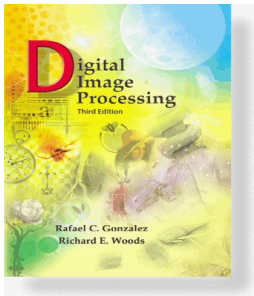
- Applications of DIP
  - Remote sensing (tracking of earth resources, geographical mapping, prediction of agricultural crops, urban growth, fllod control, weather and environmental conditions)
  - Image transmission and storage (compression)
  - Medical image processing
  - Military applications
  - Industrial machine vision
  - Document image processing

Chapter 1

Introduction

- Course Contents
  - Image fundamentals
  - Imaging geometry
  - Image transforms
  - Image enhancement and filtering
  - Image restoration
  - Image segmentation
  - Image representation, description, recognition
  - Image compression

- Text/Reference Books
  - R C Gonzalez & R E Woods, Digital Image Processing, 3rd/4th Ed, PHI
  - A. K. Jain, Fundamentals of DIP, PHI
  - Wiliam K Pratt, DIP, Wiley Student Publishers, 3ed.
  - R C Ganzalez, R E Woods & S L Eddins, DIP using MATLAB, 2nd Ed.

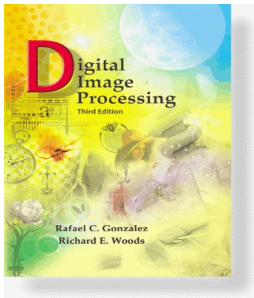


Chapter 1

Introduction

Source: Chapter 01 of DIP, 3E: Introduction

- What is Digital Image Processing
- The Origins of Digital Image Processing
- Examples of Fields that use Digital Image Processing
  - Gamma-Ray Imaging
  - X-Ray Imaging
  - Imaging in UV Band
  - Imaging in Visible & IR Bands
  - Imaging in Microwave Band
  - Imaging in Radio Band
  - Examples where other Imaging Methods are used



Chapter 1

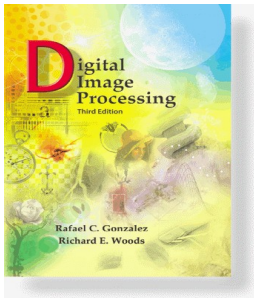
Introduction

Source: Chapter 01 of DIP, 3E: Introduction

- Fundamental Steps in Digital Image Processing
- Components of an Image Processing System

- An image is a 2-D function f(x,y):
  - x, y: spatial coordinates
  - f: intensity / grey level
  - f(x,y): Pixel
- If x, y and f are discrete: Digital Image
  - Digitization of x, y: Spatial Sampling
  - Digitization of x, y: Quantization

- If f(x, y) is:
  - 0 / 1: Binary Image
  - [0, 255]: Gray Scale B/W Image
  - <[0, 255], [0, 255], [0, 255]>: Color or Multi-spectral Image
    - RGB: Red-Green-Blue
    - HSV: Hue-Saturation-Value
    - HSL: Hue-Saturation-Lightness
    - CMYK: Cyan-Magenta-Yellow-Black



Chapter 1

Introduction

- DIP is processing of digital images by digital computers

Chapter 1

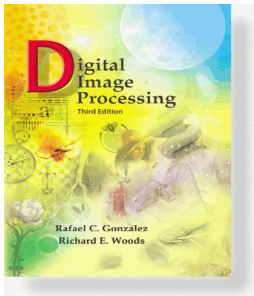
Introduction

- Vision: Most important human perception
  - Limited to Visual Band of EM Spectrum
- DIP applies beyond visual:
  - Gamma Rays to Radio Waves
  - Ultra-sound, Electron Microscopy, …
  - Synthetic Images – Visualized Information

- DIP relates deeply to other areas
  - Pattern Recognition
  - Computer Vision
  - Artificial Intelligence
  - Machine Learning
  - Computer Graphics

- Three types of Computer Processes:
  - Low-level
    - Noise reduction, Contrast Enhancement, Image Sharpening
    - I/P & O/P: Both images
  - Mid-level
    - Segmentation / Object Description / Recognition
    - I/P: Images, O/P: Attributed Entities
  - High-level
    - Interpretation, ‘Making Sense’, …

- Example: Automated Analysis of Document
  - Acquiring the image of the area containing the text
  - Preprocessing
  - Extraction of individual characters (Segmentation)
  - Describing the characters suitable for computer processing (deriving the attributes/features)
  - Recognition of individual characters
  - Making sense of the content of the page

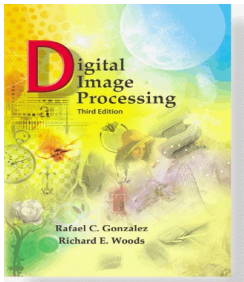


Chapter 1

Introduction

Source: Chapter 01 of DIP, 3E: Introduction

- History of Digital Image Processing
- Examples of Fields that use Digital Image Processing
  - Gamma-Ray Imaging
  - X-Ray Imaging
  - Imaging in UV Band
  - Imaging in Visible & IR Bands
  - Imaging in Microwave Band
  - Imaging in Radio Band
  - Examples where other Imaging Methods are used



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Introduction

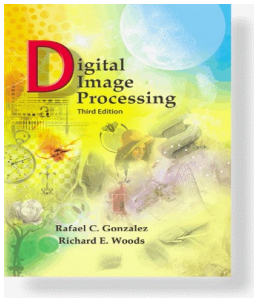
FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

Bartlane System, 1920

Trans-Atlantic Transmission

1921: Five gray levels
1929: Fifteen gray levels

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



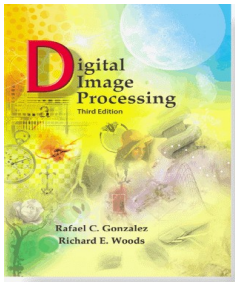
Chapter 1

Introduction

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

Bartlane System, 1920

Fifteen gray levels here



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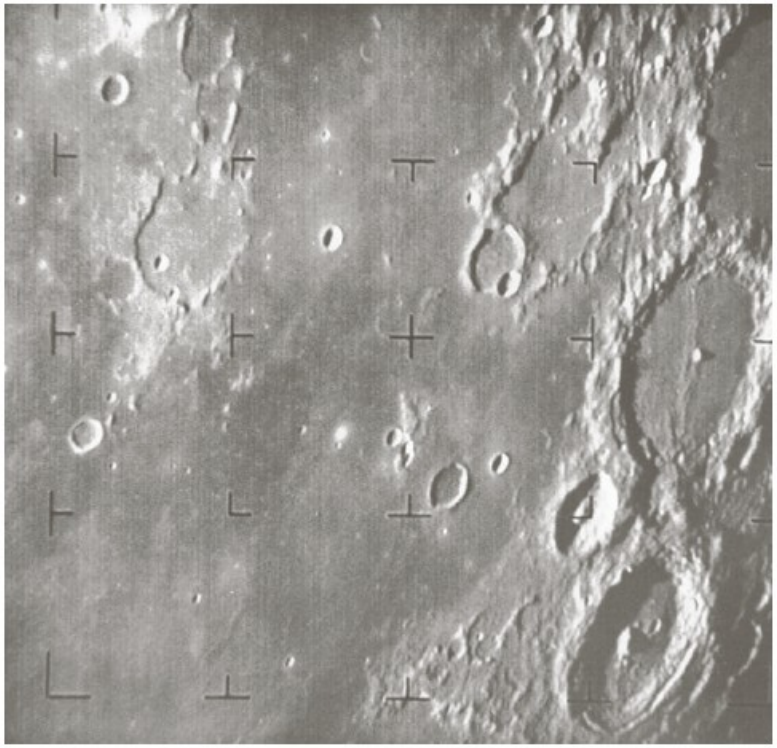
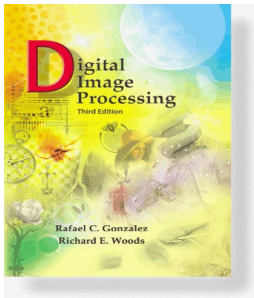


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

- Digital Computers
  - 1948: Transistor, Bell Labs
  - 1950's, 1960's: High-Level Languages
  - 1958: IC, TI
  - Early 1960's: OS
  - Early 1970's: Microprocessors, Intel
  - 1980's /1990's: VLSI / ULSI
  - Advances in Mass Storage / Display System

- Digital Image Processing
  - 1964: Space Probe, Jet Propulsion Laboratory
  - 1960's / 1970's:
    - Medical Imaging
    - Remote Sensing
    - Astronomy
  - Early 1970's: CAT (Computerized Axial Tomography) or CT

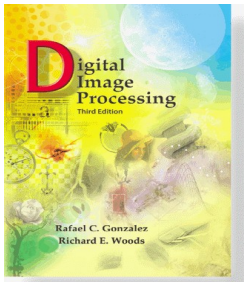
- Human interpretation
  - Enhance the contrast or code the intensity into appropriate color for easy interpretation
  - Study of pollution patterns from satellite images
  - Image enhancement and restoration
  - Archeology (blurred, degraded)
  - Physics (high energy plasma & electron microscop
  - Astronomy, biology, nuclear madicine, law enforcement, defense, industry
- Machine perception
  - Extract information from images for computer processing (statistical moments, fourier transform coeff and distance measures)
  - Automatic char rec, industrial machine vision for product assembly and inspection, military, automatic processing of fingerprints



Chapter 1

Introduction

- Energy Sources for Images
  - EM Energy Spectrum
  - Acoustic
  - Ultrasound
  - Electronic
  - Synthetic



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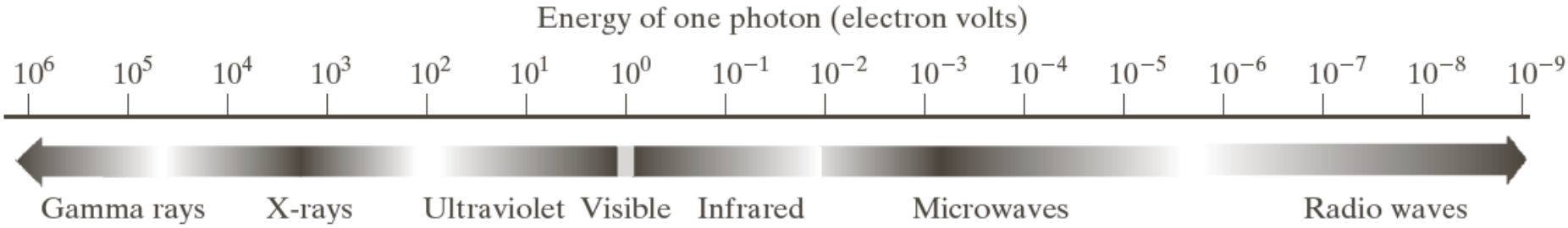
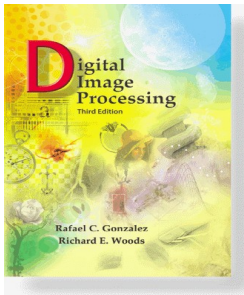


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.



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1eV = 1.602176565·10^{-19} J

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Introduction

E = hν = hc/λ, h is Planck's constant (h = 6.625 × 10^{-34} Joule-seconds or J-s)

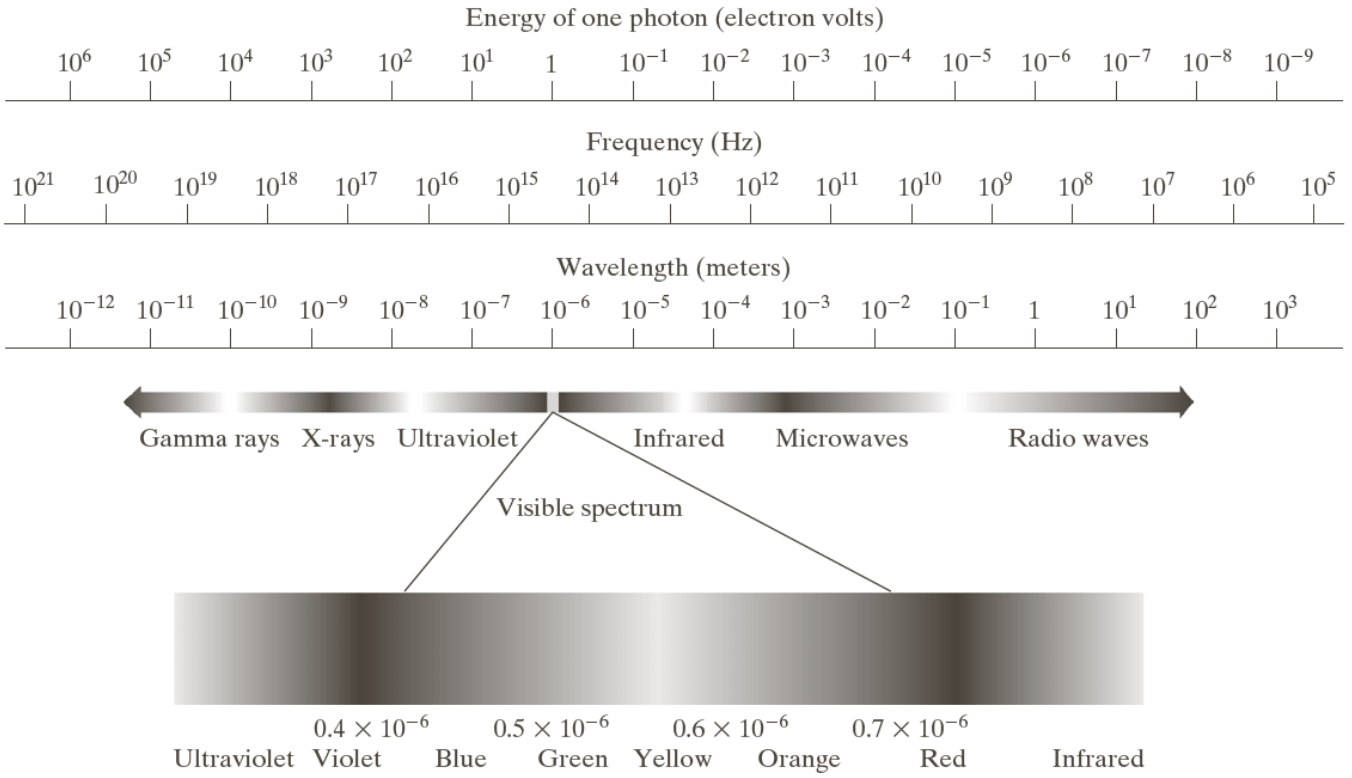
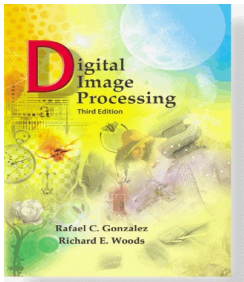


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

λν=c, λ is the **wavelength**, ν is the **frequency** and c is the speed of light.



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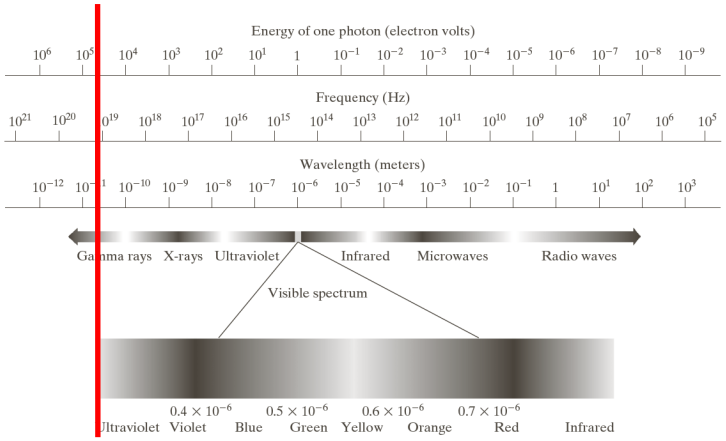
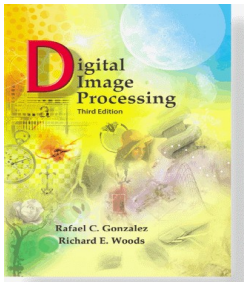


- Gamma Ray Imaging
  - Nuclear Medicine (Bone Scan, PET)
  - Astronomical Observations



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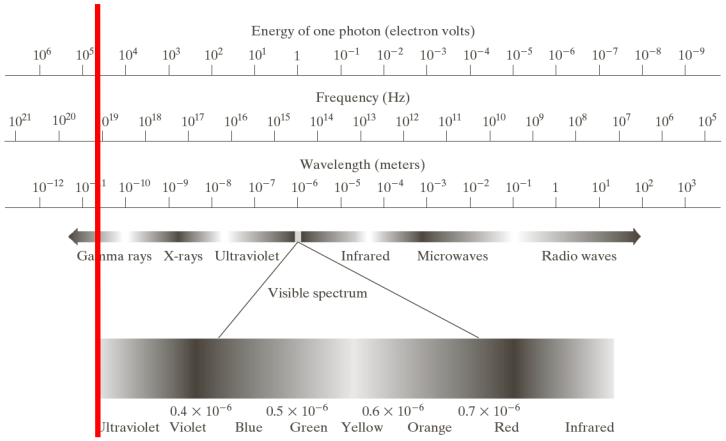
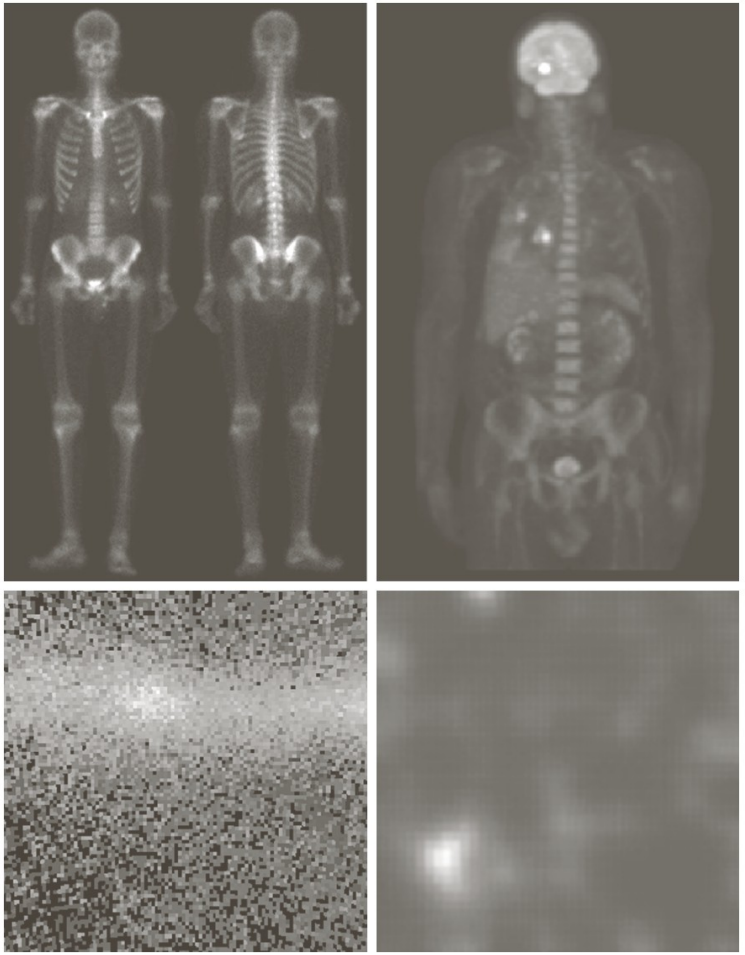
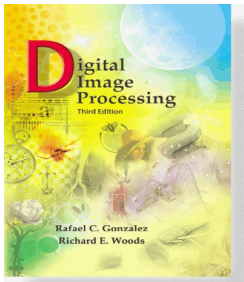




a b
c d

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.)



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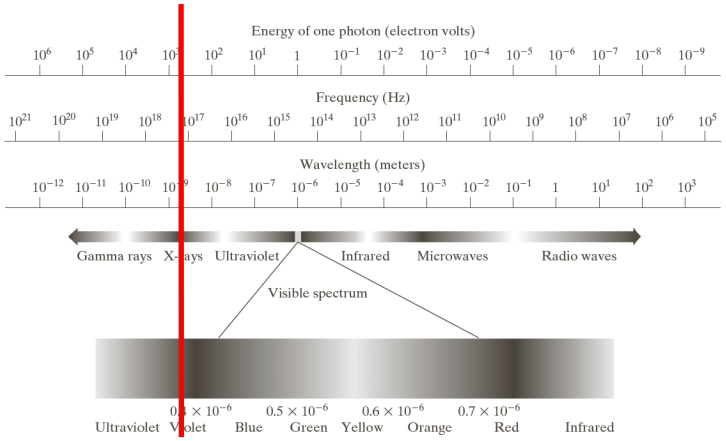
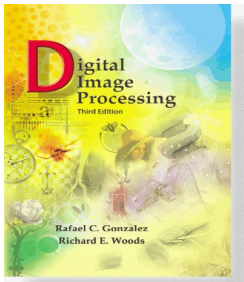


- X-Ray Imaging
  - Medical Diagnosis
    - Bone X-Ray
    - Angiography
    - CAT
  - Industrial Scanning & Testing
  - Astronomy



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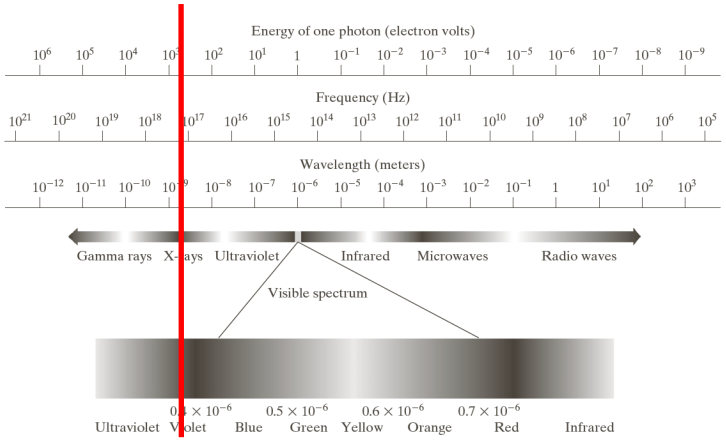


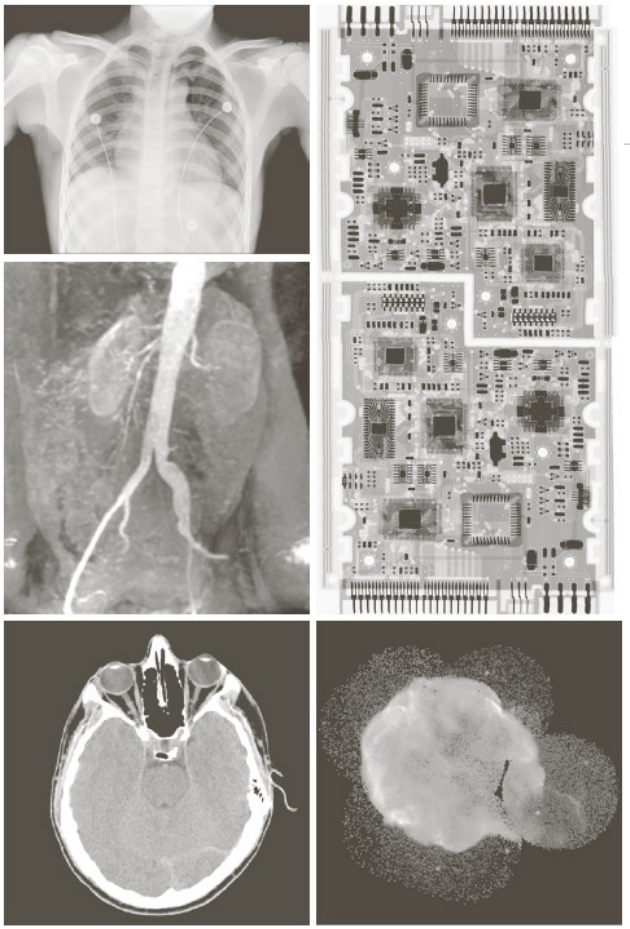
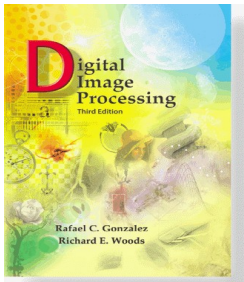


FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical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



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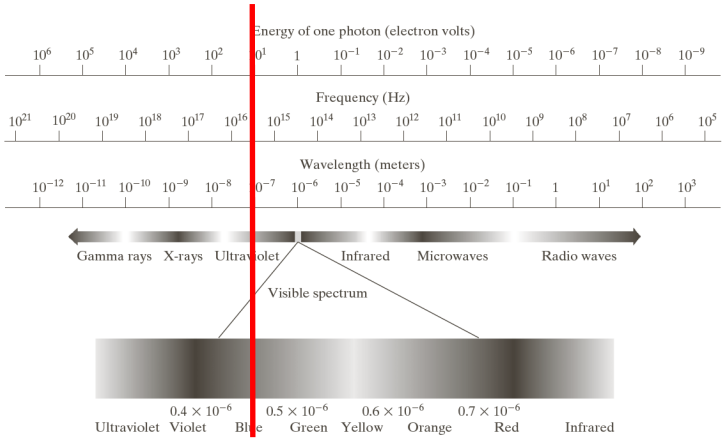
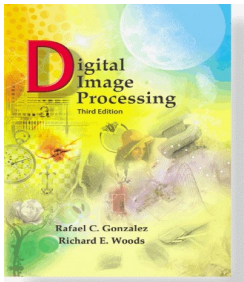


- Imaging in Ultra-Violet Band
  - Industrial Inspection
  - Microscopy (Fluorescence)
  - Lasers
  - Biological Imaging
  - Astronomical Observations



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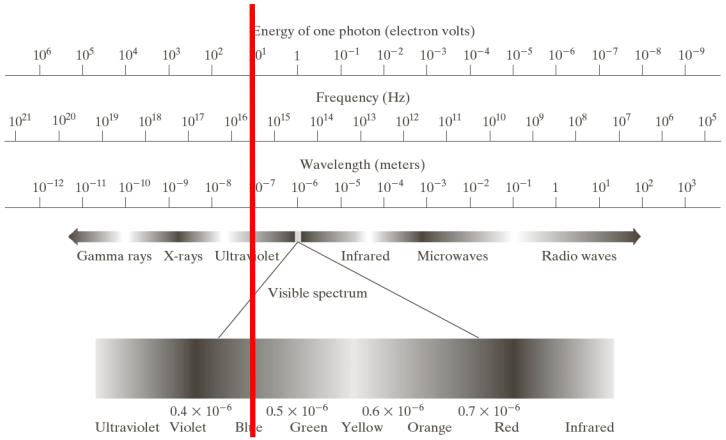
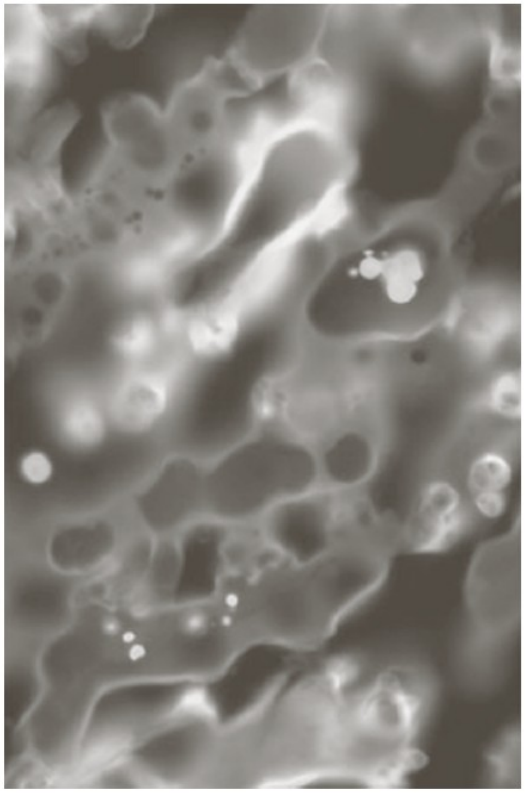
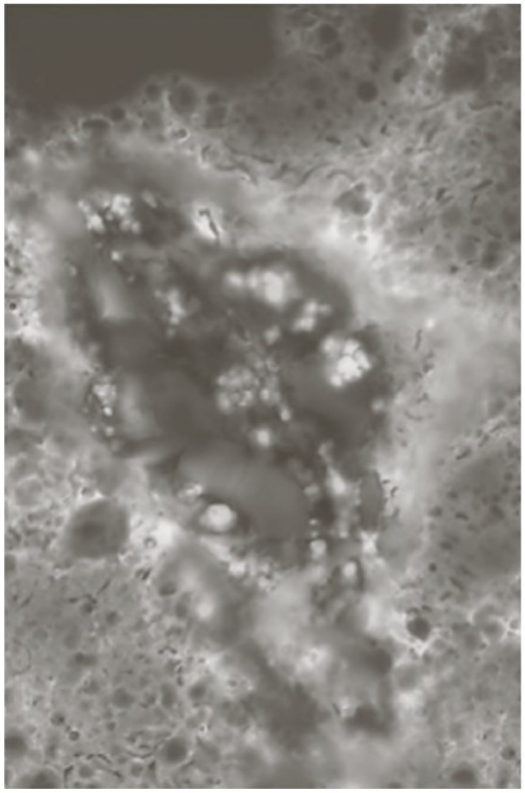






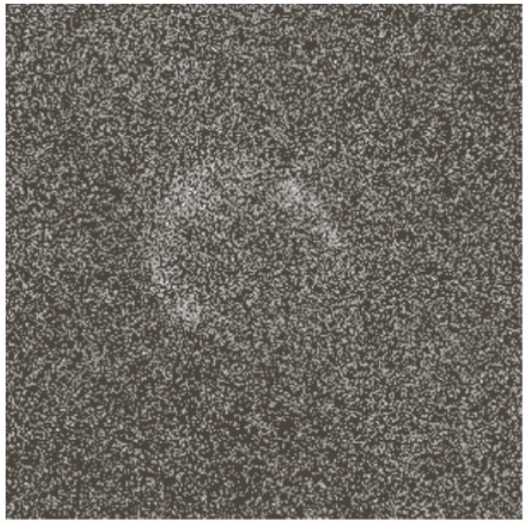
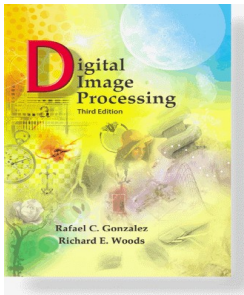


FIGURE 1.8 Examples of ultraviolet imaging. (a) Normal corn (b) Smut corn. (c) Cygnus Loop (Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)



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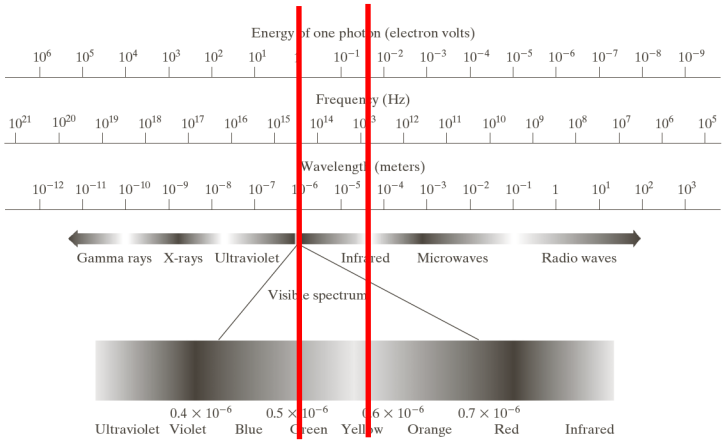
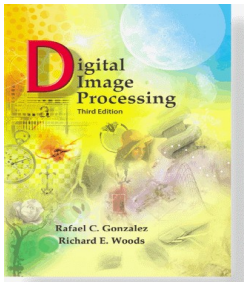


- Imaging in the Visible and Infrared Bands
  - Light Microscopy
  - Remote Sensing
  - Weather Observation / Prediction
  - Automated Visual Inspection
  - Finger Printing
  - Iris Recognition



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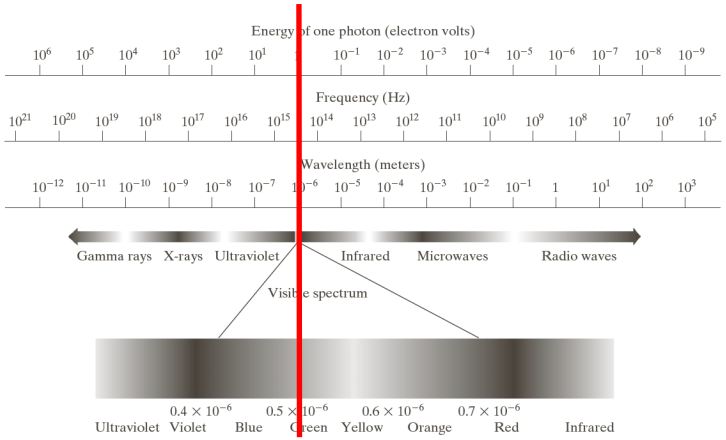
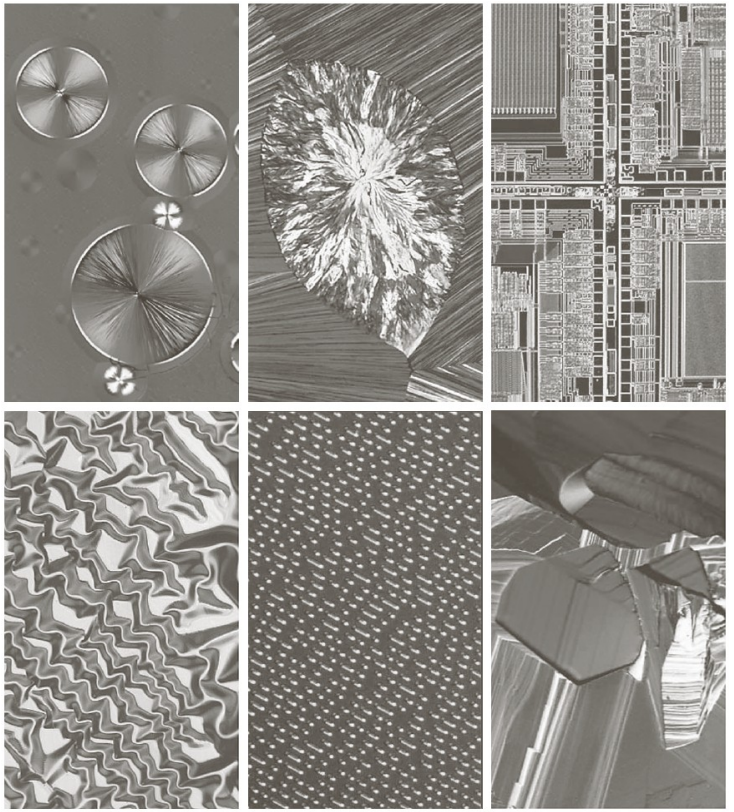
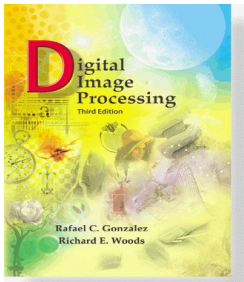




a b c
d e f

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.)



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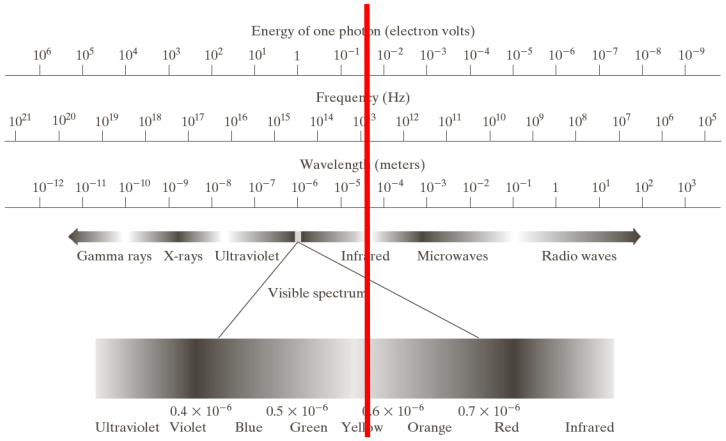


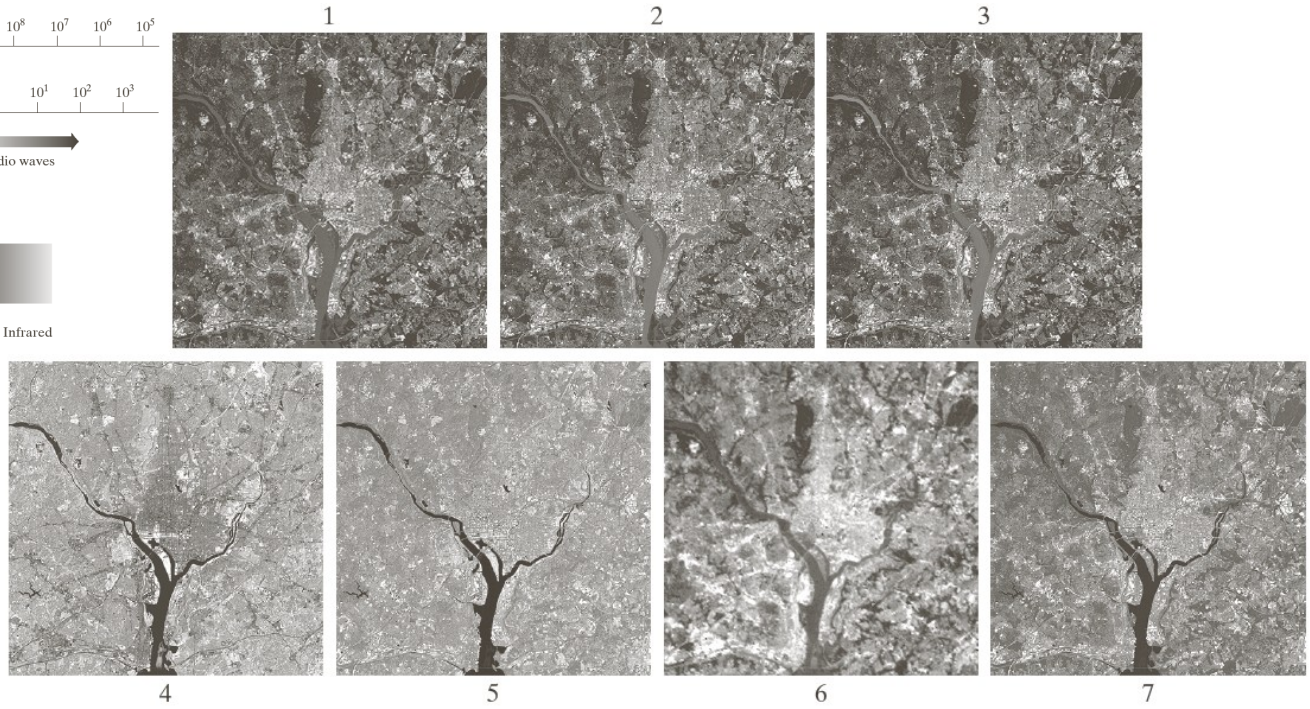
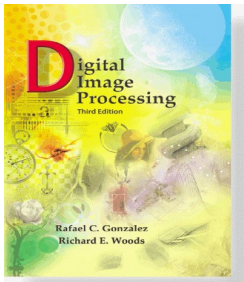


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)



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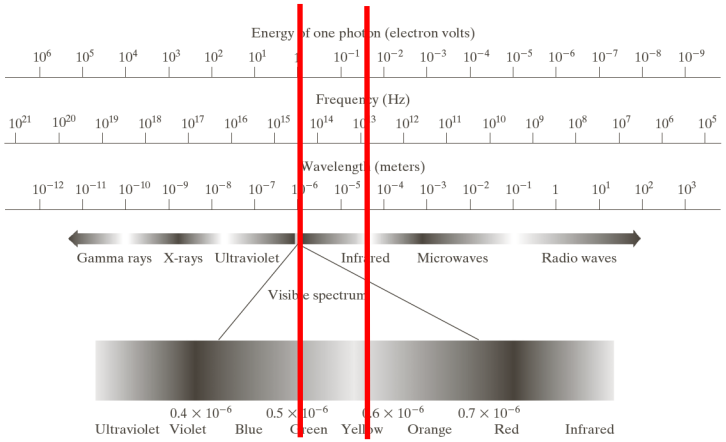
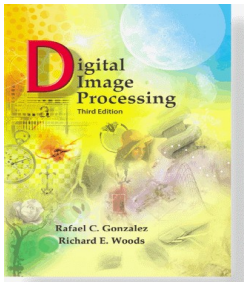


TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

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



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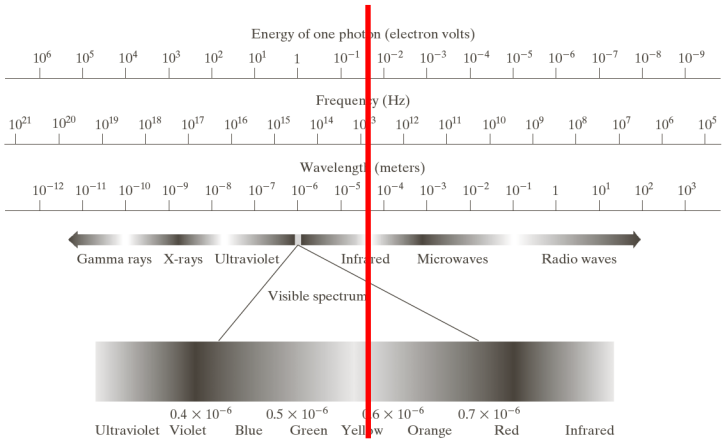
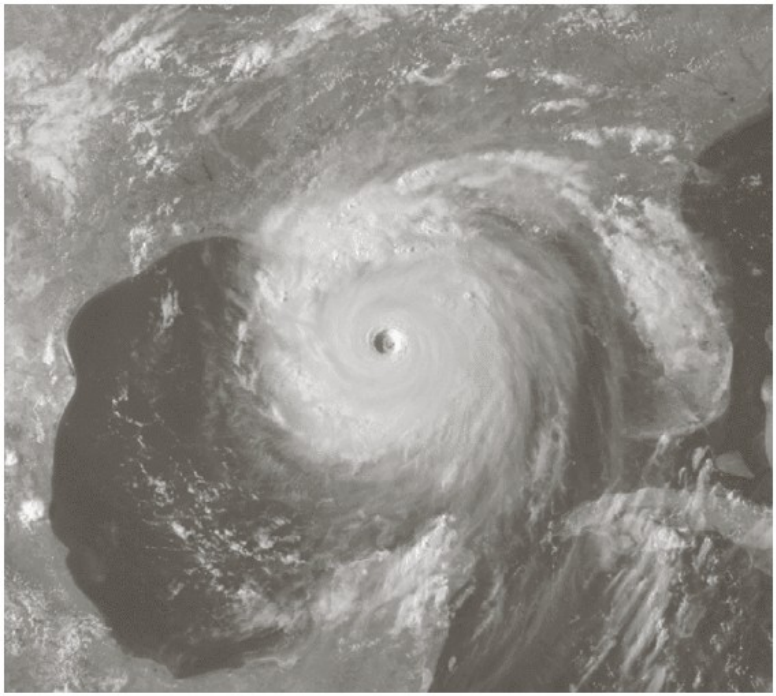
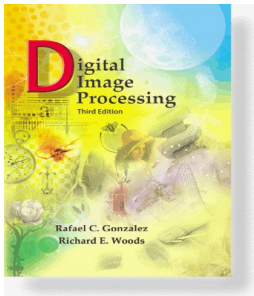


FIGURE 1.11 Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)





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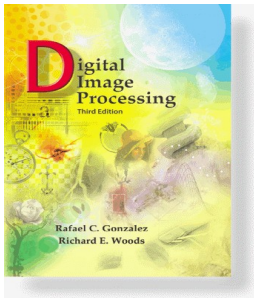

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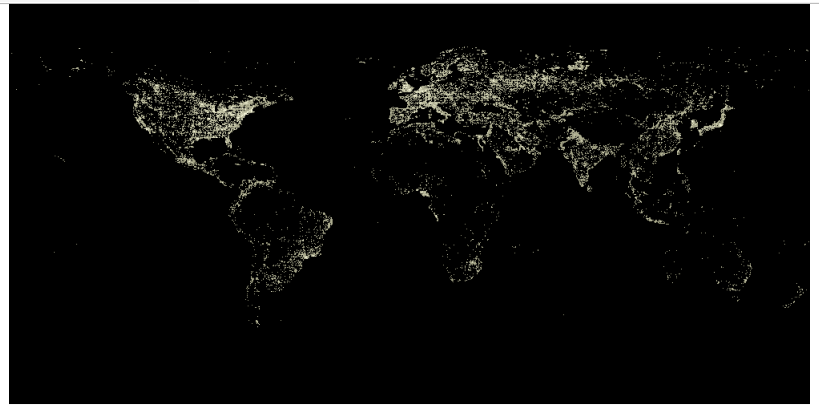

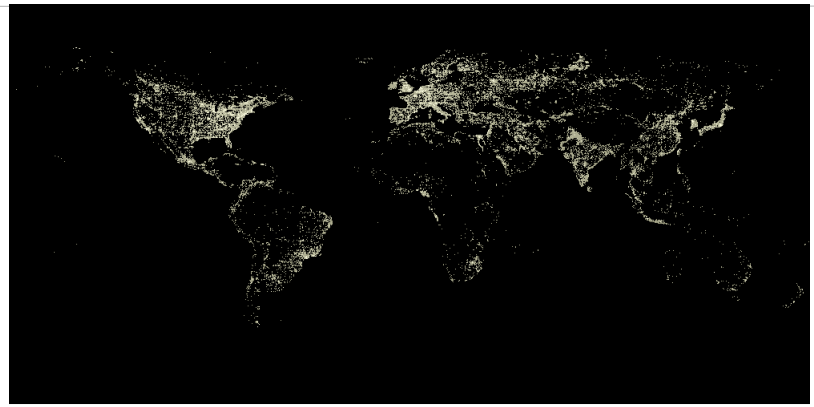

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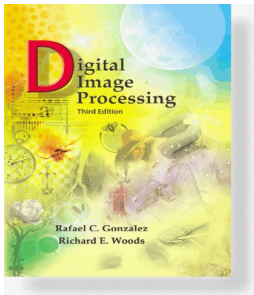

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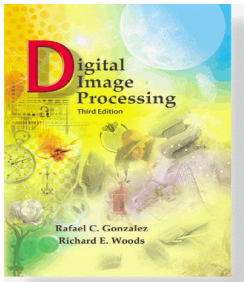
FIGURE 1.12 Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)



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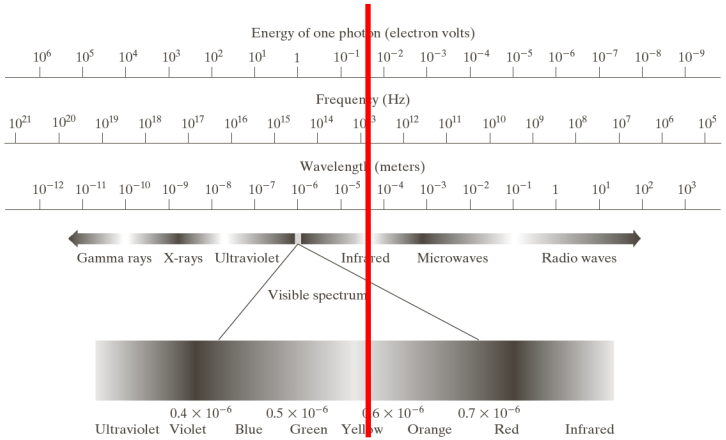
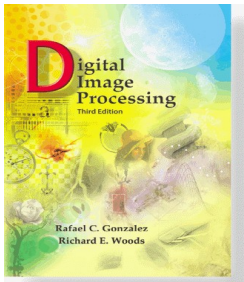


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)



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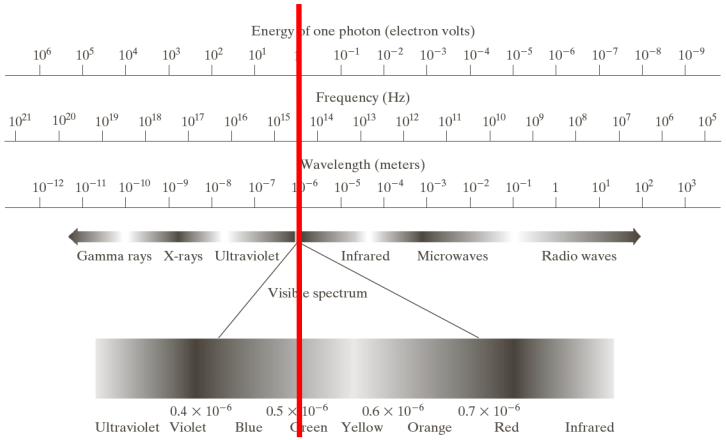
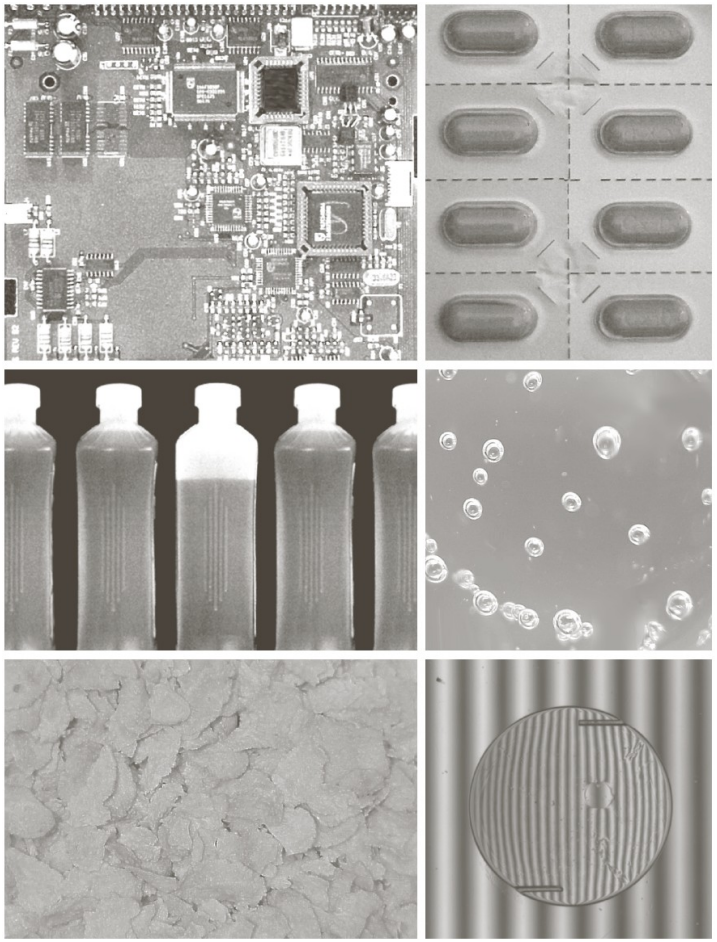
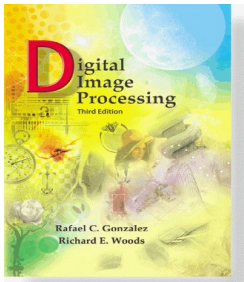




a b
c d
e f

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) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)



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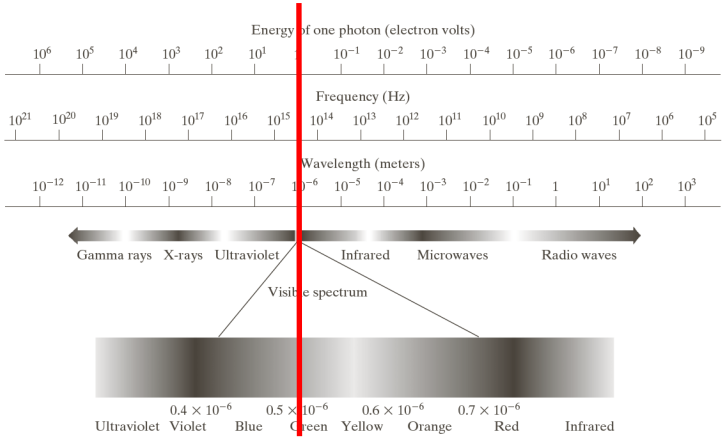

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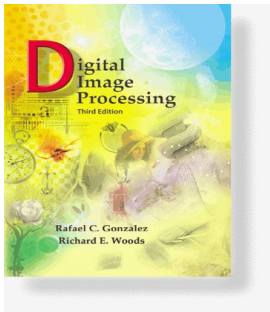
FIGURE 1.15 Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)



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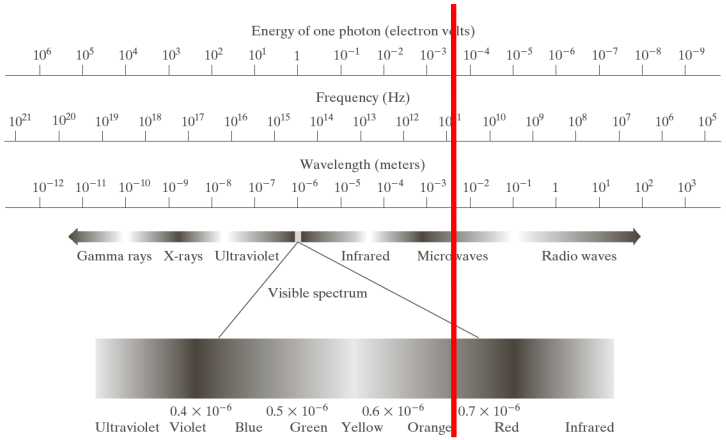
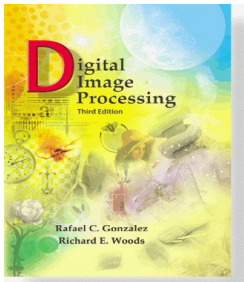


- Imaging in the Microwave Bands
  - Radar



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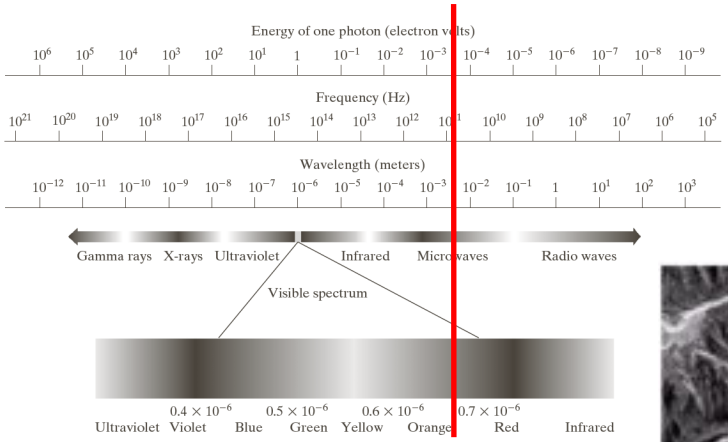
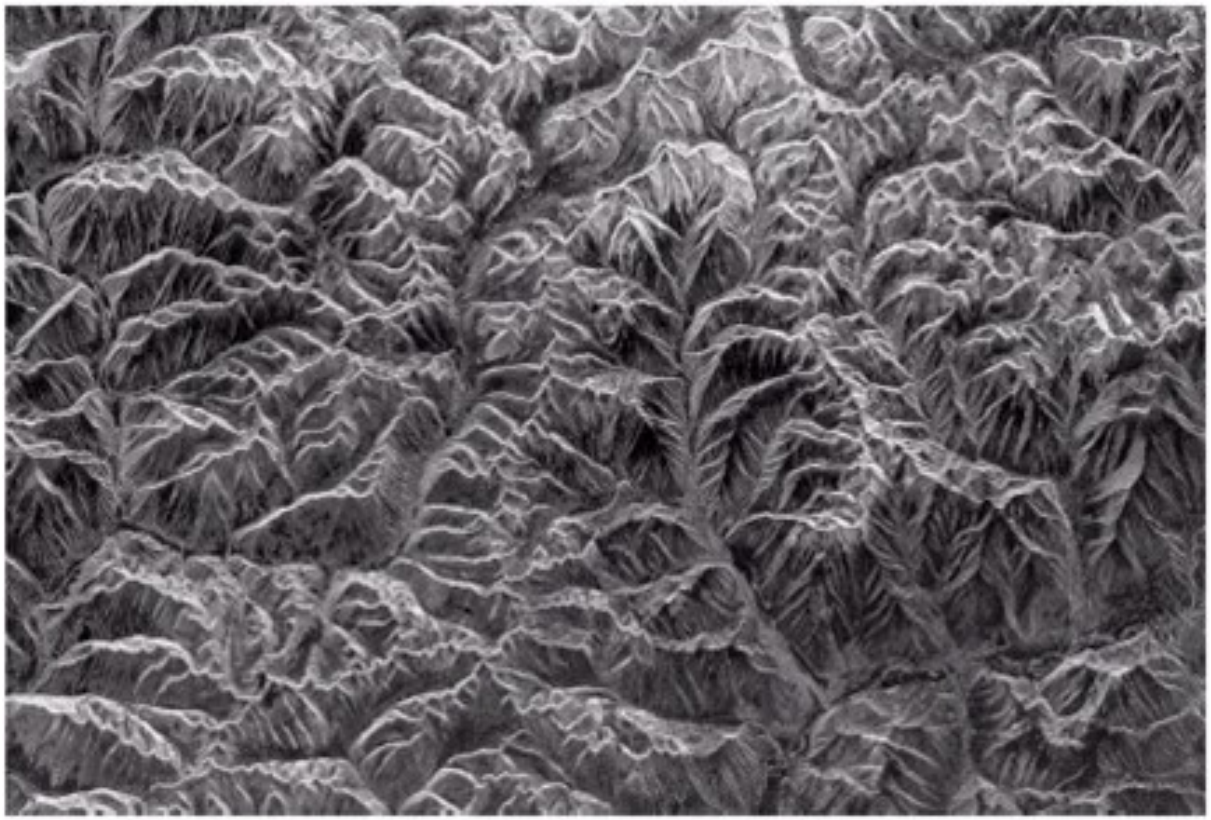
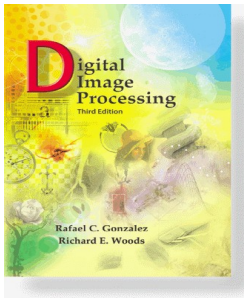


FIGURE 1.16 Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)





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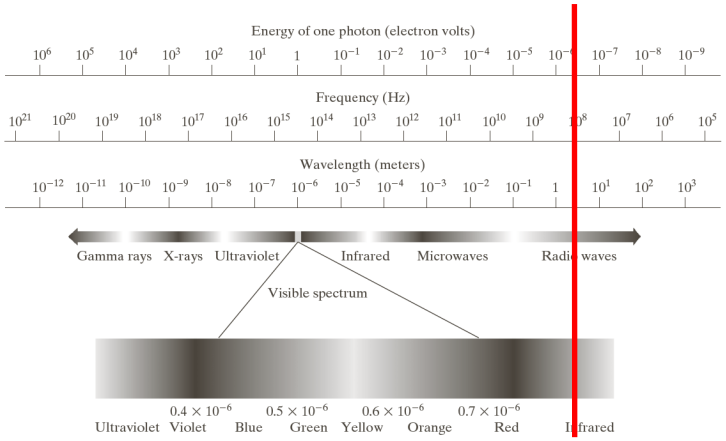
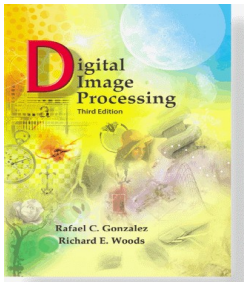


- Imaging in the Radio Bands
  - Medicine: MRI
  - Astronomy



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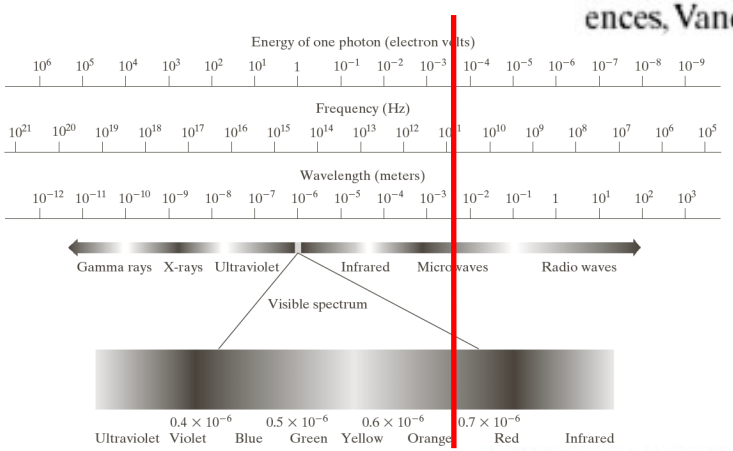
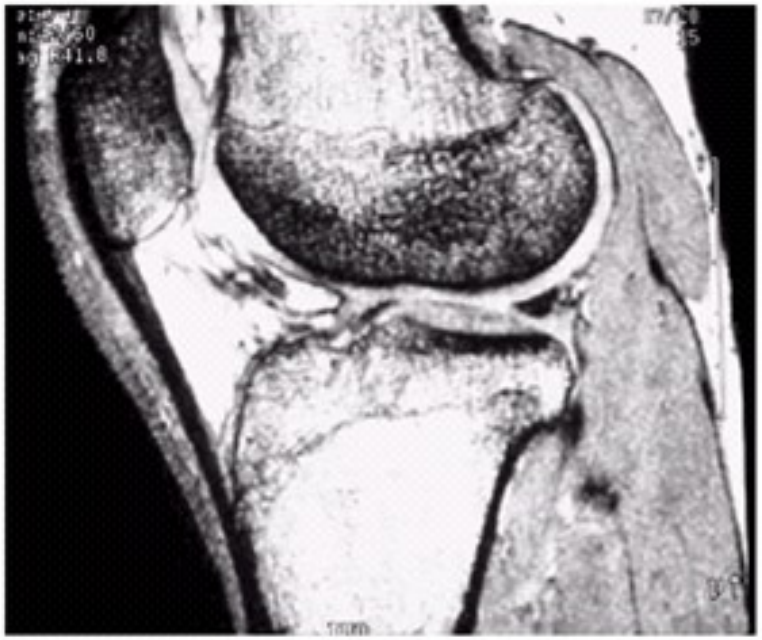
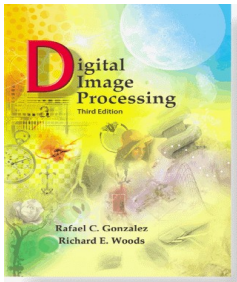
a b

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.)







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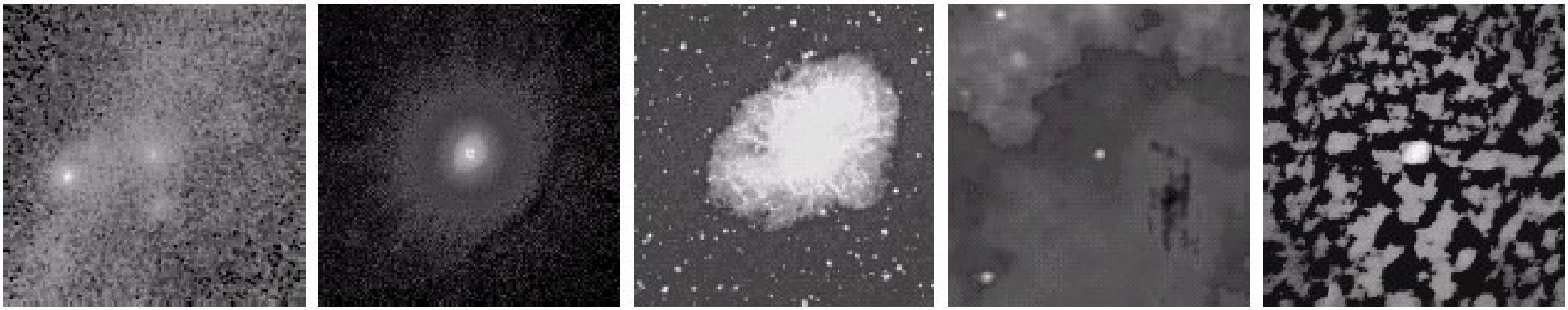
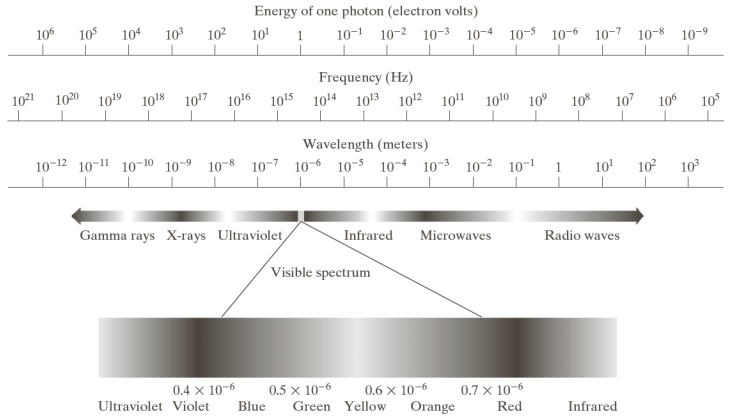
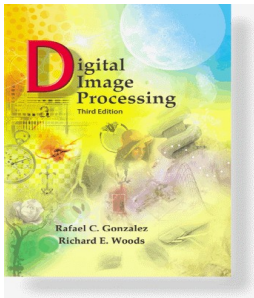


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)





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Non EM

- Acoustic
- Ultrasound
- Electronic
- Synthetic

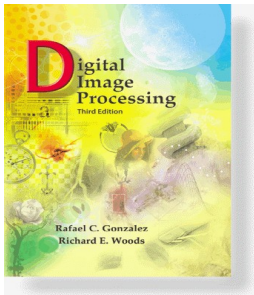

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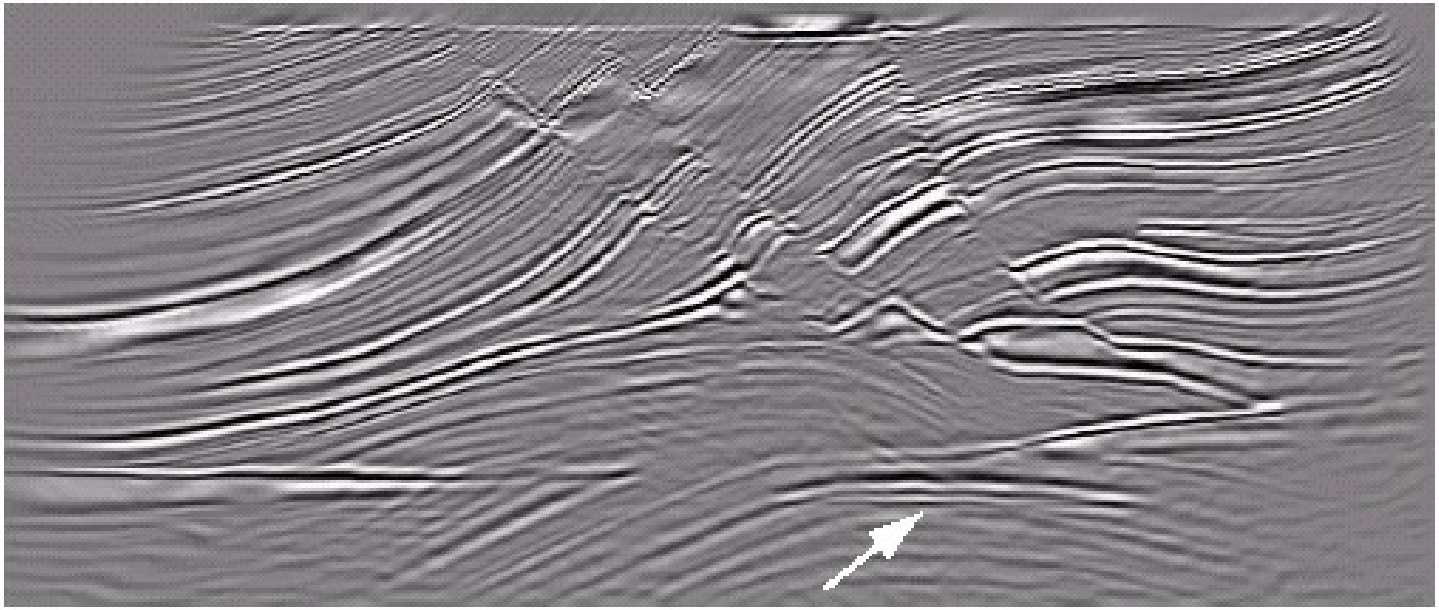
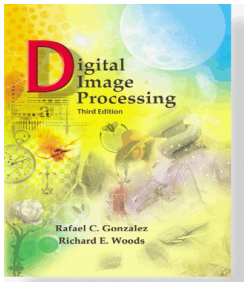
FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)



Seismic Image



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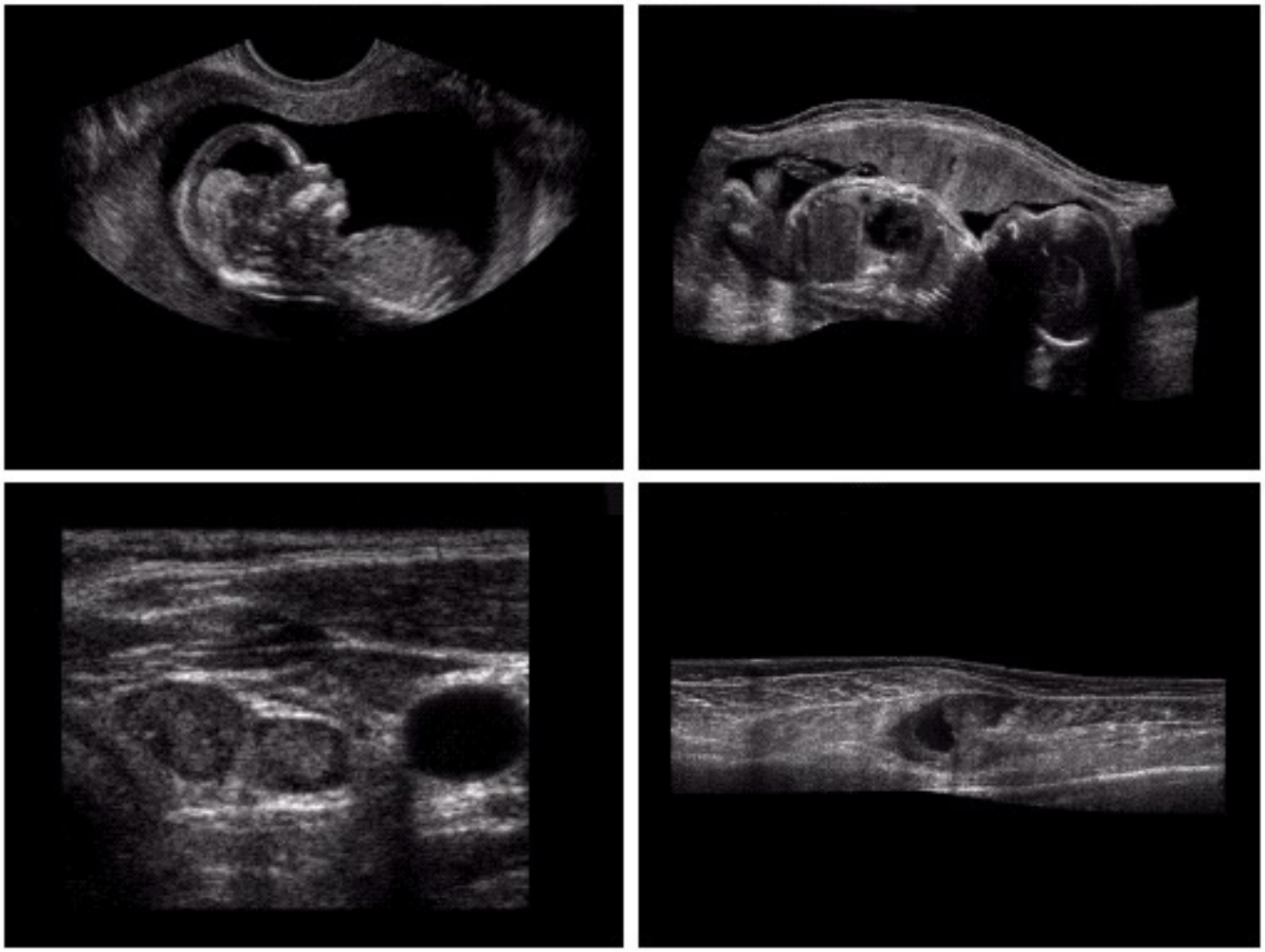
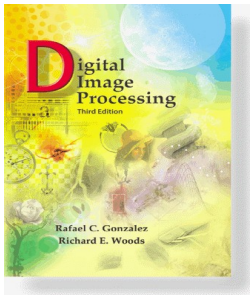


a b
c d

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.)

Ultra Sound Image



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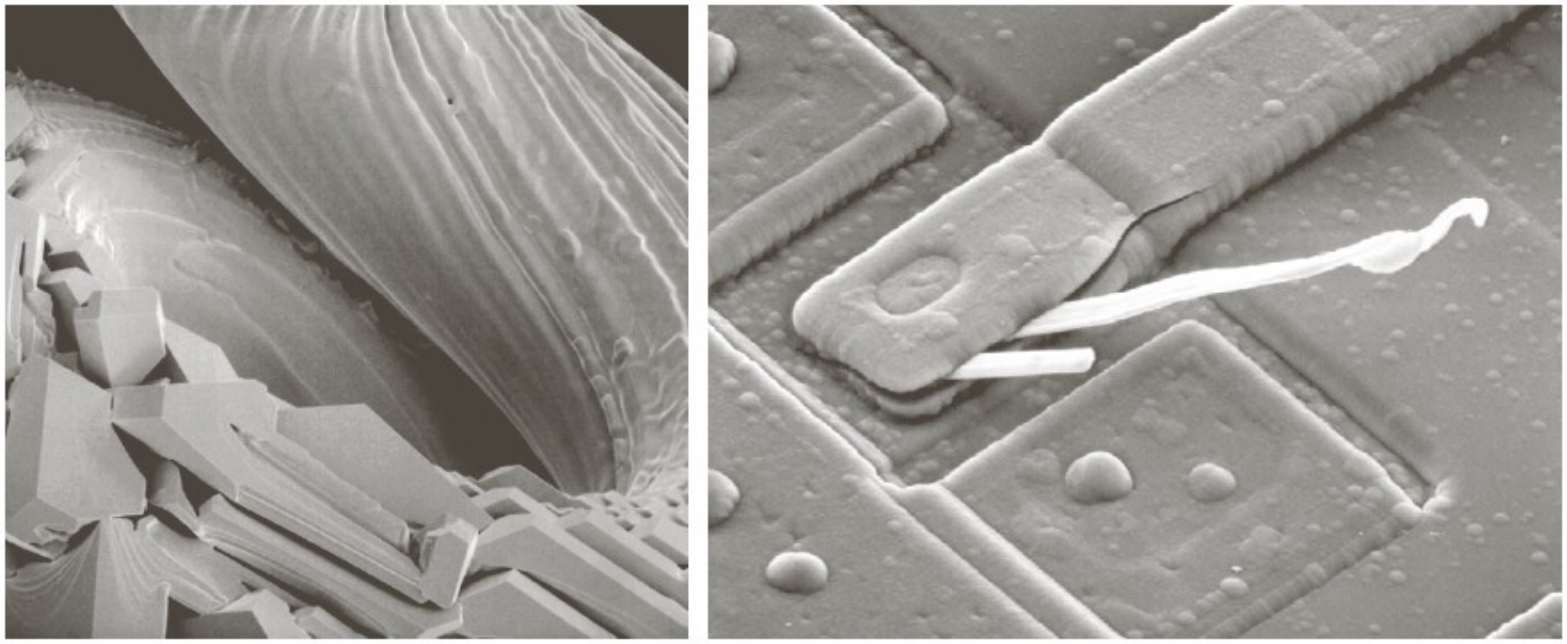
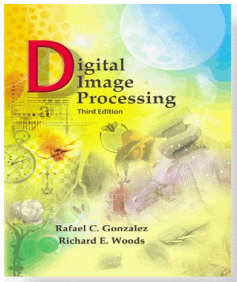
Thermal Image



a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (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.)



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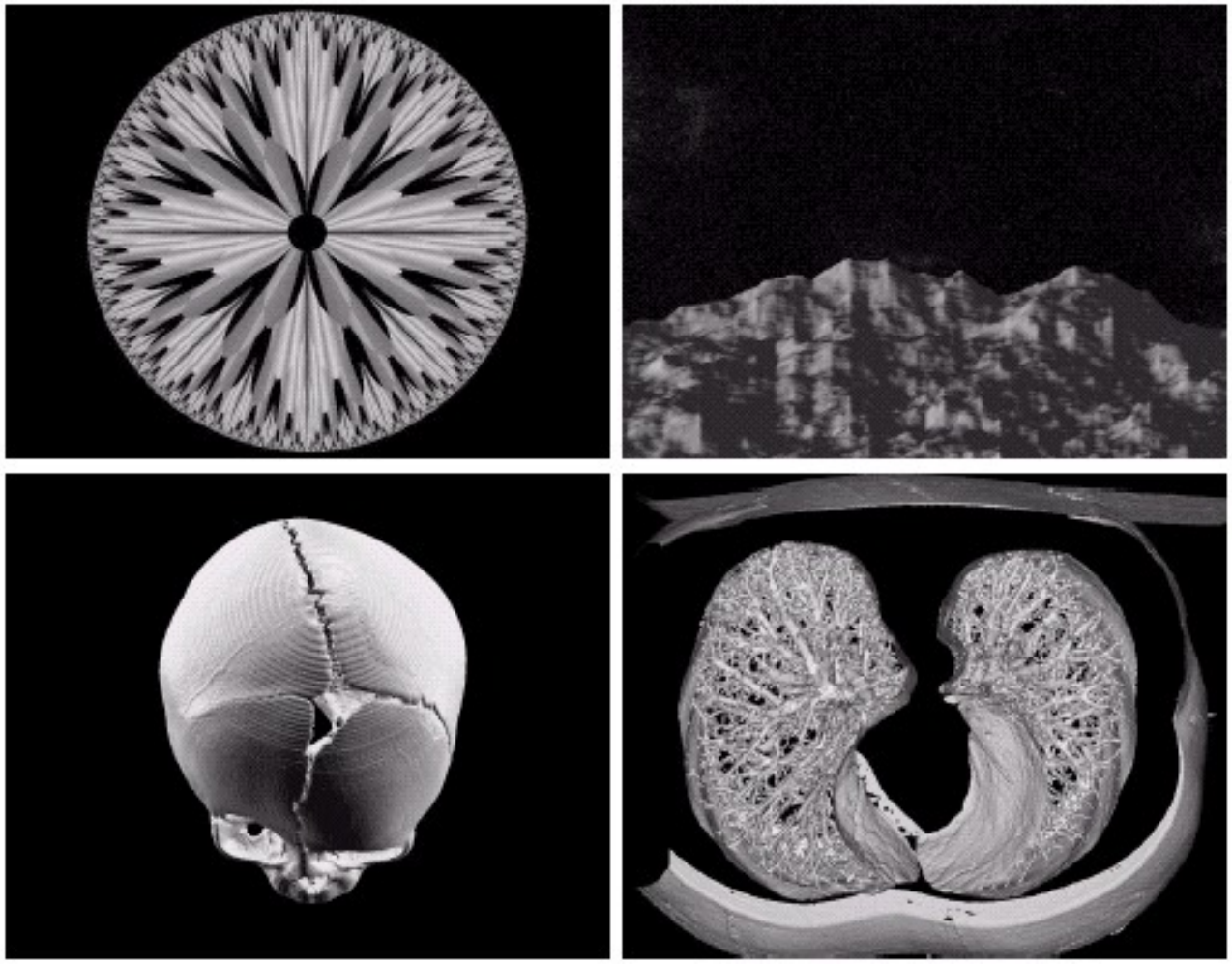

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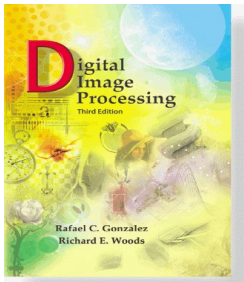
c d

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.)

Graphics Image

- EM
  - Gamma Ray Imaging
  - X-Ray Imaging
  - Imaging in Ultra-Violet Band
  - Imaging in the Visible and Infrared Bands
  - Imaging in the Microwave Bands
  - Imaging in the Radio Bands
- Non EM
  - Acoustic
  - Ultrasound
  - Electronic
  - Synthetic



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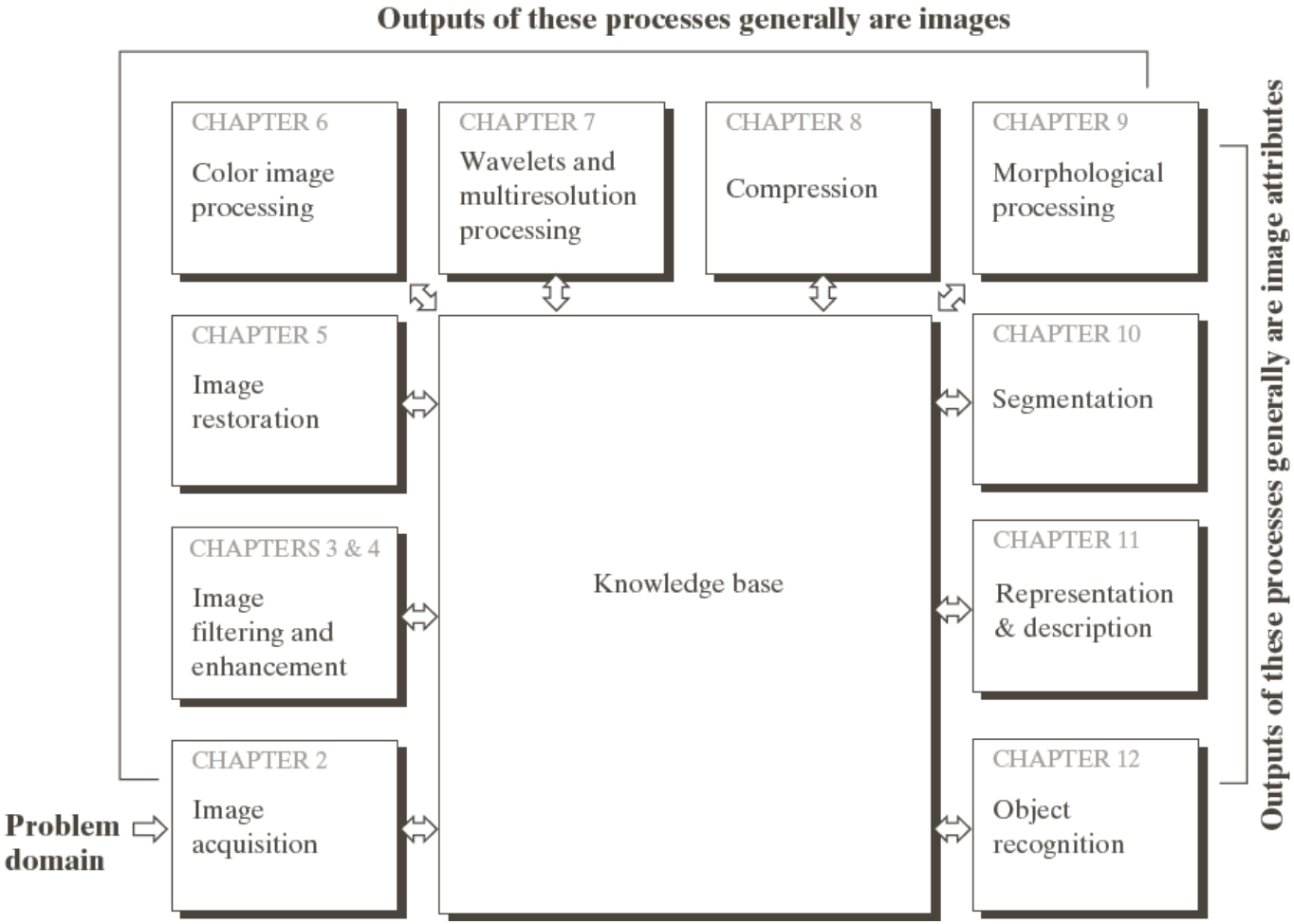
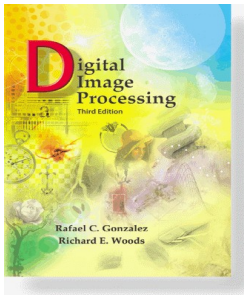


FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.



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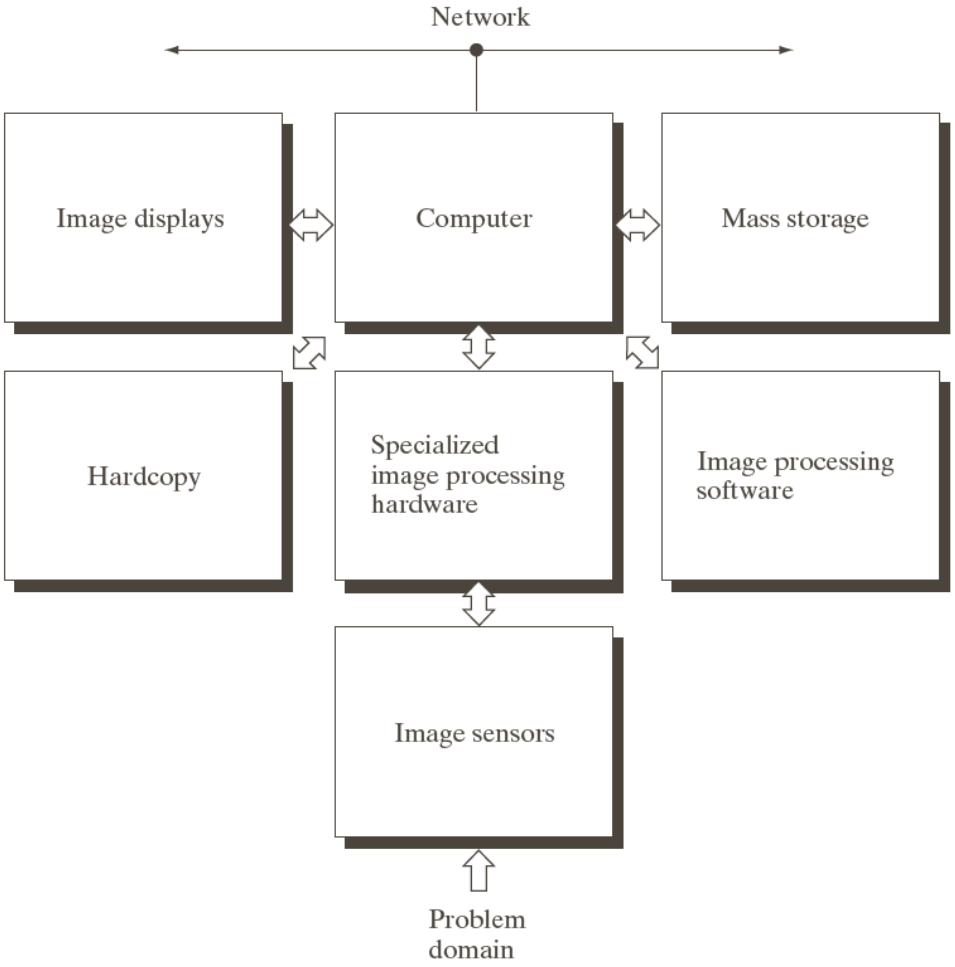

FIGURE 1.24 Components of a general-purpose image processing system.