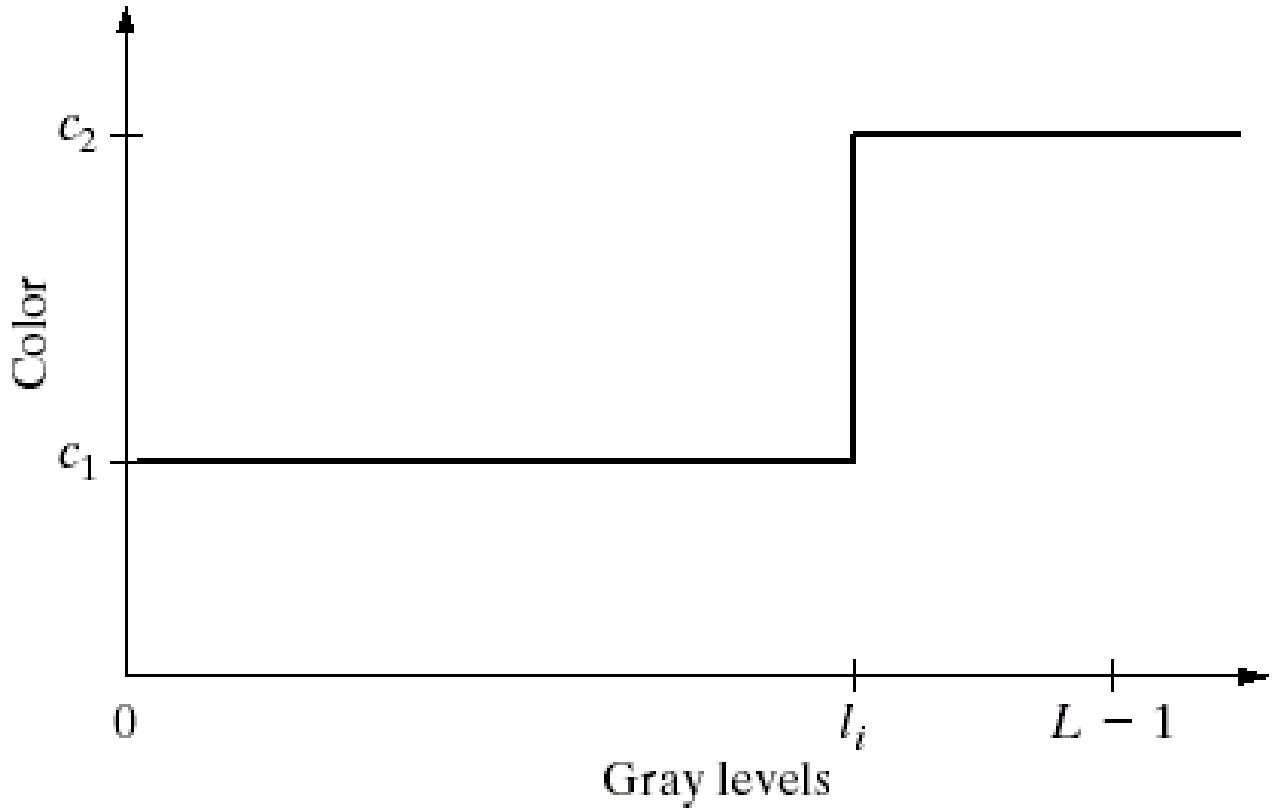


FIGURE 6.19 An alternative representation of the intensity-slicing technique.

Pseudo-color - intensity to RGB transform (1)

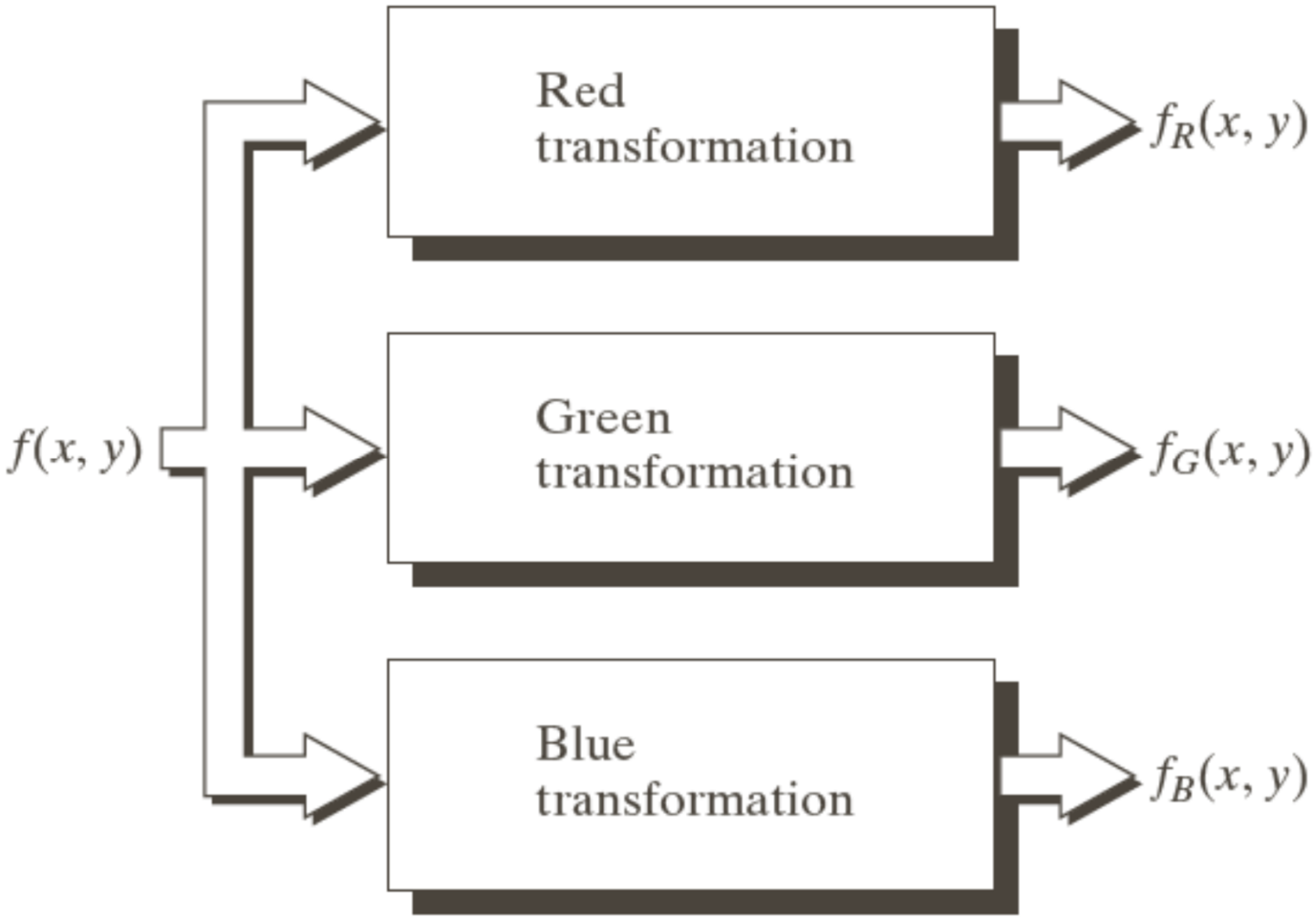
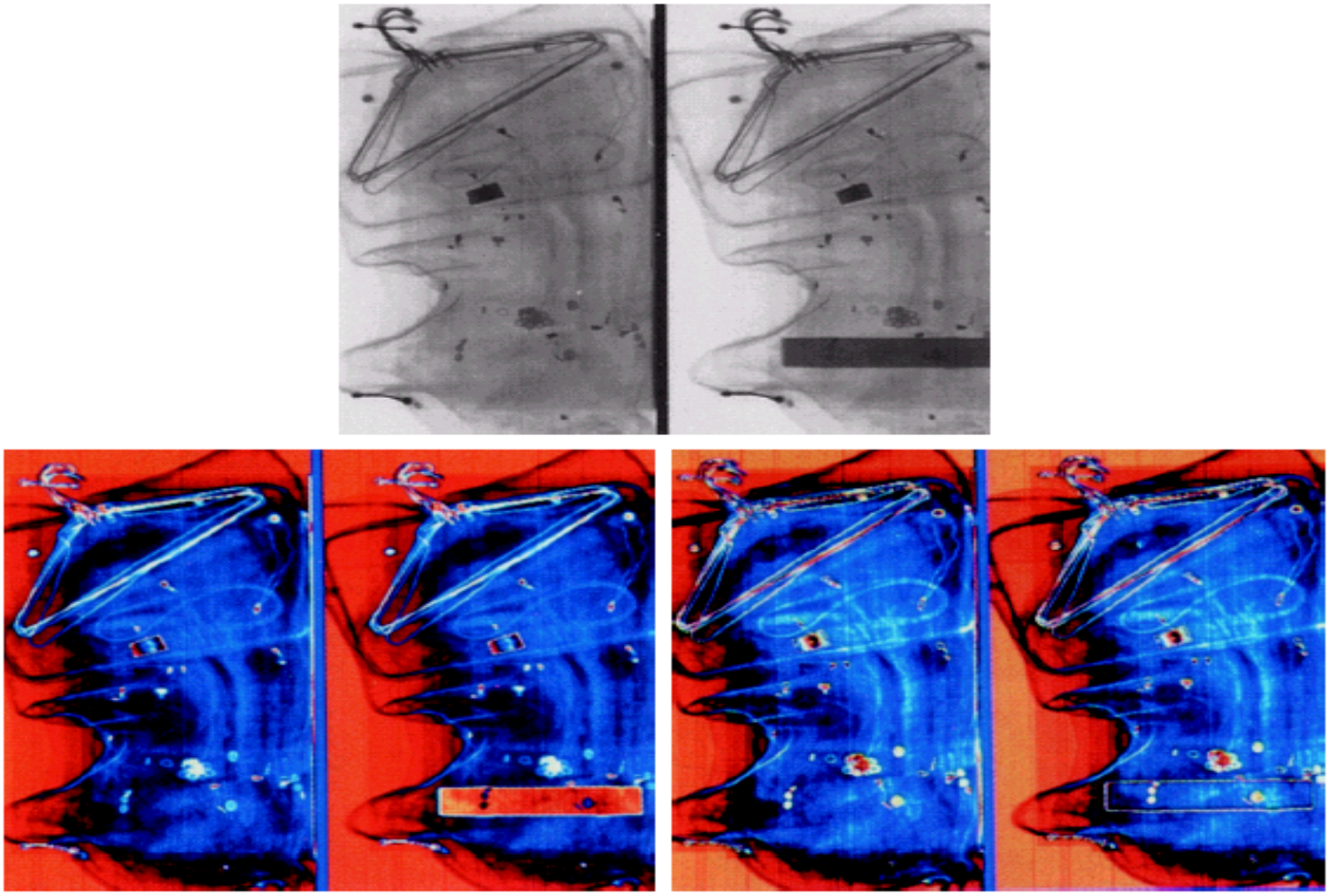


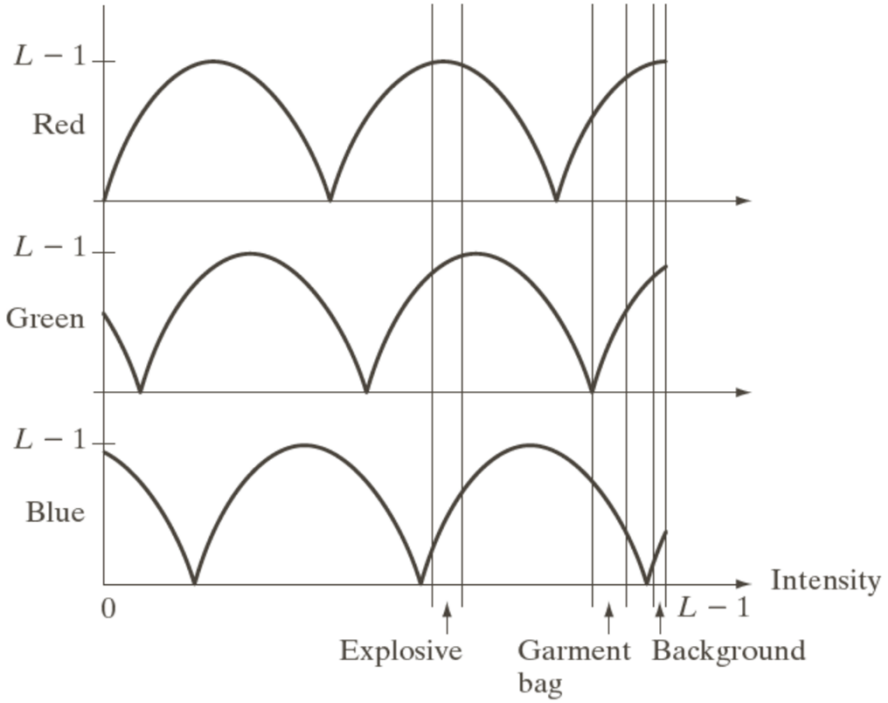
FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

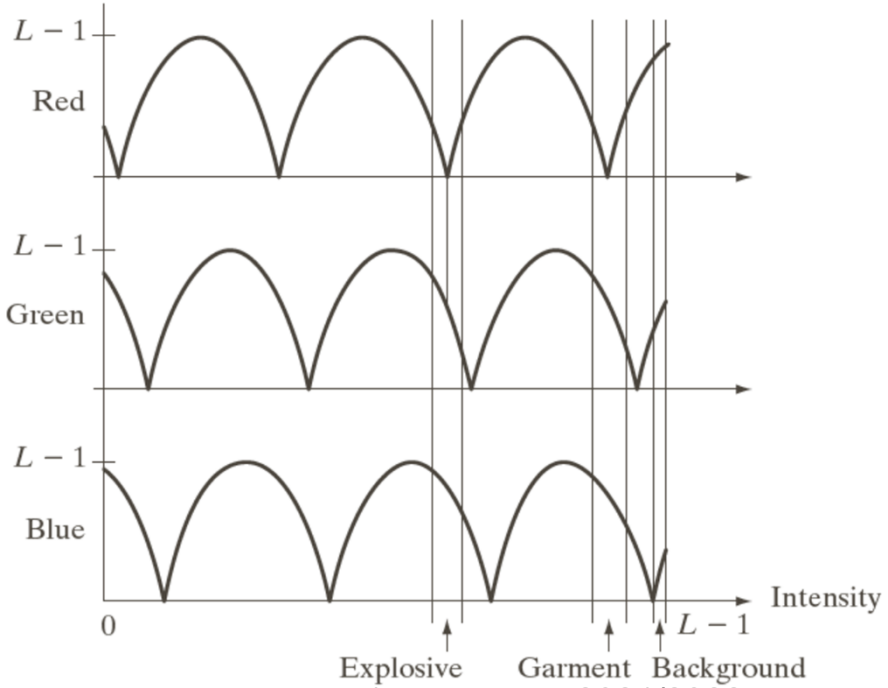
Pseudo-color - intensity to RGB transform (2)



a
b c

FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)





a
b

FIGURE 6.25
Transformation functions used to obtain the images in Fig. 6.24.

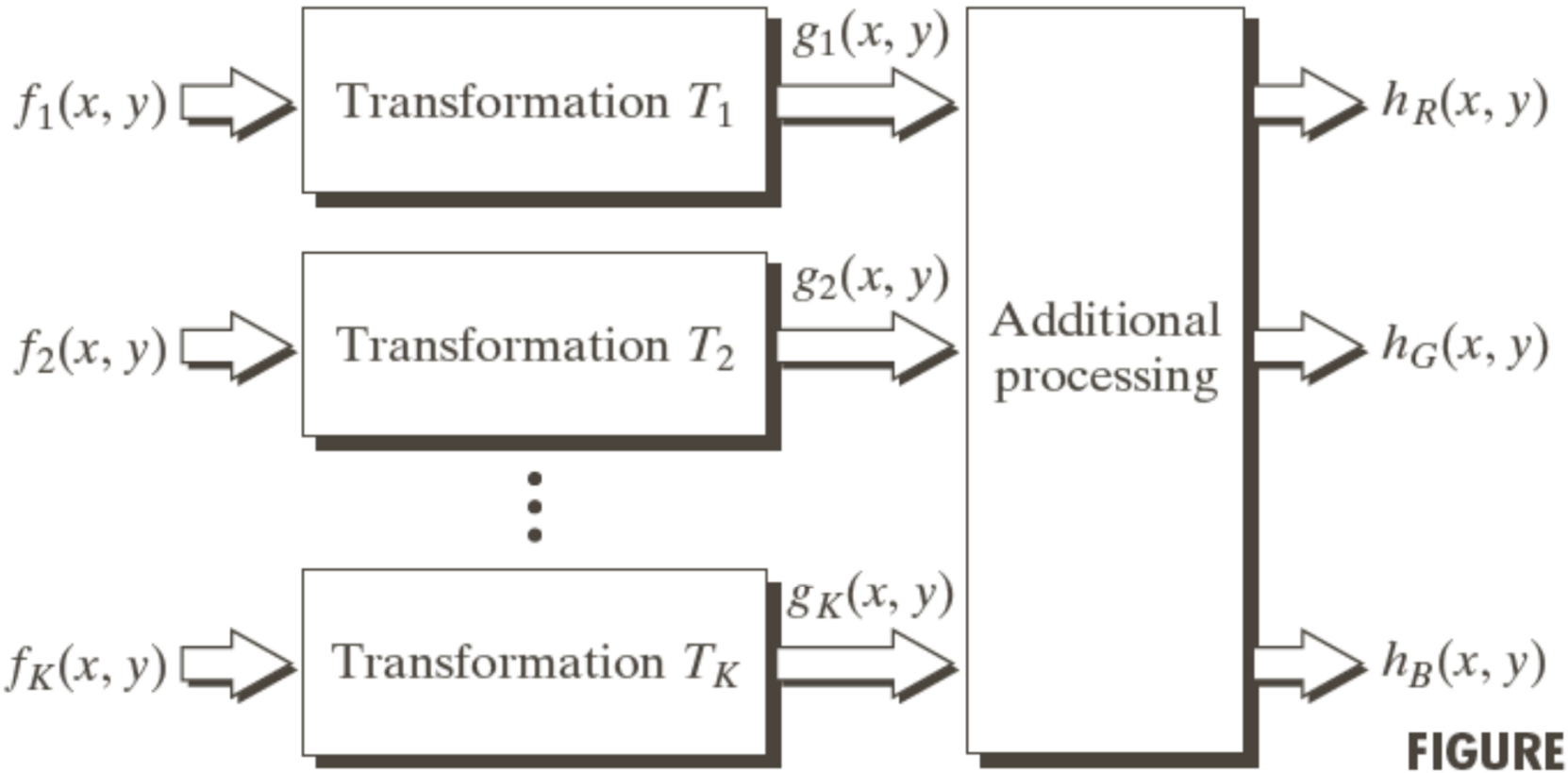


FIGURE 6.26 A pseudocolor coding approach used when several monochrome images are available.

Several input images

a b
c d
Images obtained in different frequency bands

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping

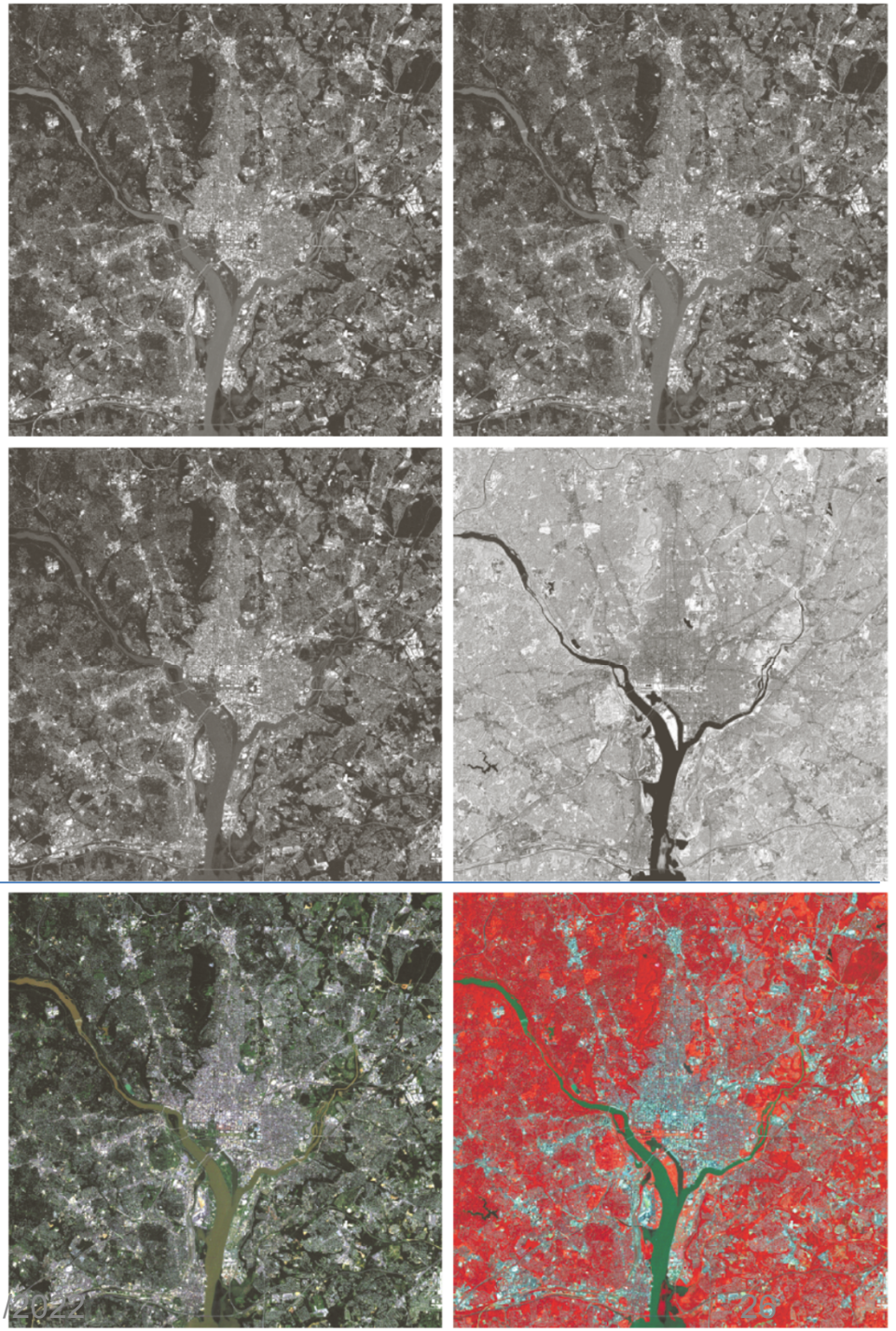
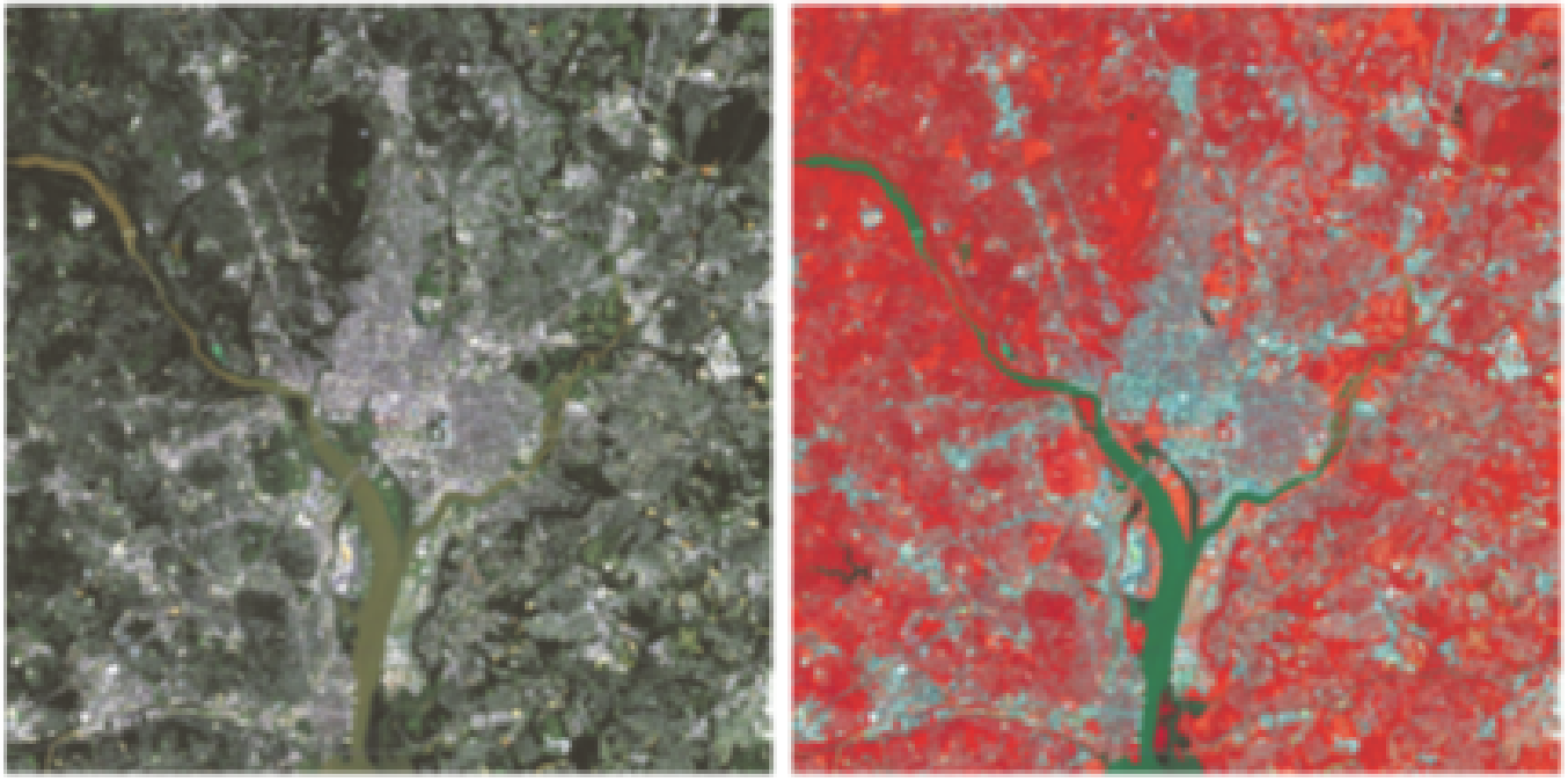


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)



e f

FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)

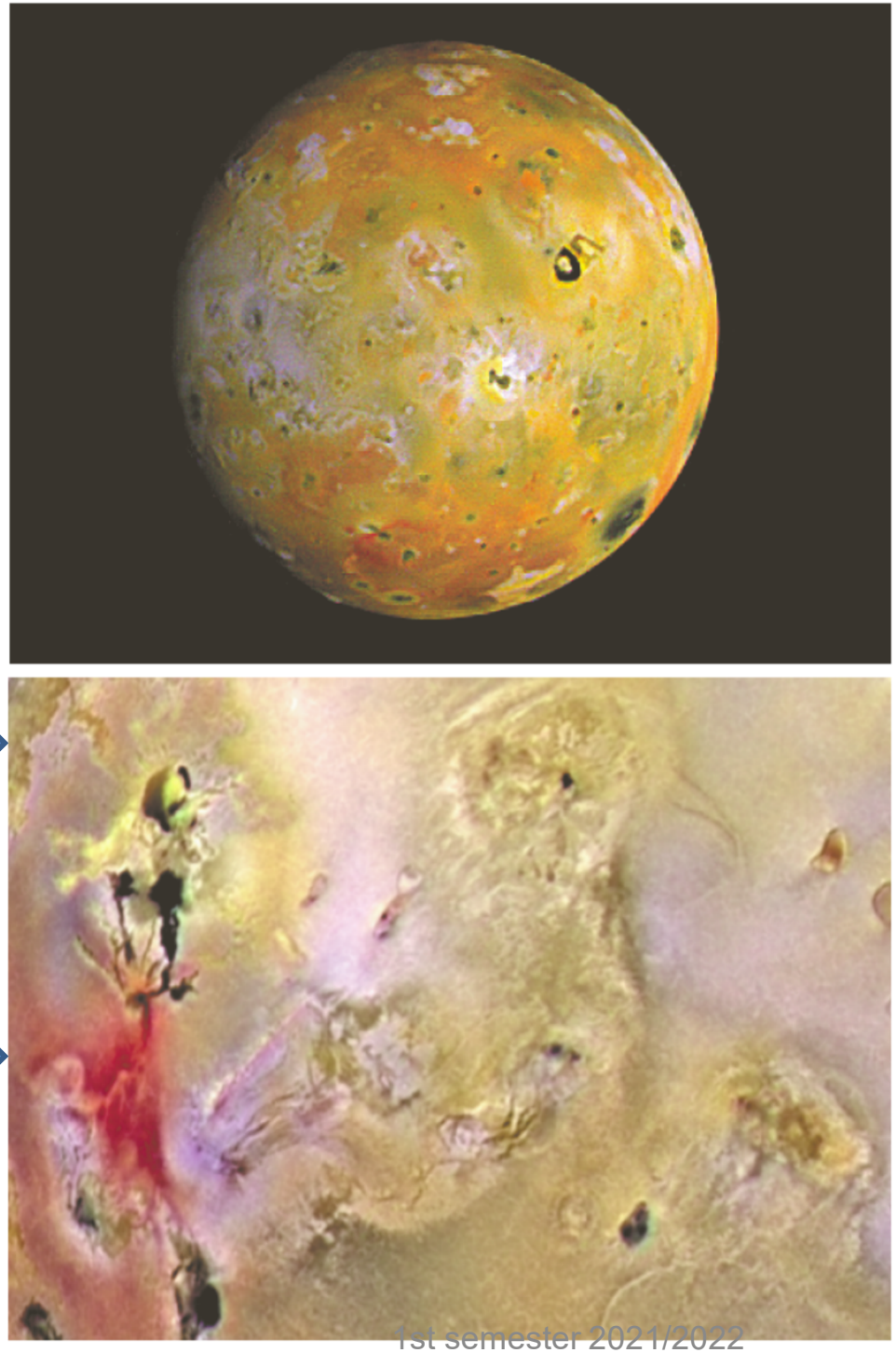
a b
c d
e f

Yellow

Older Sulfur Deposits

Bright Red

Material Newly Ejected



a
b

FIGURE 6.28
(a) Pseudocolor rendition of Jupiter Moon Io. (b) A close-up. (Courtesy of NASA.)

MATLAB functions

- *ind2rgb.m*, converts the indexed image, X, and the corresponding colormap, map, to the truecolor image, RGB

- *colormap.m*, sets the colormap for the current figure to one of the predefined colormaps.

Exercises (1)

- In Portuguese. Exercício 2 do 2.º teste parcial, verão 2016/2017, 5 de junho de 2017

2. As seguintes questões abordam técnicas de coloração de imagens monocromáticas.

   a) {1,5} Suponha que se pretende efetuar coloração da imagem monocromática I com profundidade $n = 8$ bit/pixel, através da técnica *intensity to RGB transform*, produzindo a imagem I_c. Para tal, usa-se a mesma transformação de intensidade $T[x] = 255 - x$, para definir os valores das componentes R, G e B. Qual a relação visual esperada entre as imagens I e I_c?

   b) {1,5} Considere que, numa dada aplicação, se pretende efetuar coloração de imagem monocromática recorrendo à aplicação de tabelas de *lookup*, por razões de eficiência. Qual dos seguintes pares de afirmações é verdadeiro?

      i) *É possível implementar coloração com a técnica intensity slicing, com tabelas de lookup. É possível implementar coloração com a técnica intensity to RGB transform, com tabelas de lookup.*

      ii) *É possível implementar coloração com a técnica intensity slicing, com tabelas de lookup. Não é possível implementar a técnica intensity to RGB transform, com tabelas de lookup.*

      iii) *Não é possível implementar coloração com a técnica intensity slicing, com tabelas de lookup. É possível implementar a técnica intensity to RGB transform, com tabelas de lookup.*

      iv) *Não é possível implementar coloração com a técnica intensity slicing, com tabelas de lookup. Não é possível implementar a técnica intensity to RGB transform, com tabelas de lookup.*

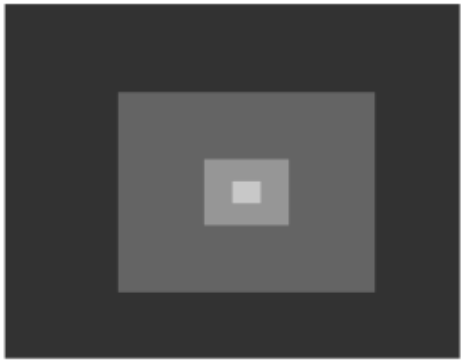
Exercises (2)

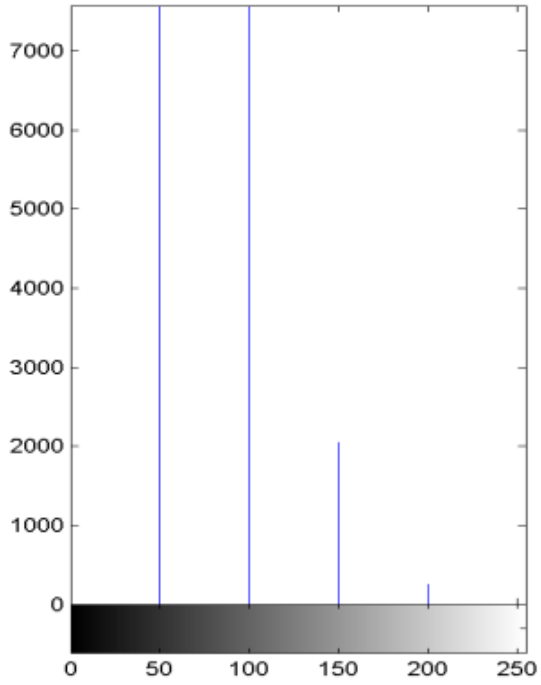
- Exercício 2 do 2.º teste parcial, verão 2015/2016, 17 de junho de 2016

2. The following questions refer to digital image processing techniques, that deal with color.

   i) {1.25} Explain what is the monochrome image coloring technique and the key reasons for its sucessful use. State two different types of approach for monochrome image coloring.

   ii) {1.25} The figure at the bottom of the page shows a monochrome image, with a pixel depth of $n = 8$ bit/pixel, as well as its histogram. For the four intensity levels, we aim to color them with the following color sequence: blue, green, red, and yellow. State a detailed procedure to achieve this goal.





Bibliography

- The images displayed in these slides are from:
  - R. Gonzalez, R. Woods, *Digital Image Processing*, 4th edition, Prentice Hall, 2018, ISBN 0133356728
  - S. Smith, *The Scientist and Engineer's Guide to Digital Signal Processing*, Newnes, 2003, ISBN 0-750674-44-X [chapter 23]
  - O. Filho, H. Neto, Processamento Digital de Imagens, Rio de Janeiro: Brasport, 1999, ISBN 8574520098.
  - Wikipedia and Mathworks web pages