BME4120
Biomedical Image Processing

Lecture-1

Course Objectives

You will learn about biomedical images and will gain theoretical knowledge in medical image processing and its relevant mathematical basics.

Course Content

Basic knowledge about

- ❑ Images and characteristics of digital images
- ❑ Biomedical image acquisition and characteristics of biomedical images.
- ❑ Mathematical and statistical foundations in biomedical imaging
- ❑ Obtaining biomedical imaging from various parts of the body
- ❑ Image restoration methods and their mathematical and statistical fundamentals.
- ❑ Image restoration in spatial and frequency domains.
- ❑ Feature extraction and statistical measurements.
- ❑ Various filters such as smoothing, sharpening.
- ❑ Point, line and edge detection algorithms.

Textbooks

- Machine Vision, Wesley E. Snyder & Hairong Qi,
- Medical Image Processing: Concepts And Applications, Sinha G. R, Patel, B. C., Prentice Hall, 2014.
- Insight into Images: Principles and Practice for Segmentation, Registration and Image Analysis, Terry S. Yoo
- Biosignal and Medical Image Processing, John L. Semmlow, , CRC Taylor and Francis, 2008

Learning Outcomes

In this course you will

- ❑have theoretical information about how biomedical images are obtained
- ❑acquire theoretical knowledge digital aspects of imaging
- ❑will learn mathematical and statistical concepts of image processing
- ❑will learn about image processing, filtering, compression techniques
- ❑will learn and be able to apply image segmentation algorithms

Evaluation

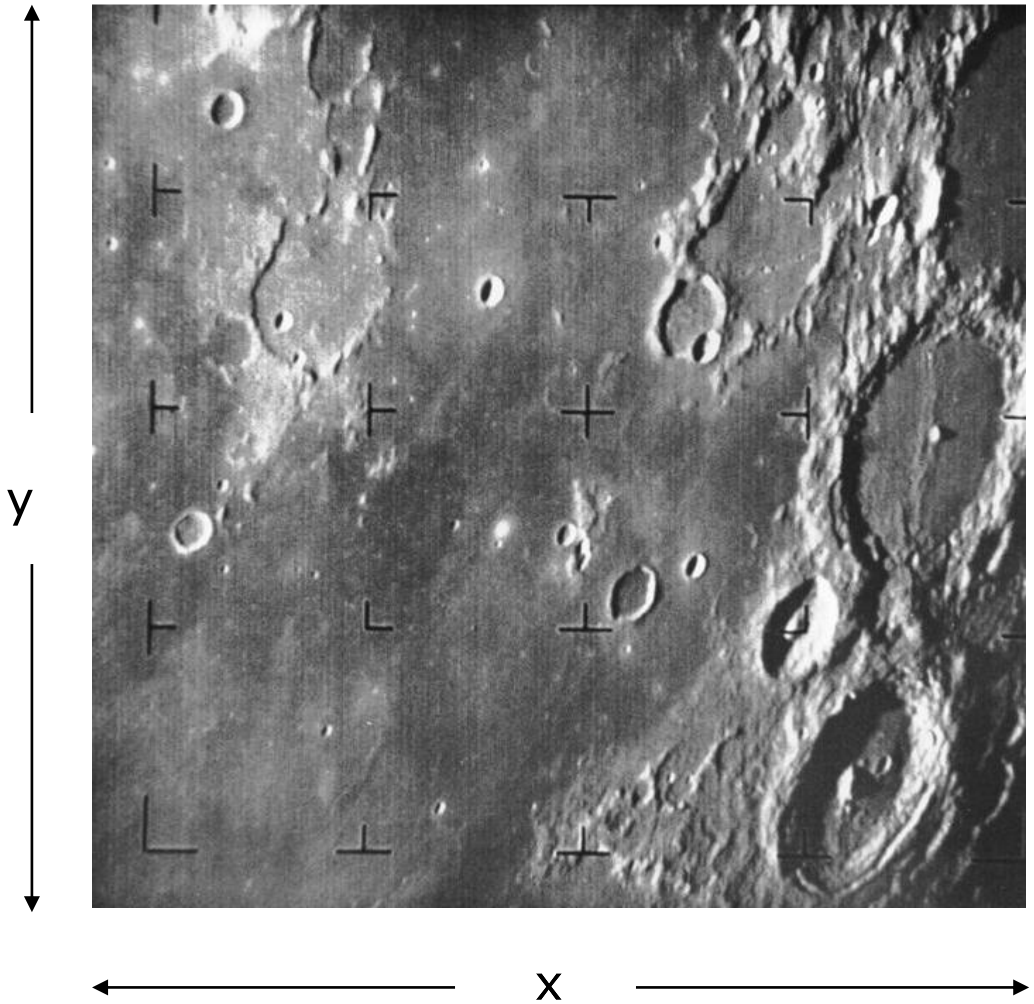
Homework Assignments	3	10
Presentations/Jury		
Project		
Seminar/Workshop		
Mid-Terms	1	30
Final	1	40
Percentage of In-Term Studies		60
Percentage of Final Examination		40
TOTAL		100

Weekly Subjects

WEEKS	COURSE OUTLINE	Related Preparation
1	What is image? Fundamentals and characteristics of digital images.	Textbooks – Lecture Notes
2	Acquiring biomedical Images	Textbooks – Lecture Notes
3	Basic mathematical and statistical concepts in biomedical image processing	Textbooks – Lecture Notes
4	Image restoration in spatial domain: gray color transormations, histogram processing	Textbooks – Lecture Notes
5	Image restoration in spatial domain: Basics of spatial domain filter, smoothing and sharpening filters	Textbooks – Lecture Notes
6	Image restoration in frequency domain: 1D and 2D Fourier transformation, basics of frequency domain filters	Textbooks – Lecture Notes
7	Image restoration in frequency domain: Image smoothing and sharpening with frequency domain filters	Textbooks – Lecture Notes
8	Midterm 1	
9	Feature extraction and statistical measurements from biomedical images	Textbooks – Lecture Notes
10	Image restoration: Degredation models and image quality determination	Textbooks – Lecture Notes
11	Image restoration: Filters and their applications	Textbooks – Lecture Notes
12	Image segmentation: Point and line detection	Textbooks – Lecture Notes
13	Image segmentation: Edge detection	Textbooks – Lecture Notes
14	Image segmentation: Splitting and Merging Techniques	Textbooks – Lecture Notes
15	Final	

What Is Digital Image Processing?

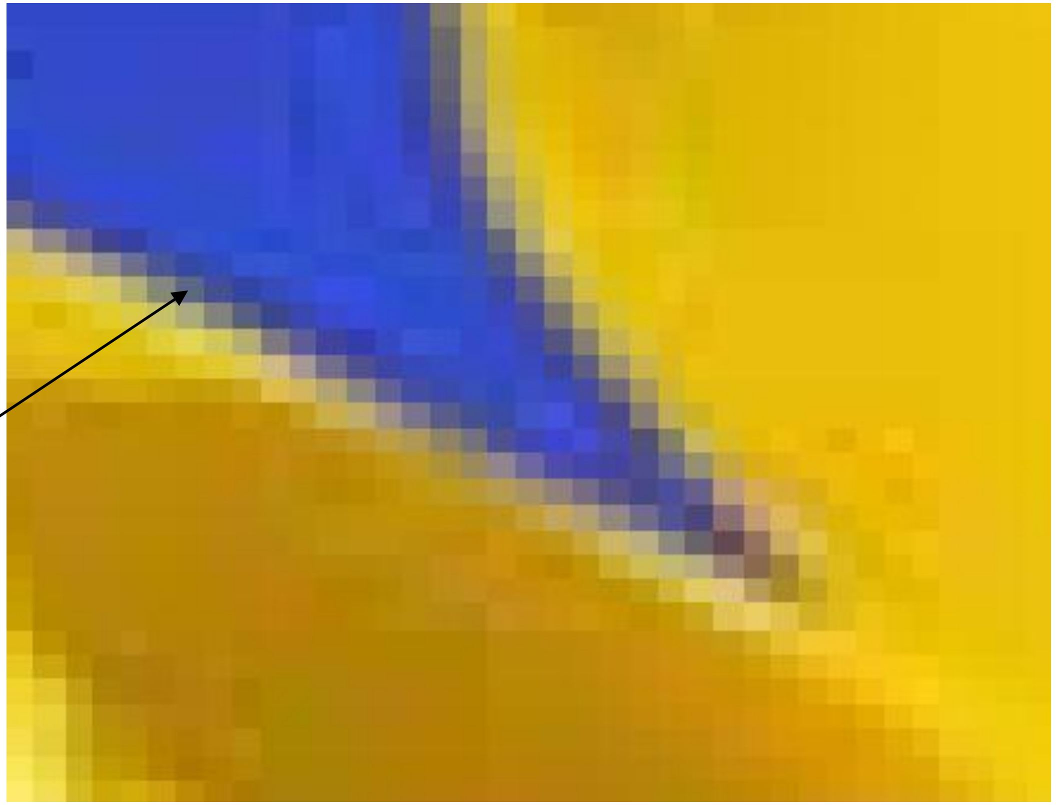
- A sample digital image. 662*640*256.



- f(x,y): A two-dimensional function, where x and y are spatial coordinates, and the amplitude of f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point.
- x size: 662, y size: 640, gray levels: 256
- Digital image: x, y, and the amplitude values of f are all finite, discrete quantities

- A sample color digital image, 800*600*24 bits

❑Pixel: The elements of a digital image.



Pixels

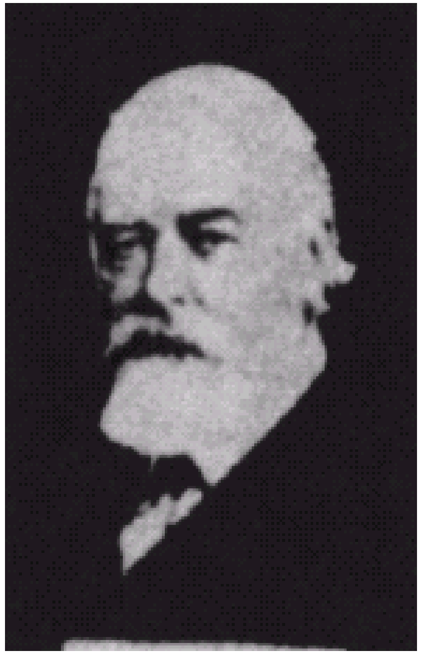
The Origins of Digital Image Processing

- One of the first applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New York.

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

- Better quality

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



- 15-tone equipment

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

- From computers, meaningful image processing tasks appeared.

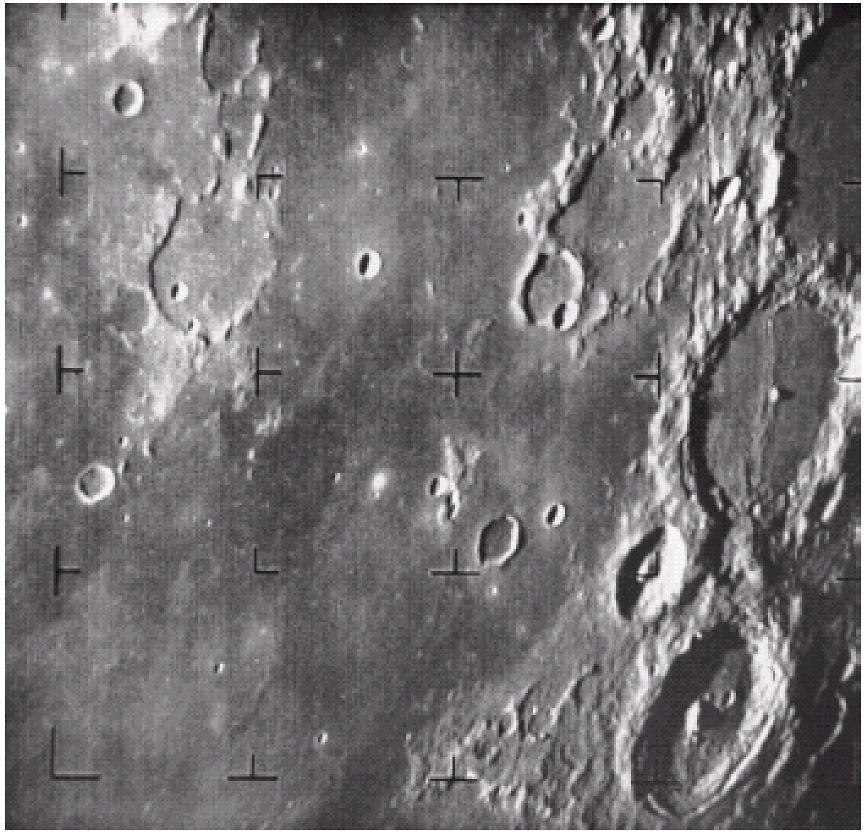


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

- Medical imaging
- Remote Earth resource observations
- Astronomy
- High-energy plasmas and electron microscopy

Examples of Fields tat Use Digital Image Processing

- Electromagnetic energy spectrum

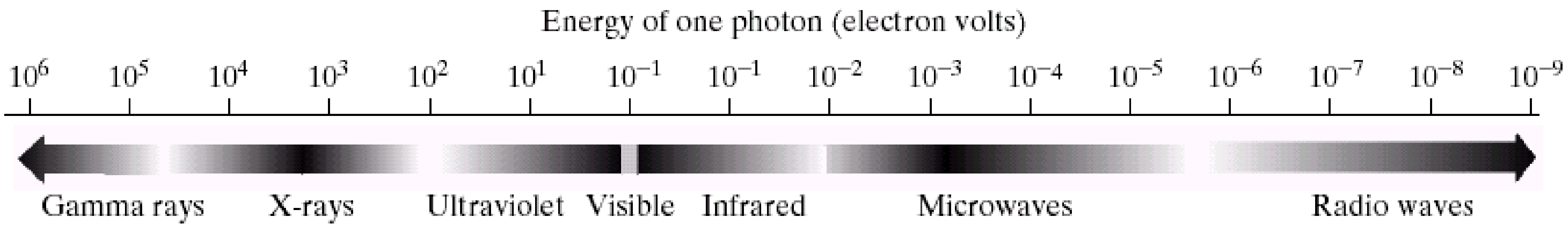
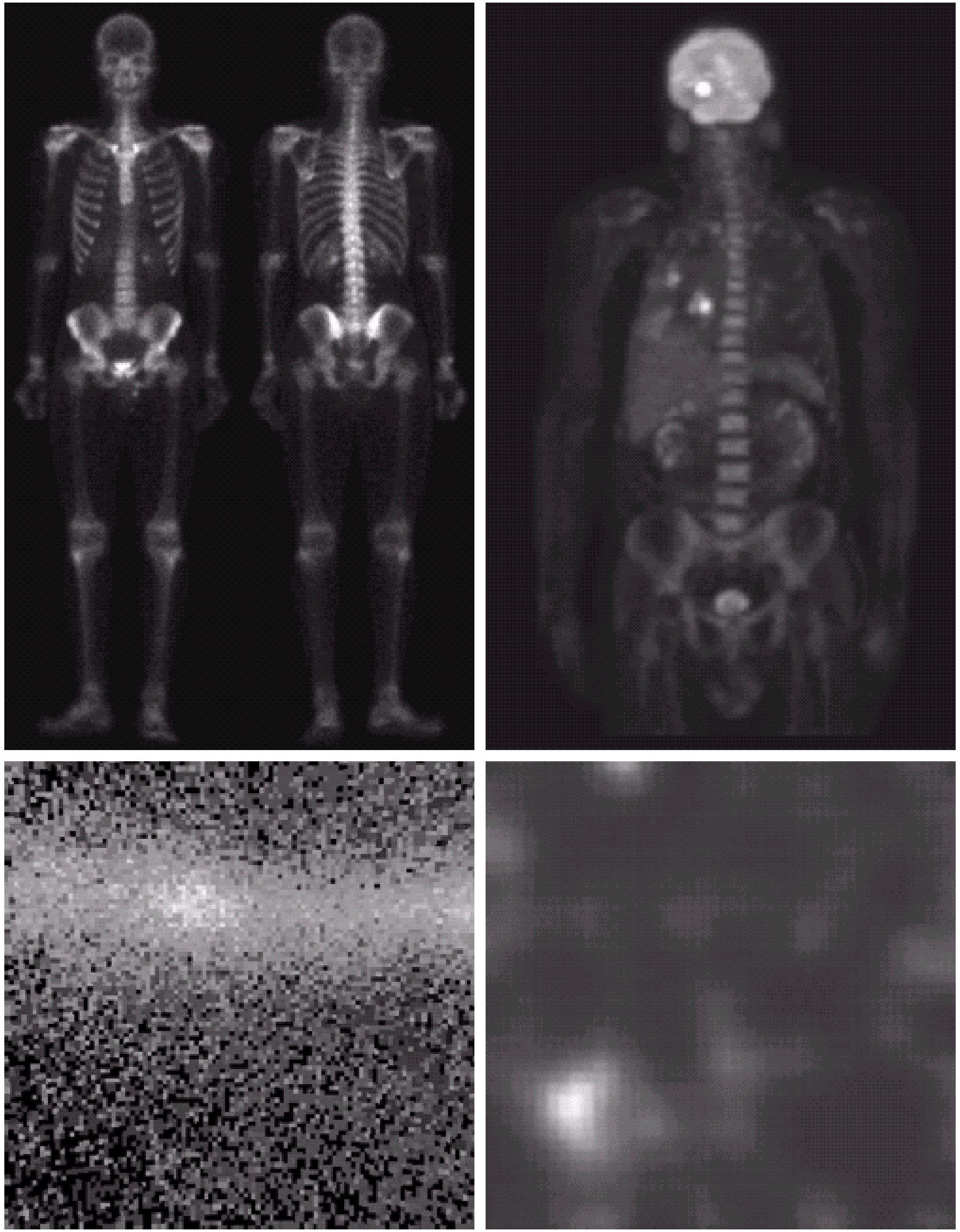


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

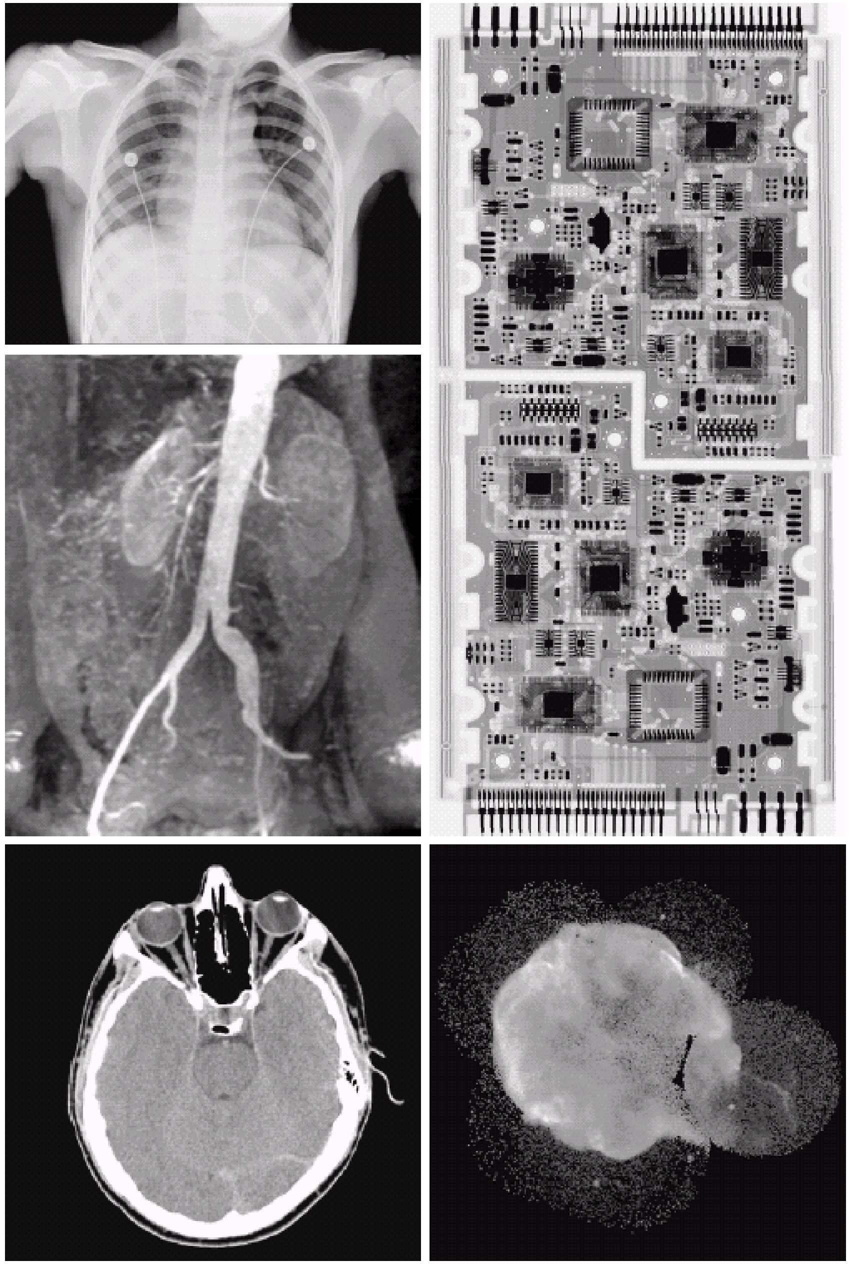


a b
c d

FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

Gamma-Ray Imaging

X-ray Imaging



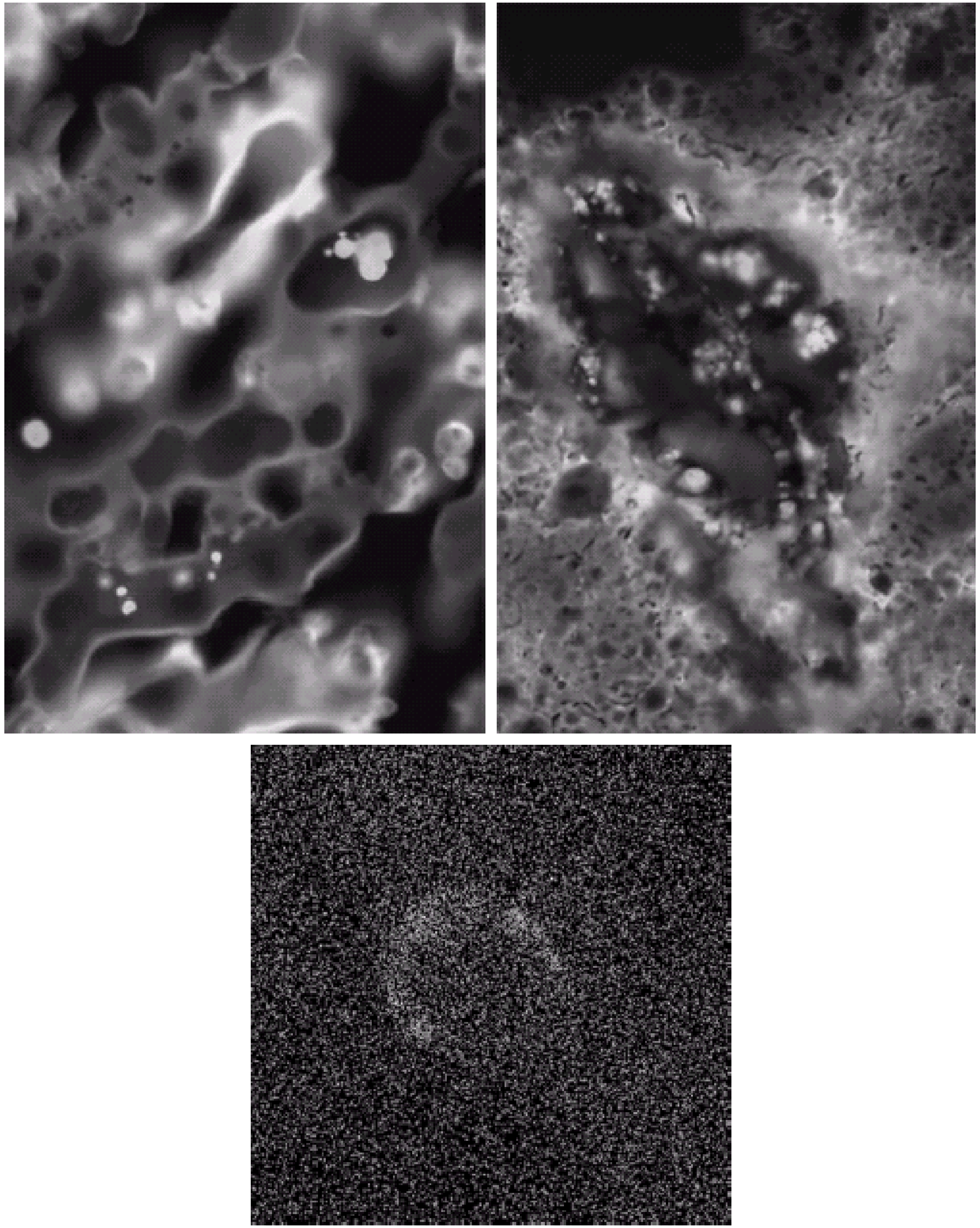
a b c d e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, (d) Mr. Joseph E. Pascente, Lixi, Inc., and (e) NASA.)

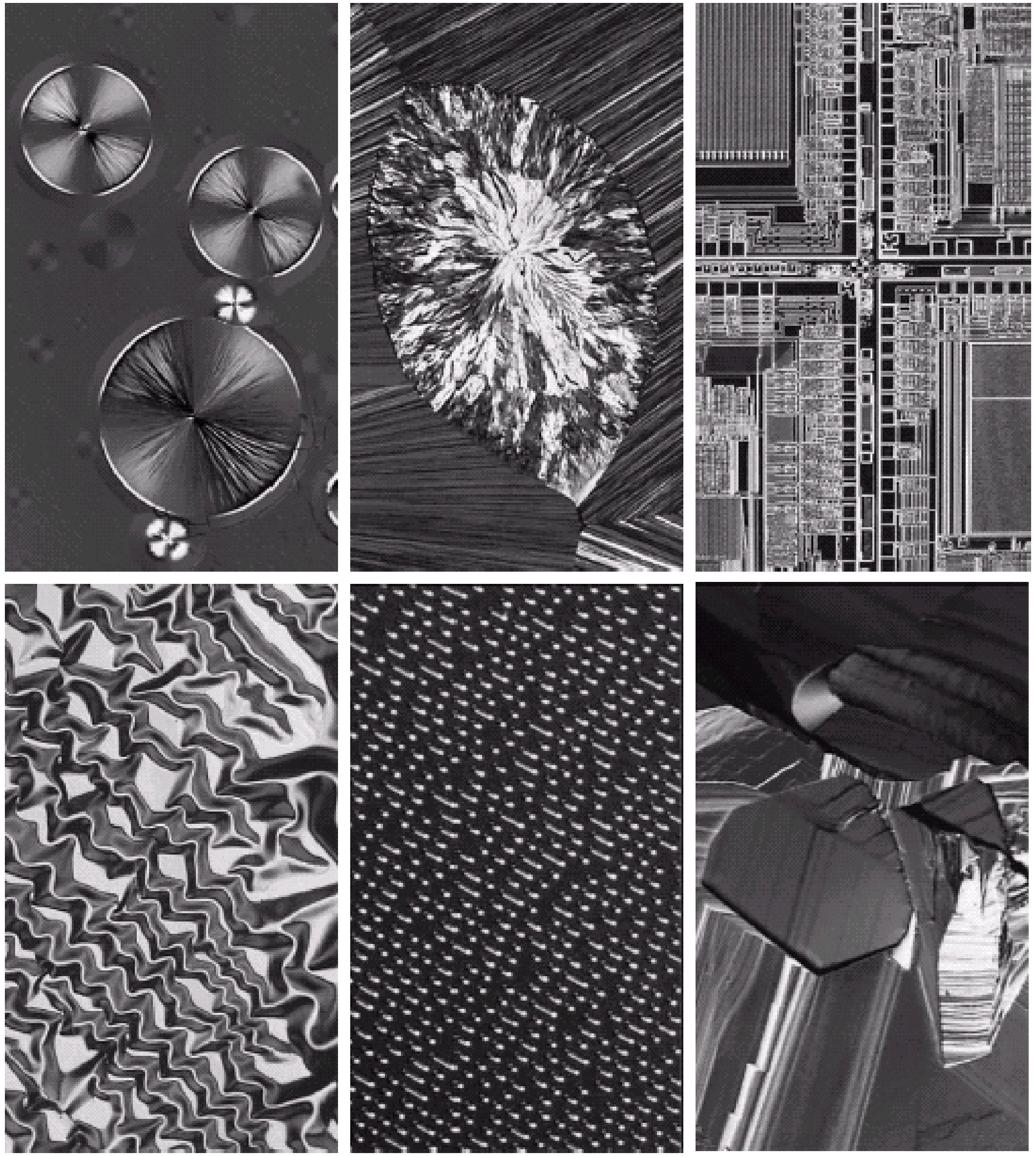
Imaging in the Ultraviolet Band

a b
c

FIGURE 1.8 Examples of ultraviolet imaging. (a) Normal corn. (b) Smut corn. (c) Cygnus Loop. (Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)



Imaging in the Visible and Infrared Bands



a b c
d e f

FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600 ×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

❑Remote sensing

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

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
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

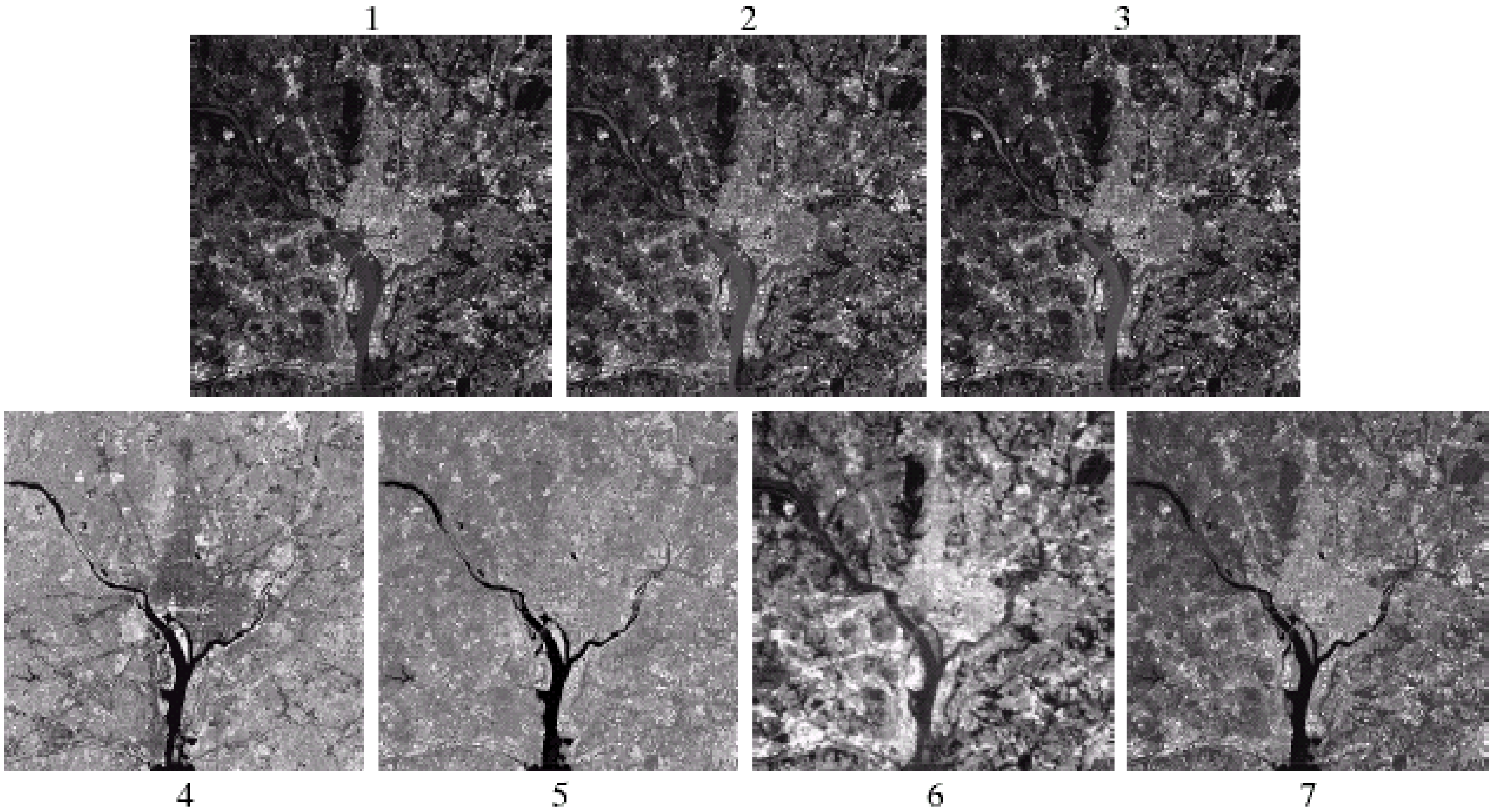


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

- Weather Observation, visible and infrared bands

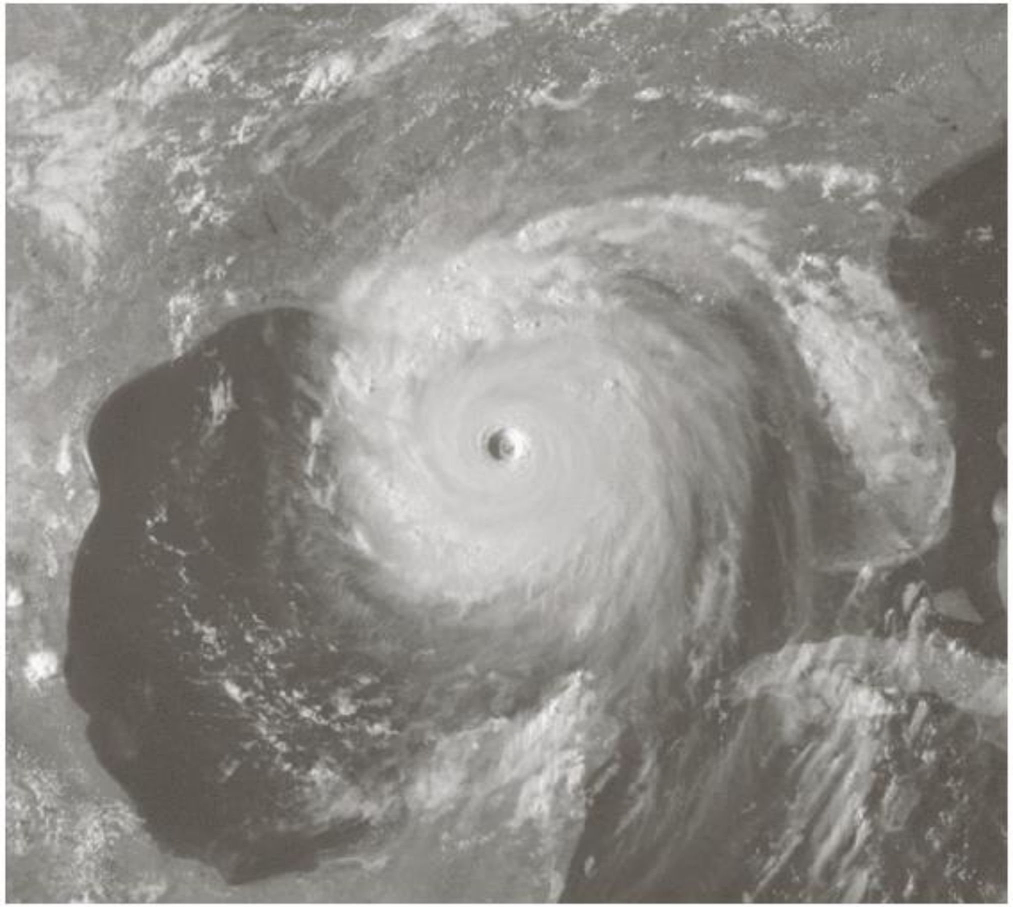


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

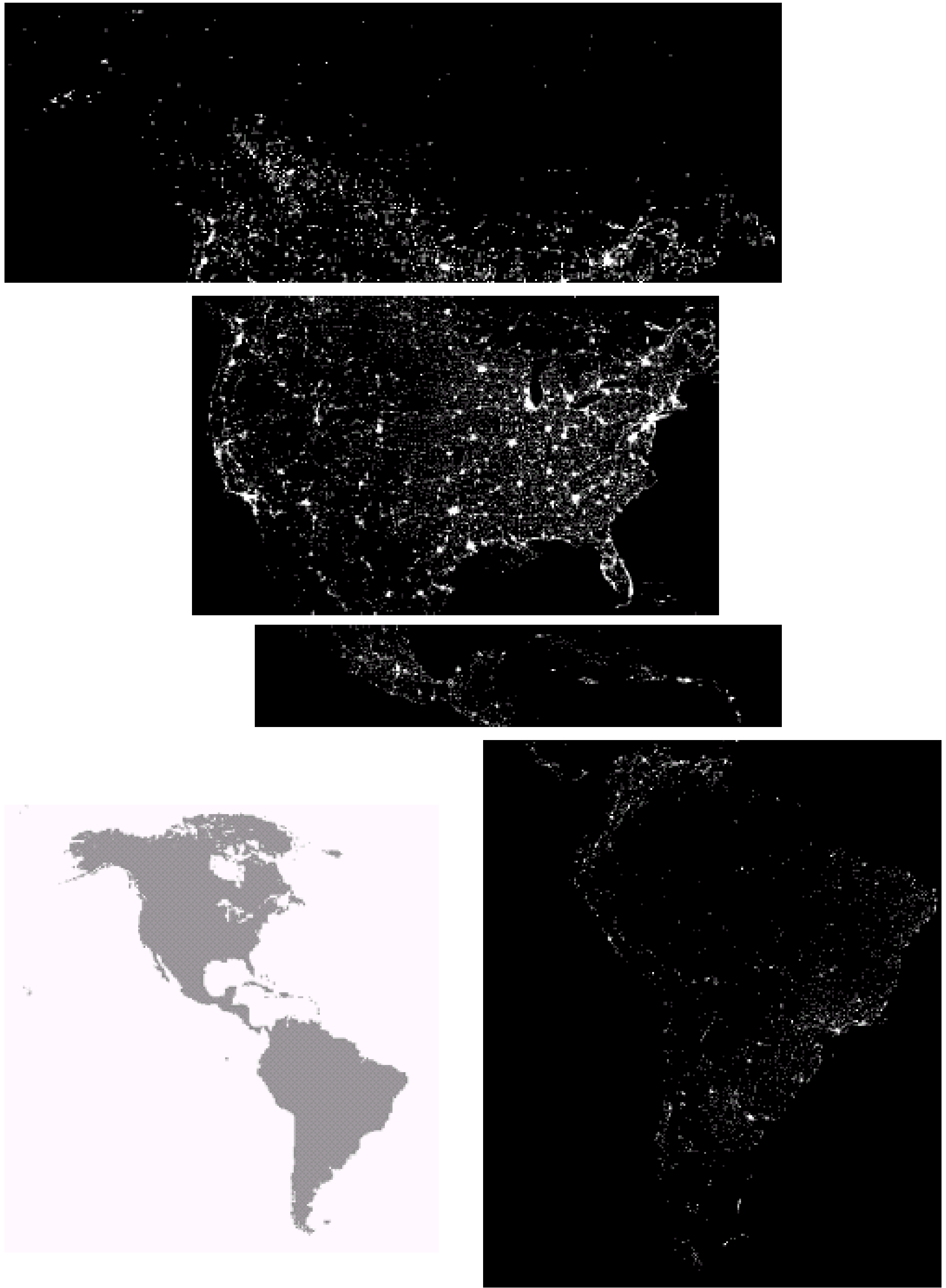


FIGURE 1.12 Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

- Infrared imaging

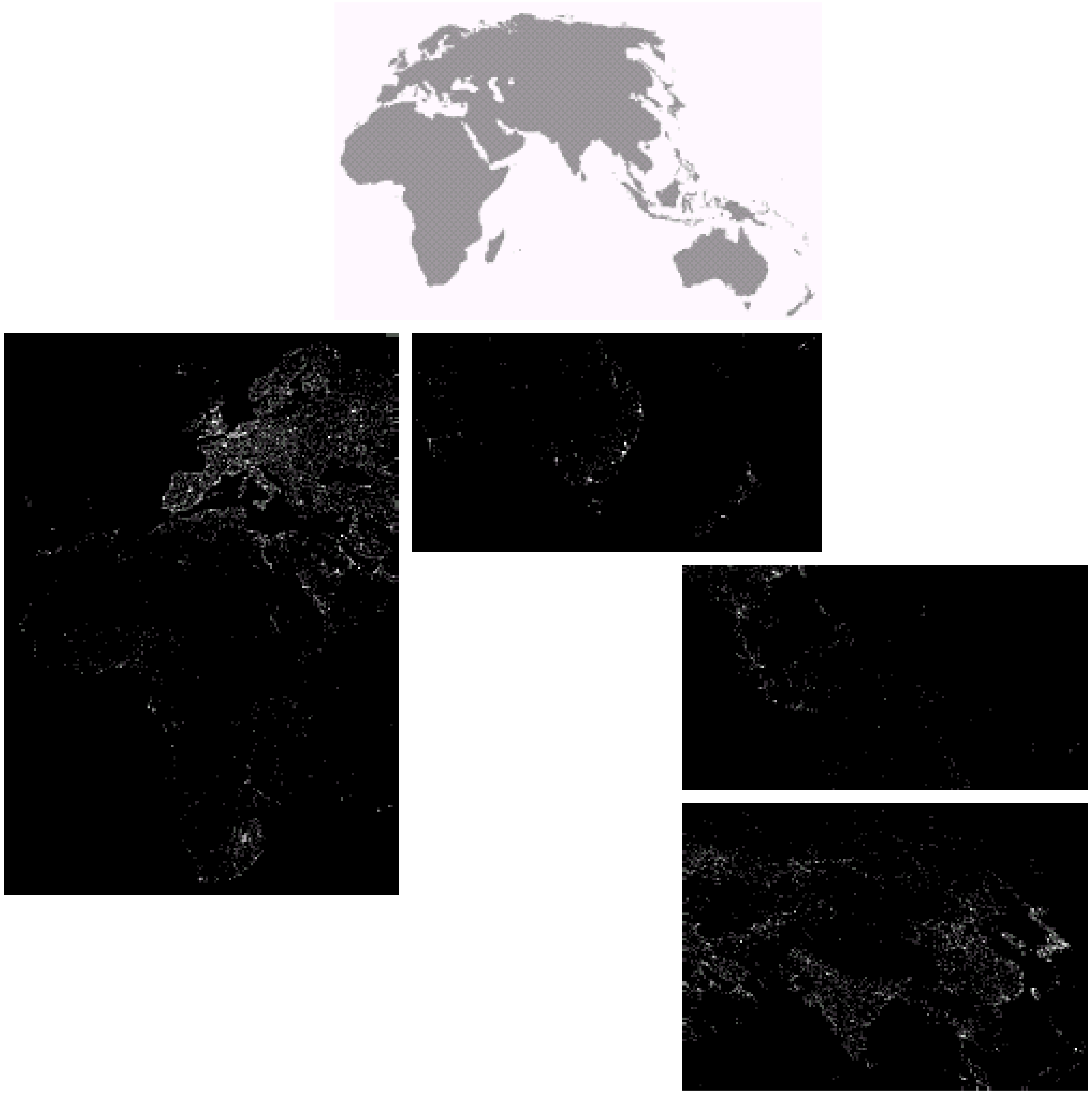


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

❑ Automated visual inspection

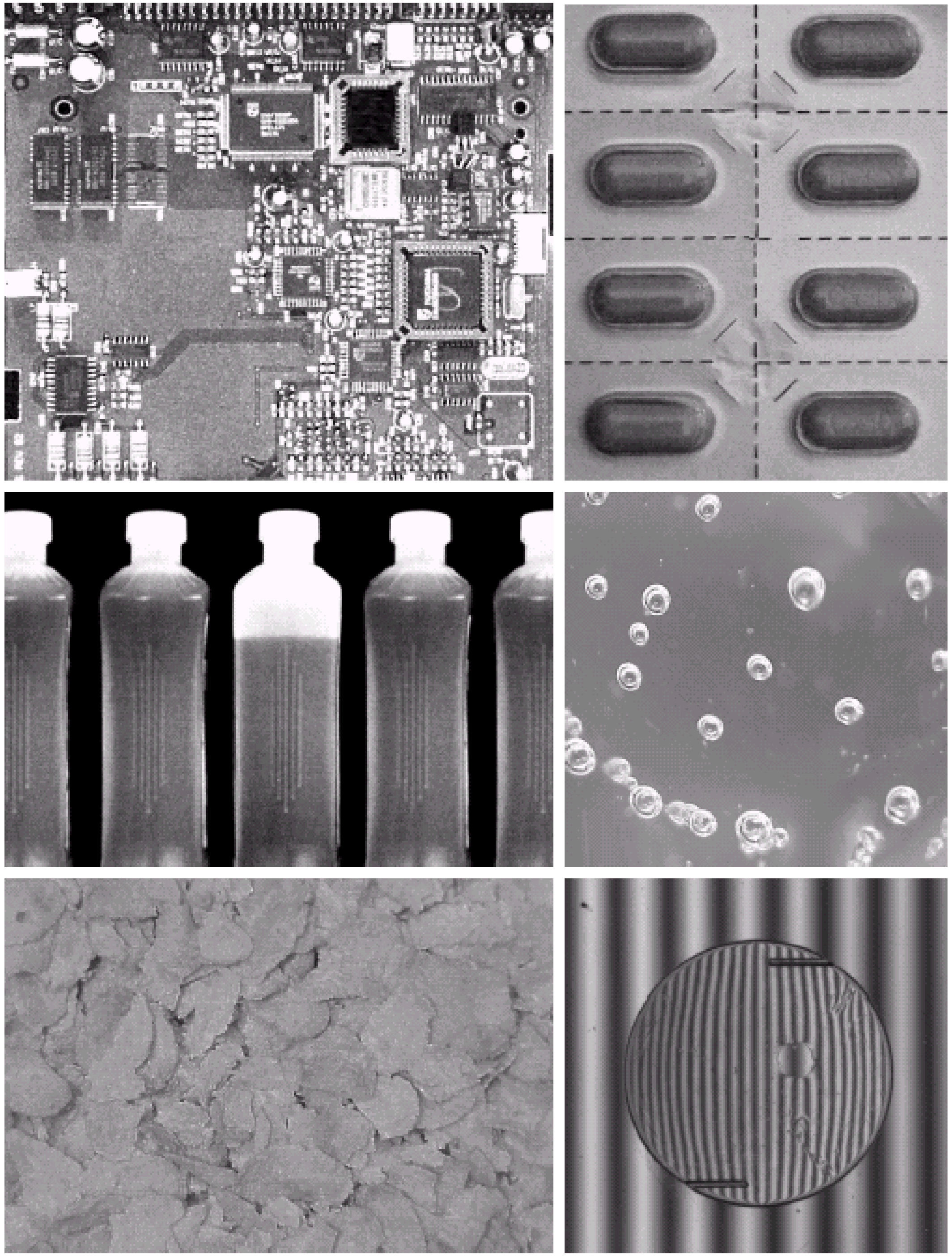


FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Bubbles in clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

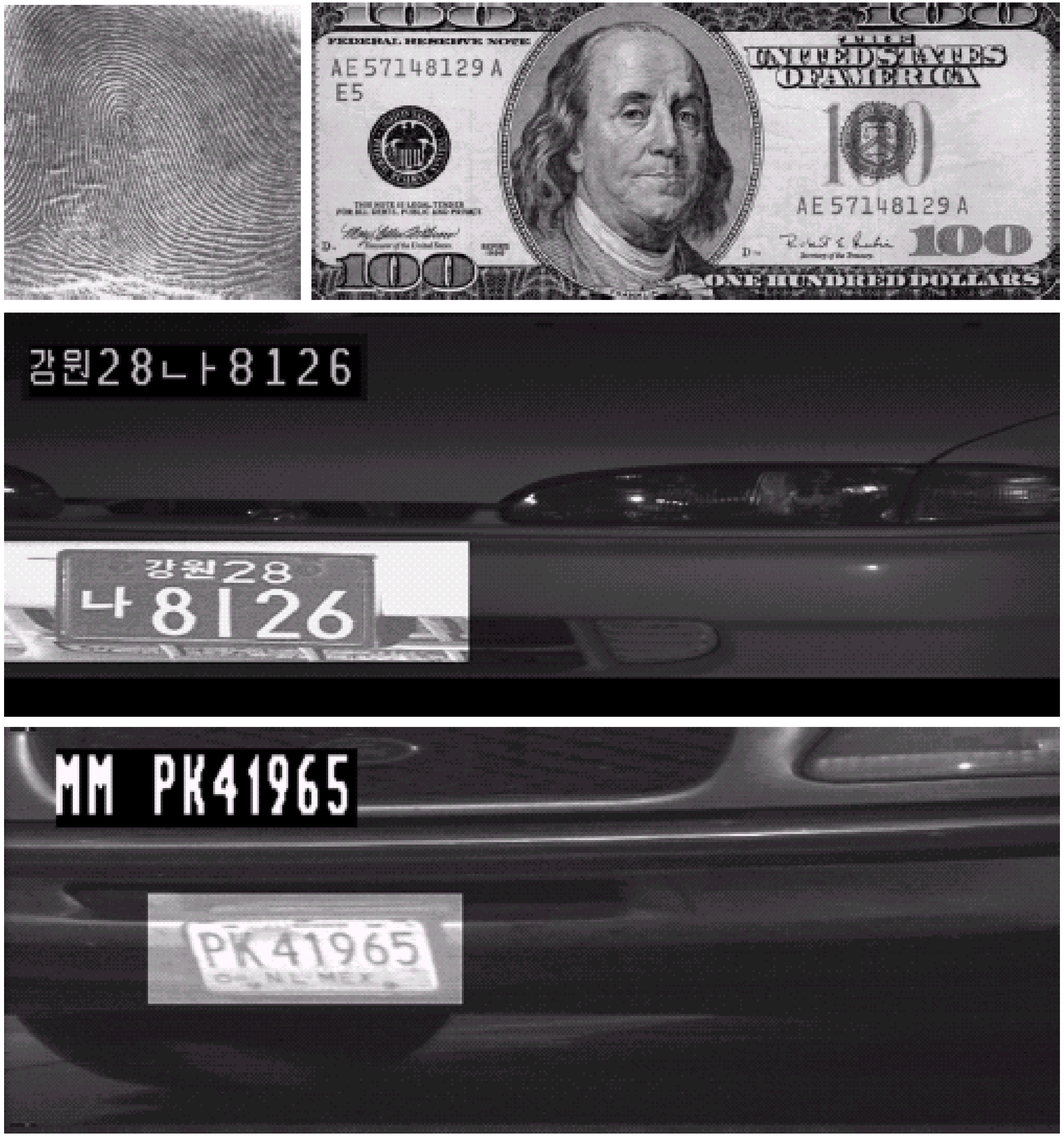


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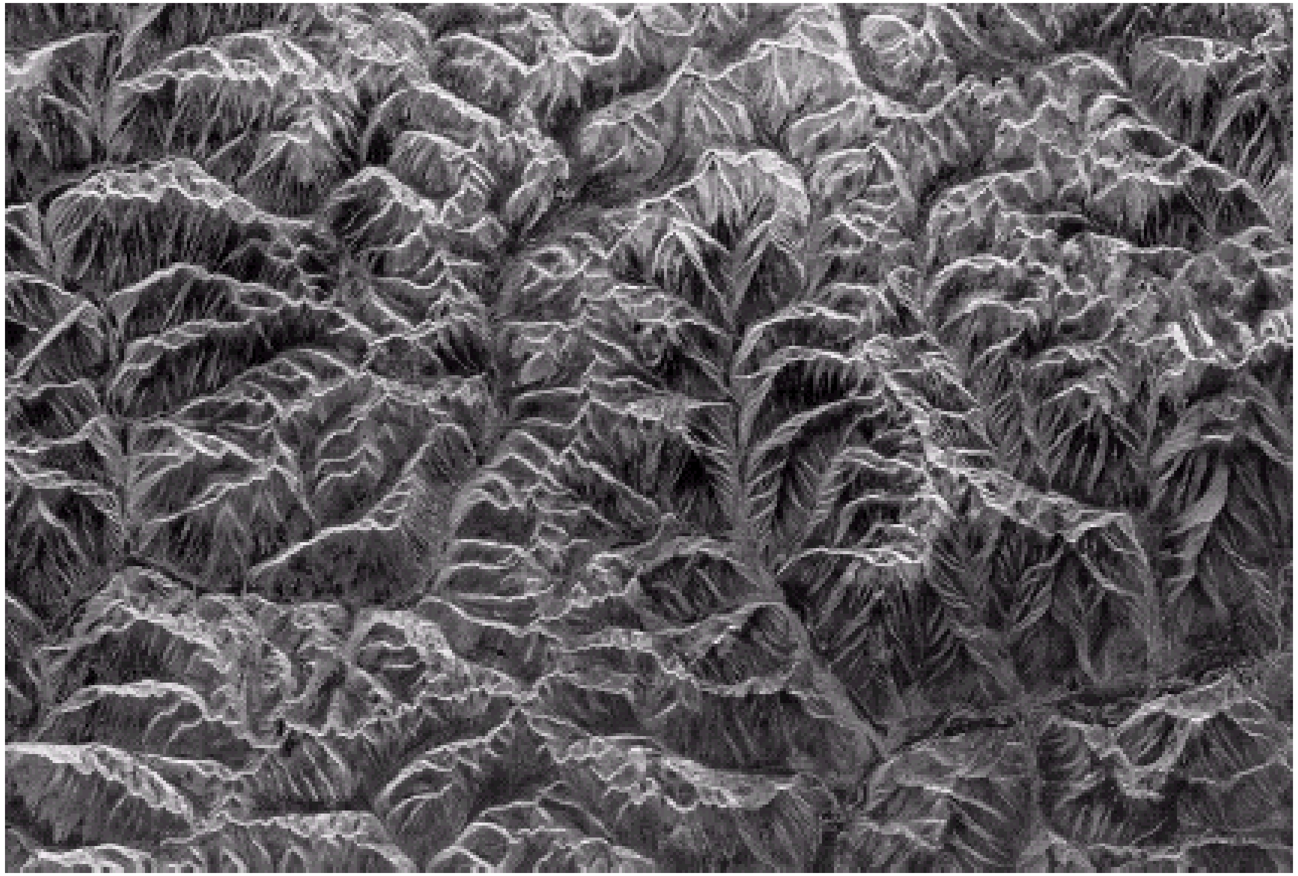
FIGURE 1.15 Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d). Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

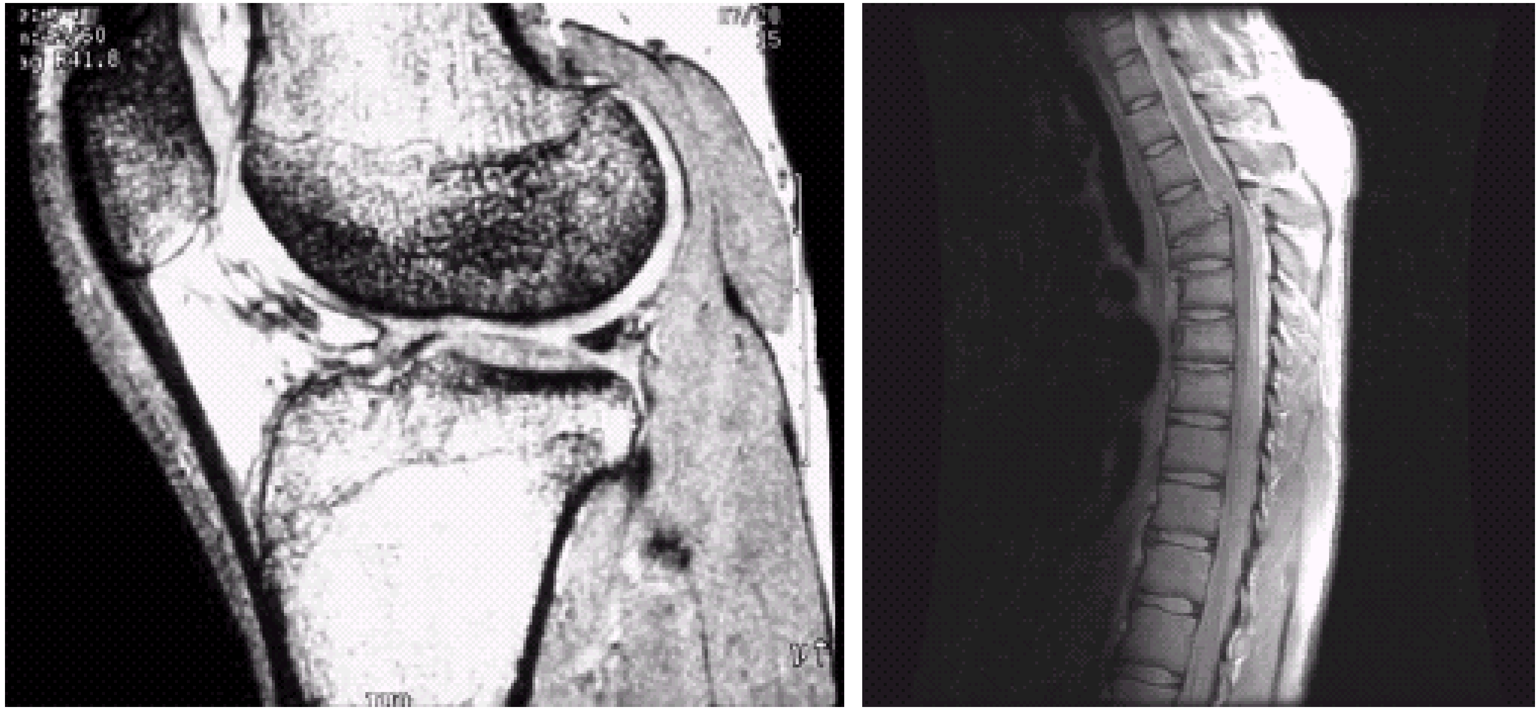
Imaging in the Microwave Band

FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)



Imaging in the Radio Band

- MRI



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

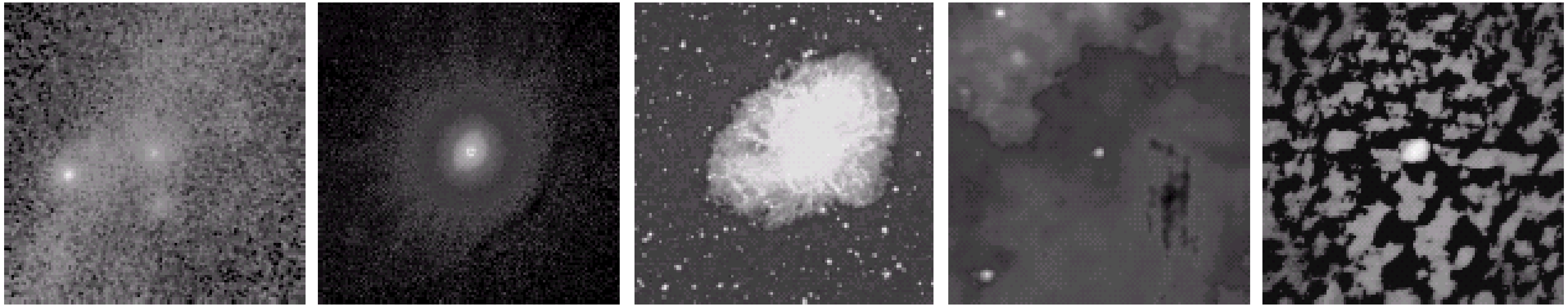


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Examples in which Other Imaging Modalities Are Used

- ❑Sound

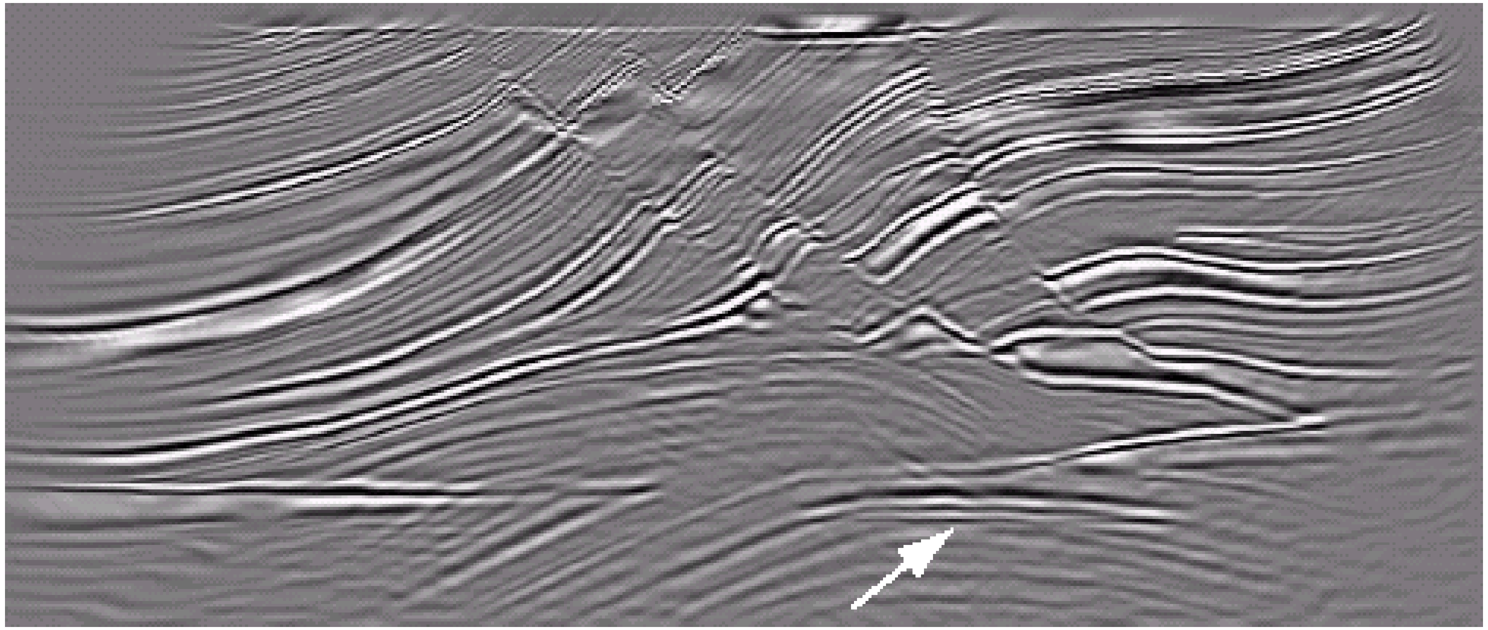
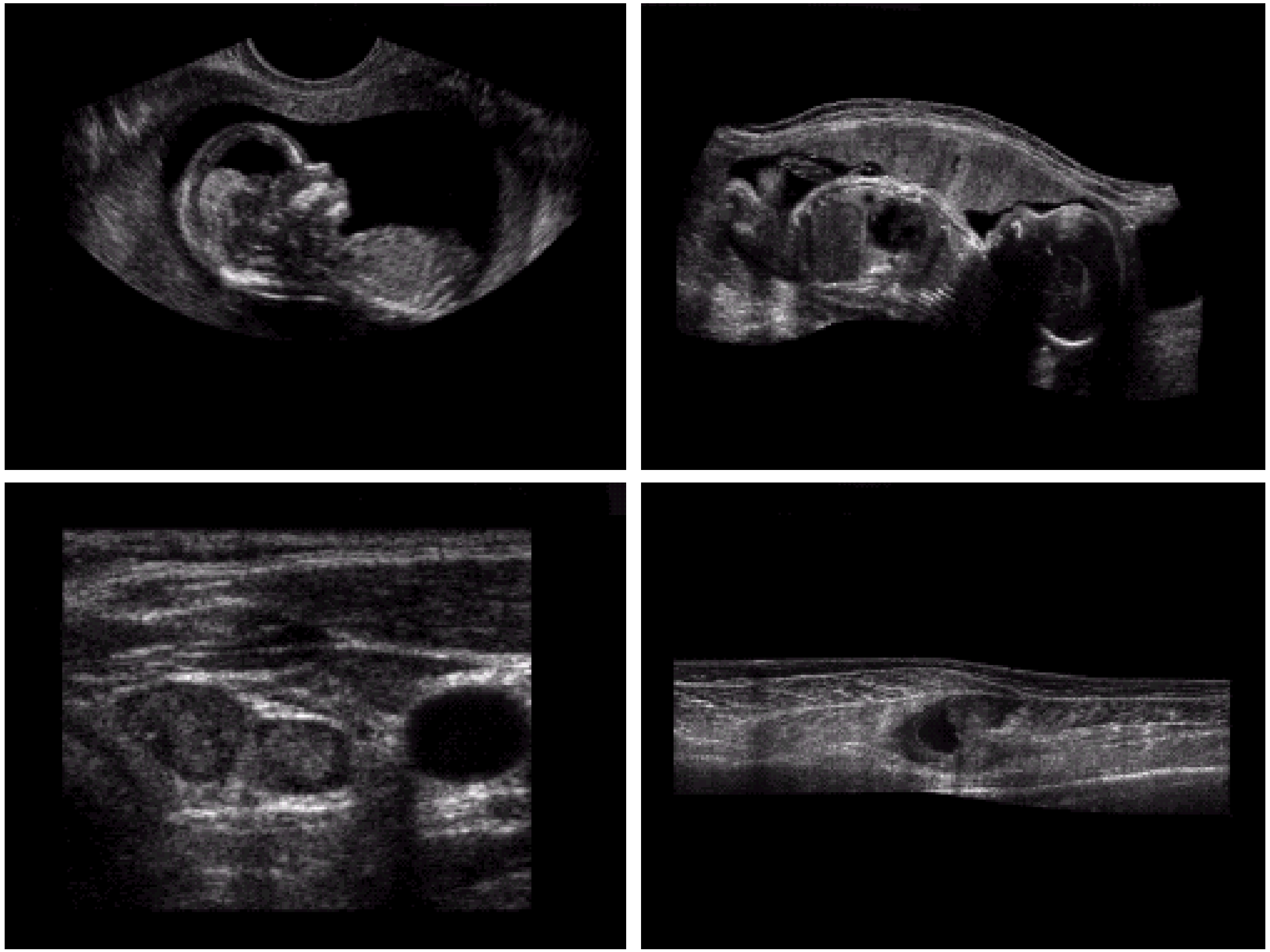


FIGURE 1.19 Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

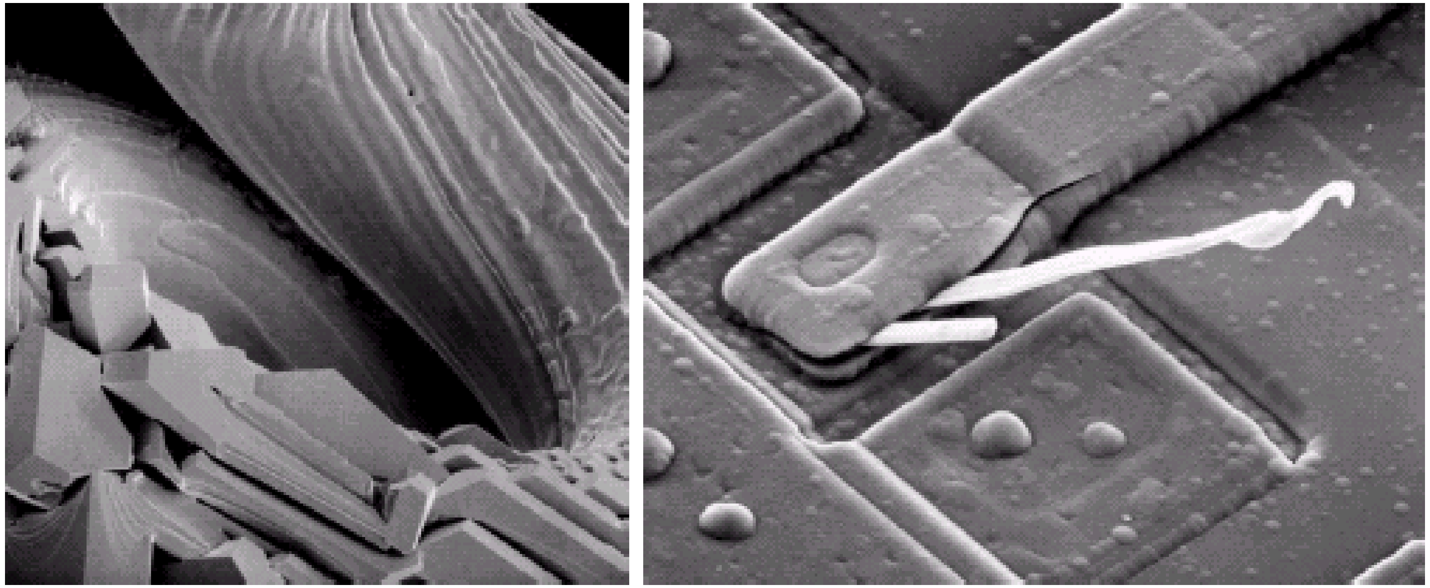
❑Ultrasound



a b
c d

FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

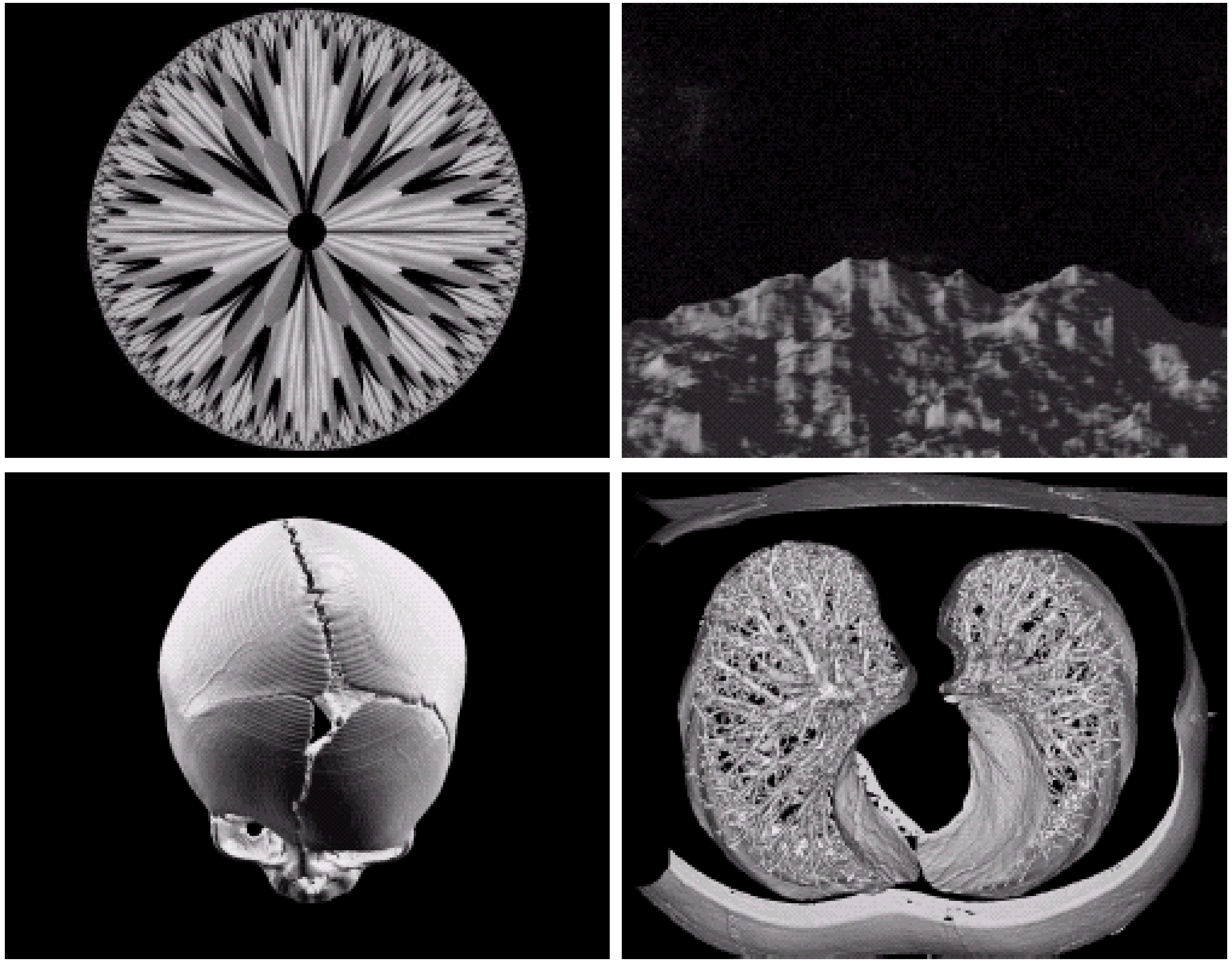
❑Electron Microscope



a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

❑Images generated by computers



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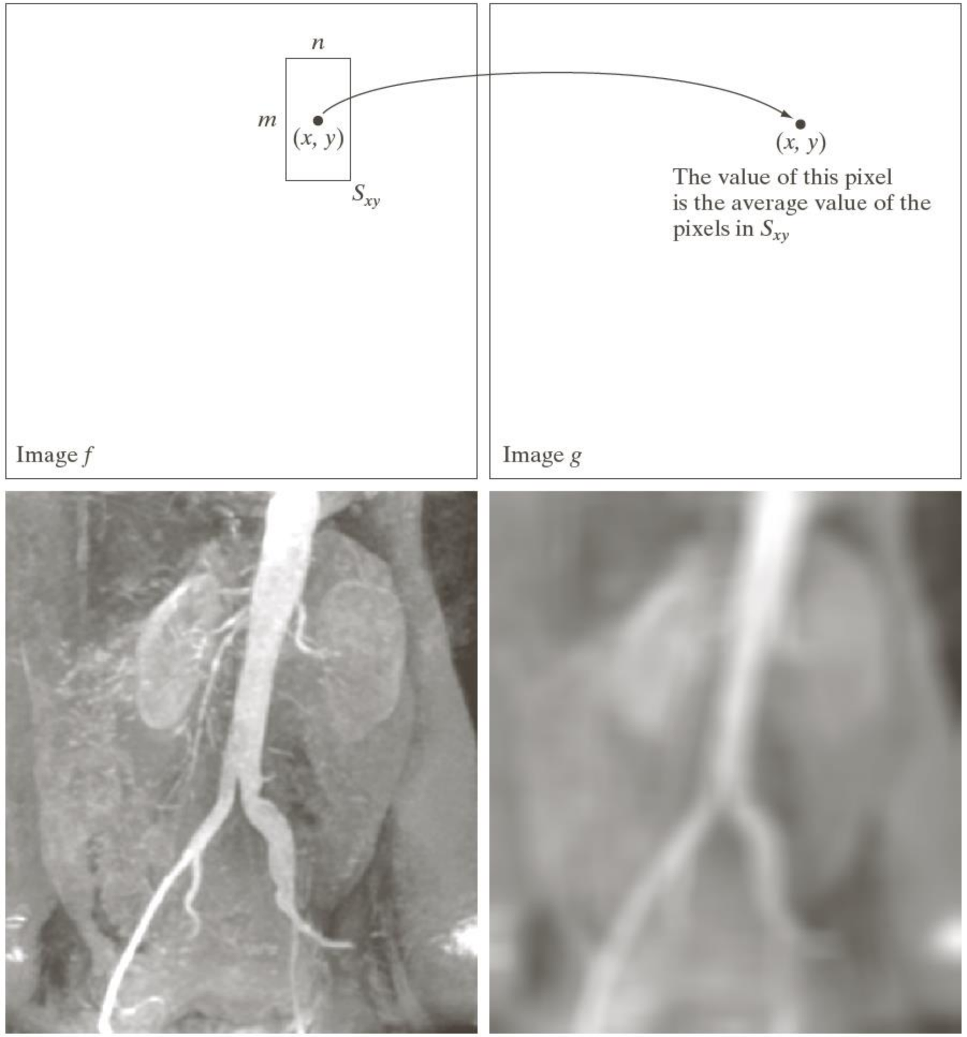
c d

FIGURE 1.22 (a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

❑Image operations



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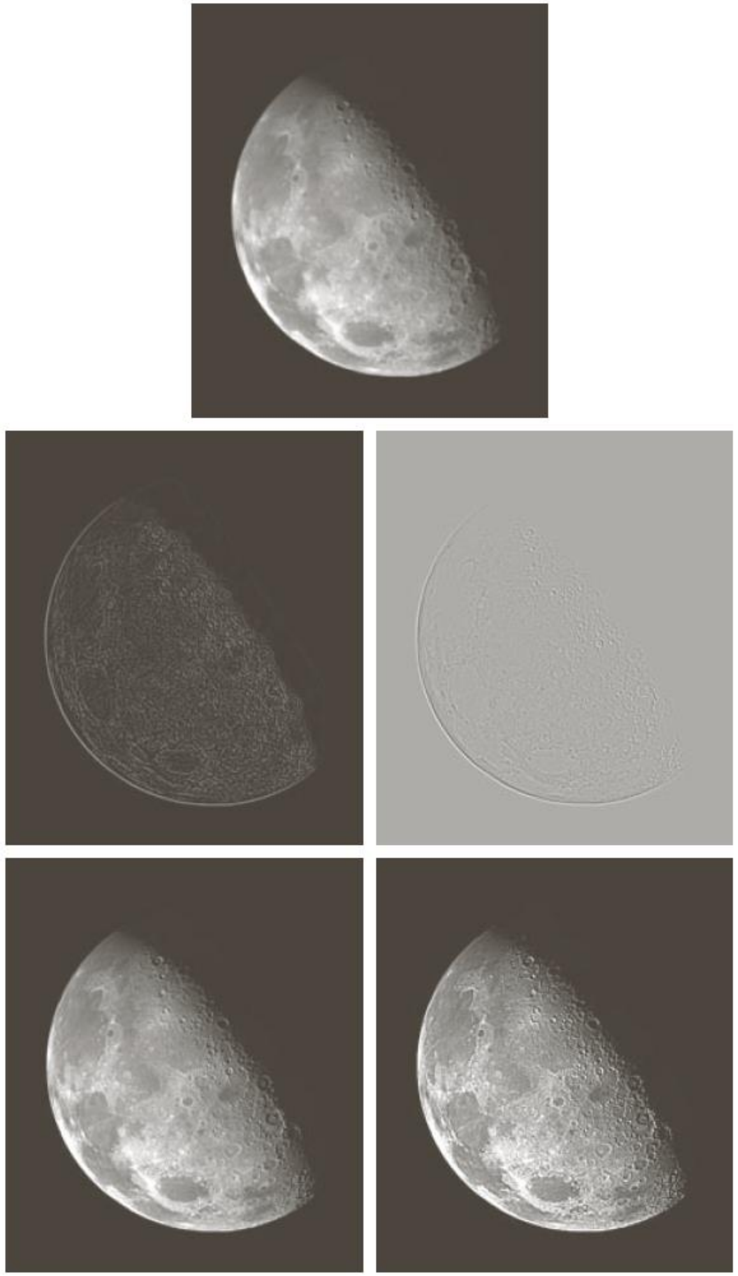
c d

FIGURE 2.35 Local averaging using neighborhood processing. The procedure is illustrated in (a) and (b) for a rectangular neighborhood. (c) The aortic angiogram discussed in Section 1.3.2. (d) The result of using Eq. (2.6-21) with $m = n = 41$. The images are of size 790×686 pixels.

❑Spatial filtering



a
b c
d e

FIGURE 3.38
(a) Blurred image of the North Pole of the moon. (b) Laplacian without scaling. (c) Laplacian with scaling. (d) Image sharpened using the mask in Fig. 3.37(a). (e) Result of using the mask in Fig. 3.37(b). (Original image courtesy of NASA.)

- Filtering in the frequency domain

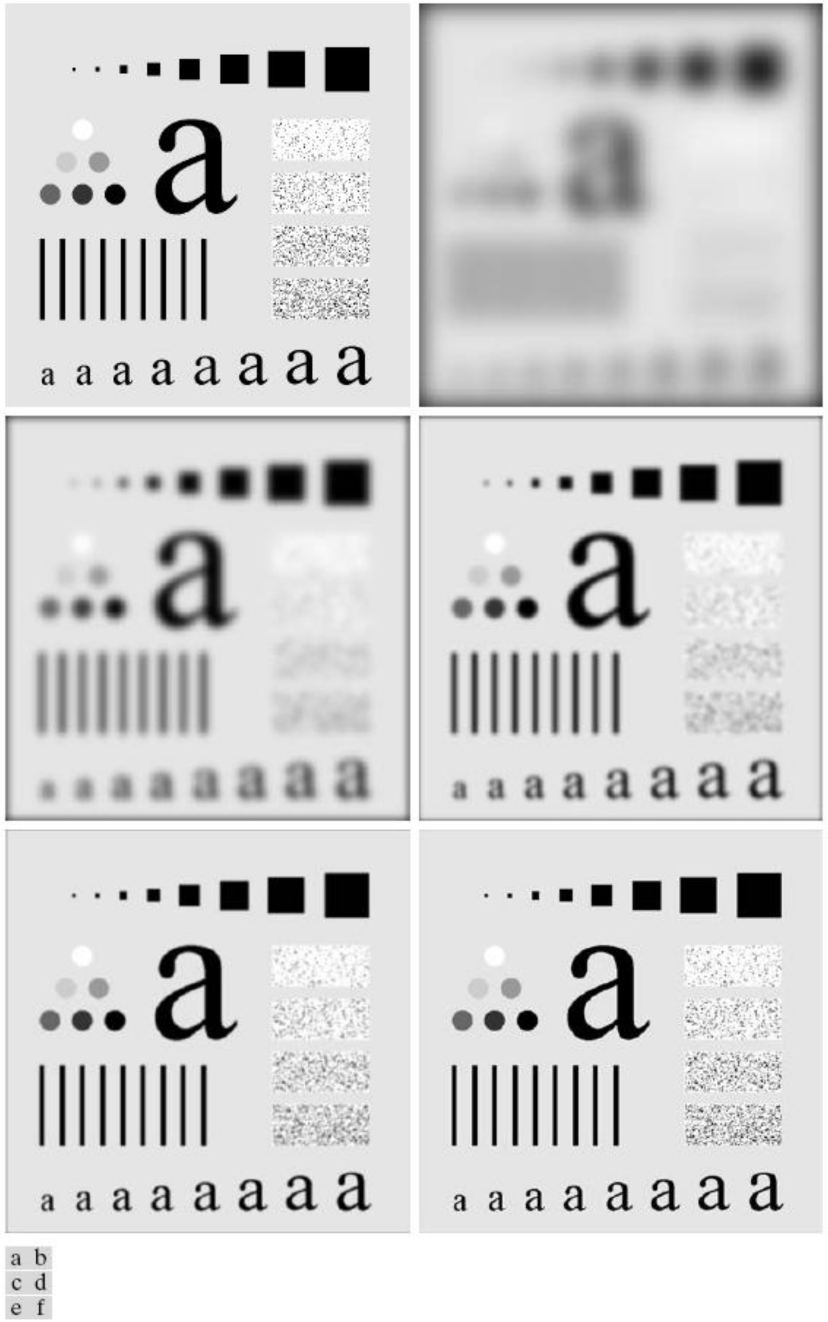
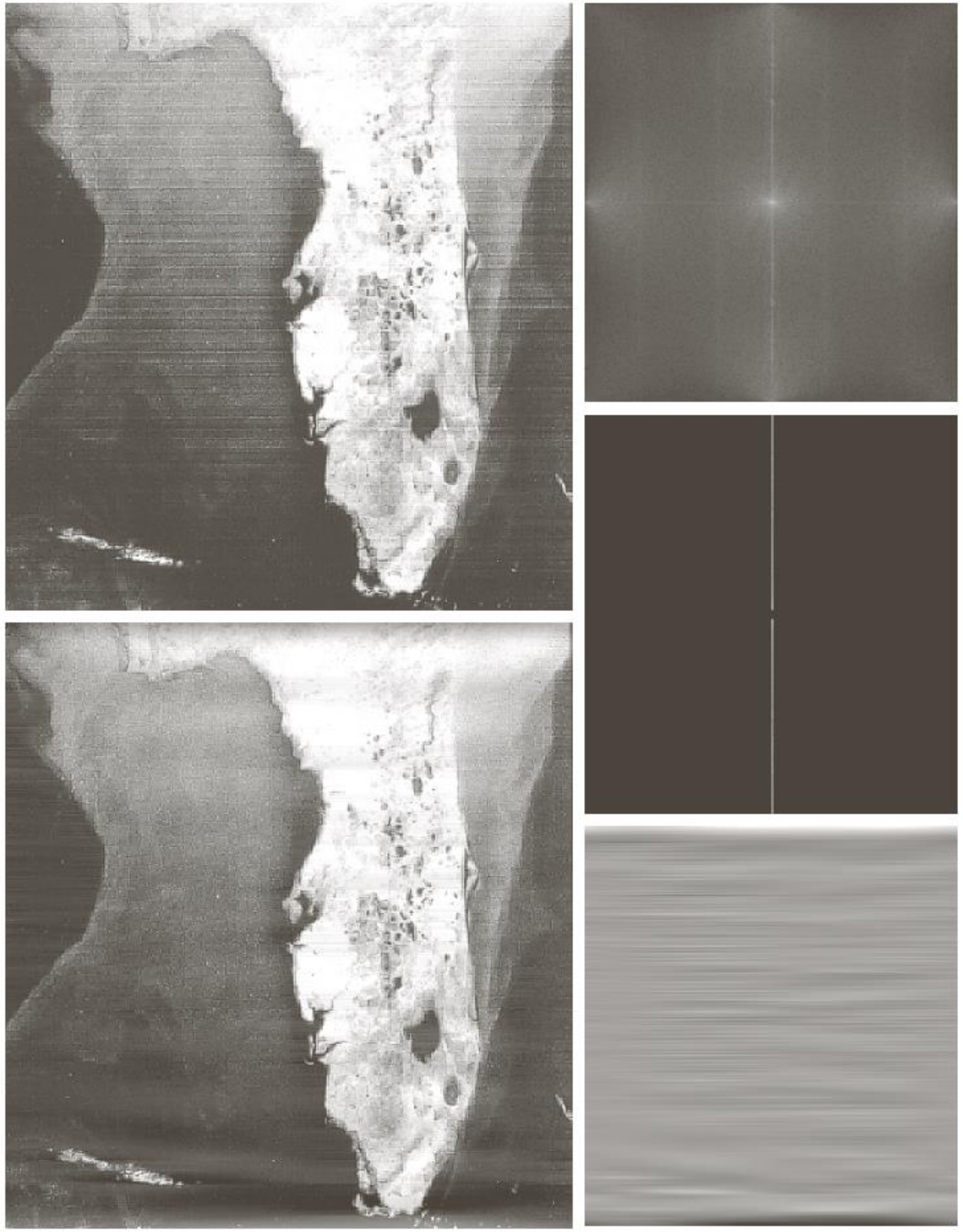


FIGURE 4.48 (a) Original image. (b)–(f) Results of filtering using GLPFs with cutoff frequencies at the radii shown in Fig. 4.41. Compare with Figs. 4.42 and 4.45.

- Image restoration



a b c e d

FIGURE 5.19 (a) Satellite image of Florida and the Gulf of Mexico showing horizontal scan lines. (b) Spectrum. (c) Notch pass filter superimposed on (b). (d) Spatial noise pattern. (e) Result of notch reject filtering. (Original image courtesy of NOAA.)