What is Digital Image Processing

- An image may be defined as:
  - A 2-d function, f(x,y).
  - where x and y are spatial (plane) coordinates
  - And the amplitude of ‘f ‘at (x,y) is called intensity or gray level of the image at that point.
- Digital Image:
  - x, y and intensity values of ‘f ‘are all finite and discrete quantities.
- Digital Image Processing:
  - Processing digital images by means of a digital computer

Why Digital image processing

- Interest in Digital image processing stemmed from two application areas:
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception.

Pixel

- A digital image is composed of finite number of elements called pixels.
- A pixel have a location, (x,y), and value, f(x,y).

Image processing, Image Analysis, Computer Vision

- low, mid, and high level processes
- Low level processing - inputs and outputs are images
  - Reduce noise
  - Contrast enhancement
  - Image sharpening
- Mid level processing-inputs are images and ouputs are attributes (eg., edges,contours, identity of individual objects)
  - Segmentation (partitioning an object in to regions or objects)
  - Description of those objects (feature vector)
  - Classification (recognition)
- High level processing
  - Making sense of the content of the input image
  - Cognitive functions (like humans) such as learning, inferencing,decision making, acting

Origins and applications of Digital Image Processing

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.)

- The first computers powerful enough to carry out meaningful image processing tasks appeared in the early 1960s.
- The following are the areas where images are processed for human interpretation:
  - Space
  - Medical imaging
  - Remote Earth resources observation
  - Astronomy
  - Archaeology
  - Physics
  - Defence
  - industry

- Typical problems in machine perception that utilize image processing techniques are:
  - Automatic character recognition
  - Product assembly and inspection
  - Military recognizance
  - Automatic processing of finger prints
  - Screening of X-rays and blood samples
  - Weather prediction and environmental assessment

Categorization of images according to their source

- The principal energy source for images in use today is the electromagnetic energy spectrum.

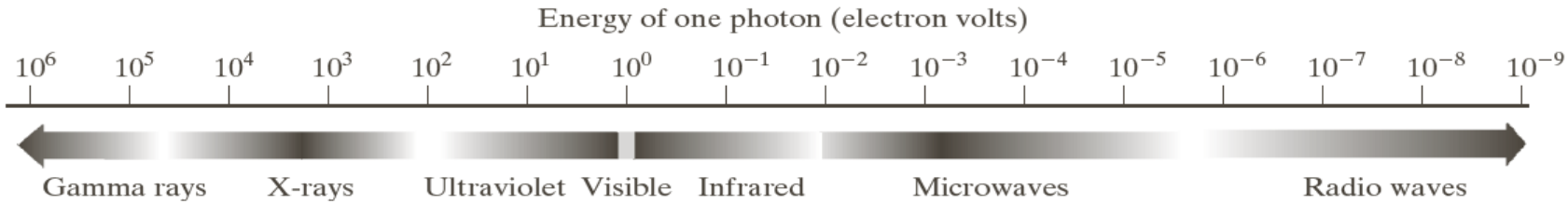

FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

- Other important sources of energy include
  - Acoustic
  - Ultrasonic
  - Electronic
- Synthetic images generated by computers

- Nuclear medicine
- Astronomical imaging

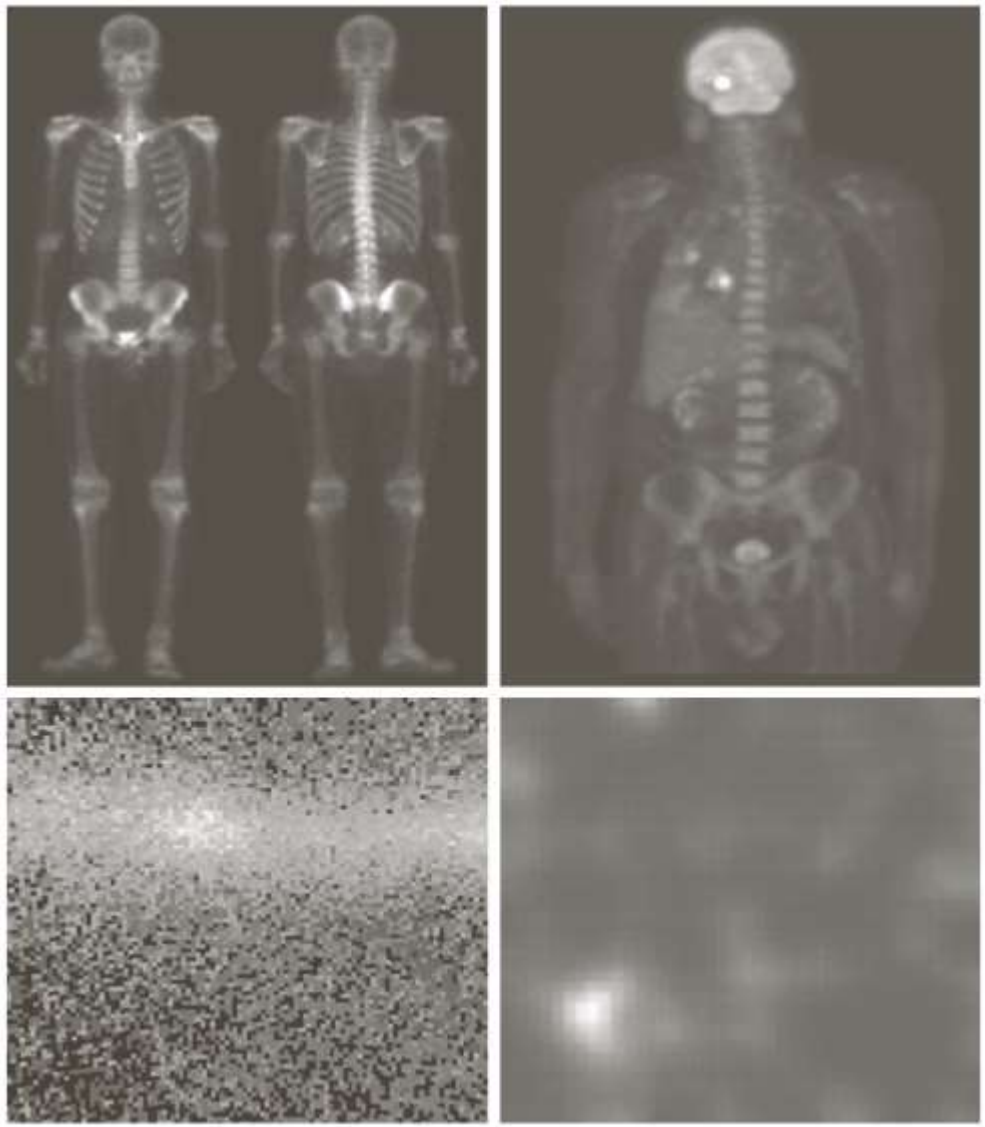

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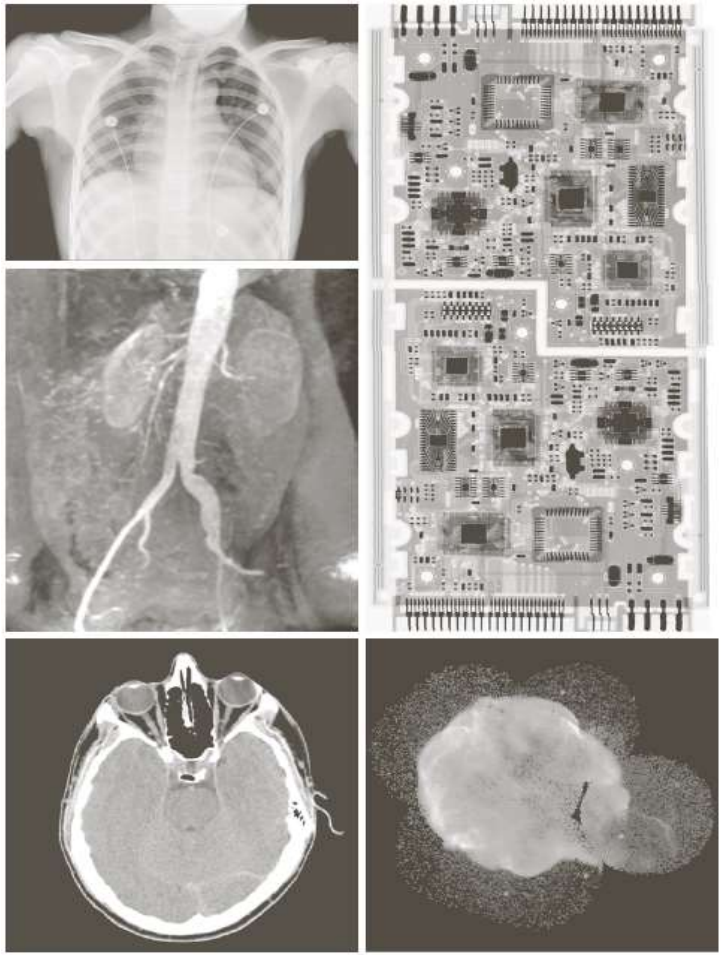
FIGURE 1.6
Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of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

- Medical diagnostics
- astronomy



a b d c 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.)

- Fluorescence microscopy
- Biological imaging
- astronomy

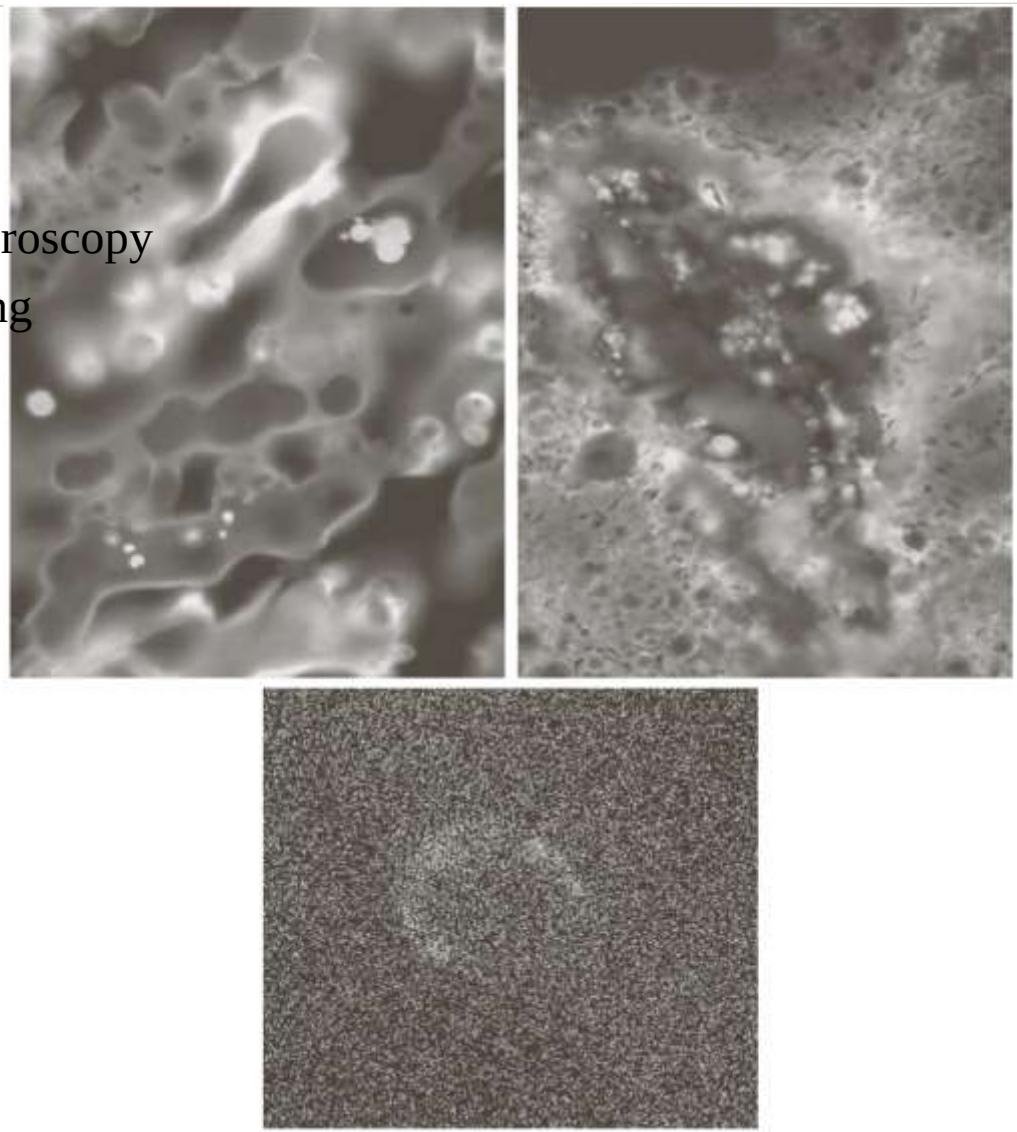


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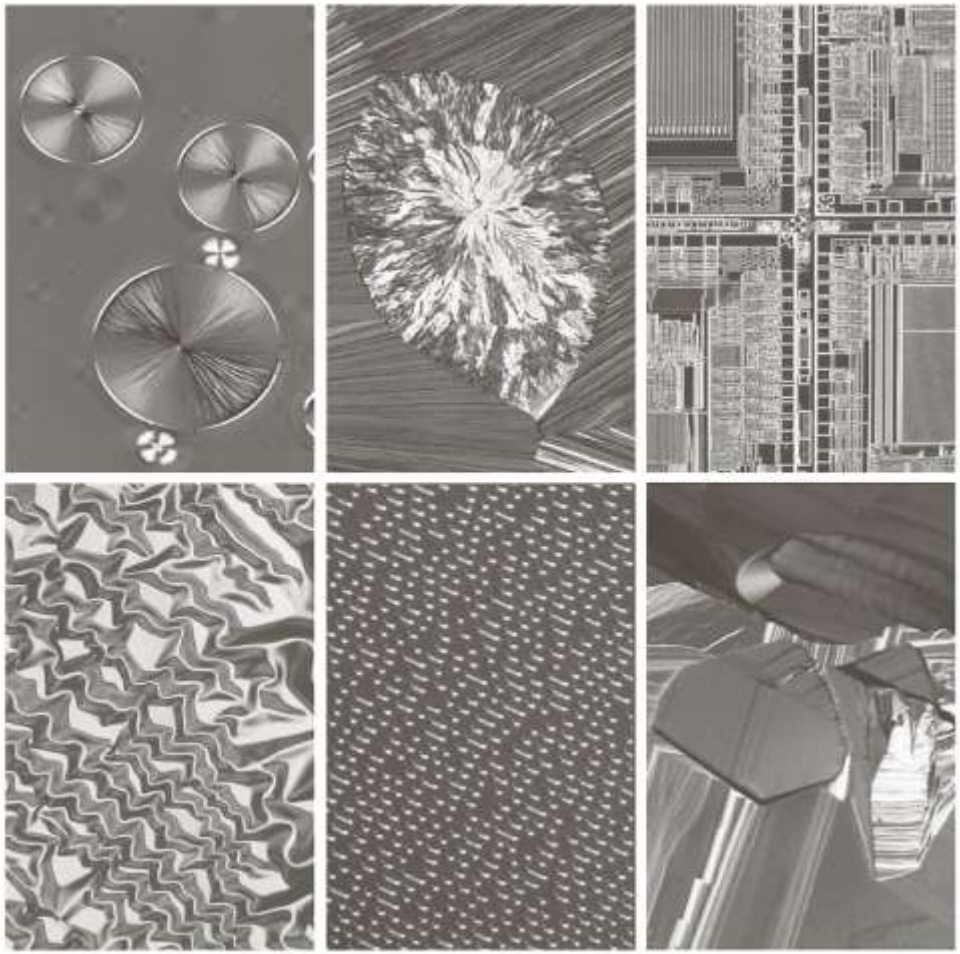
FIGURE 1.8
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University,
(c) NASA.)



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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.)

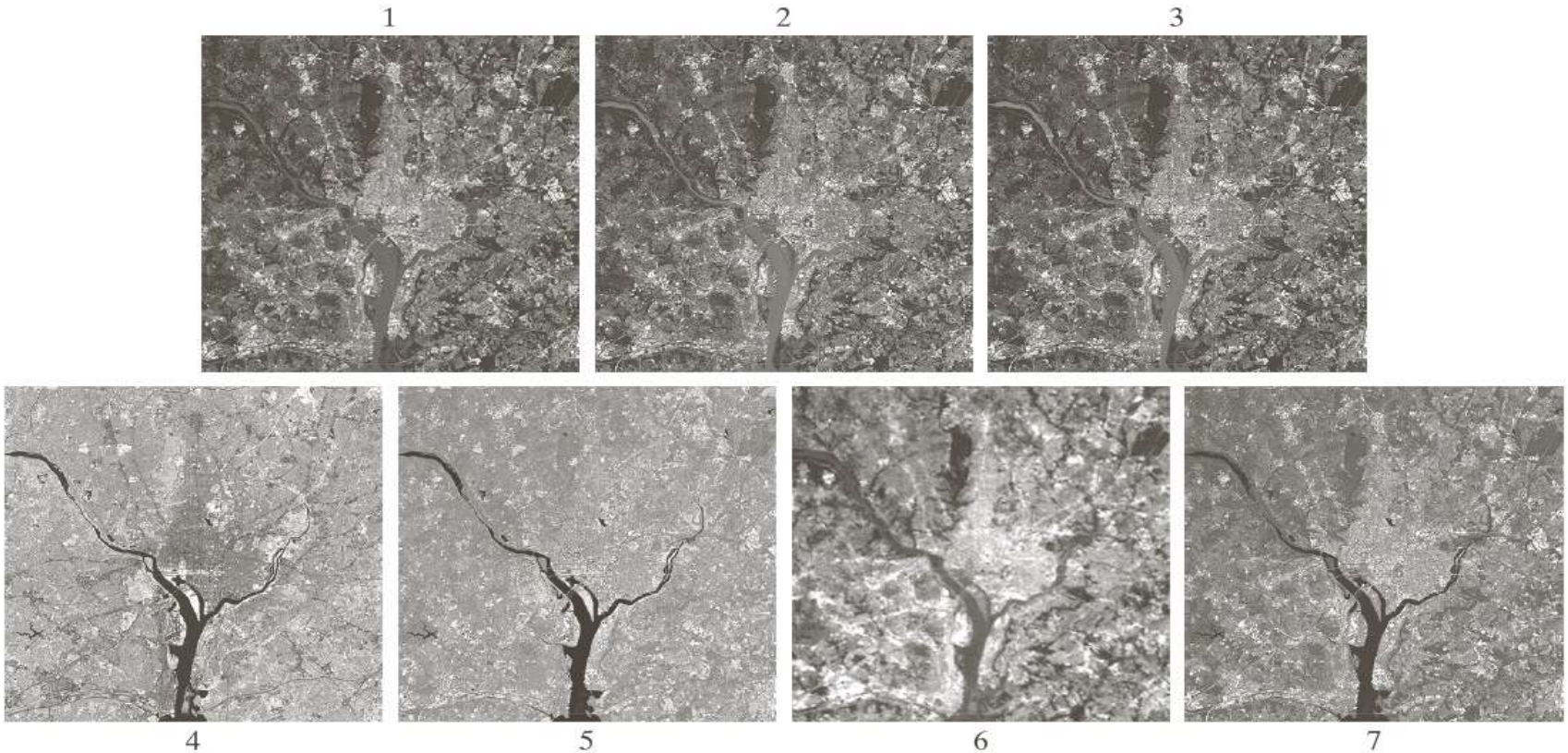


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

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

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

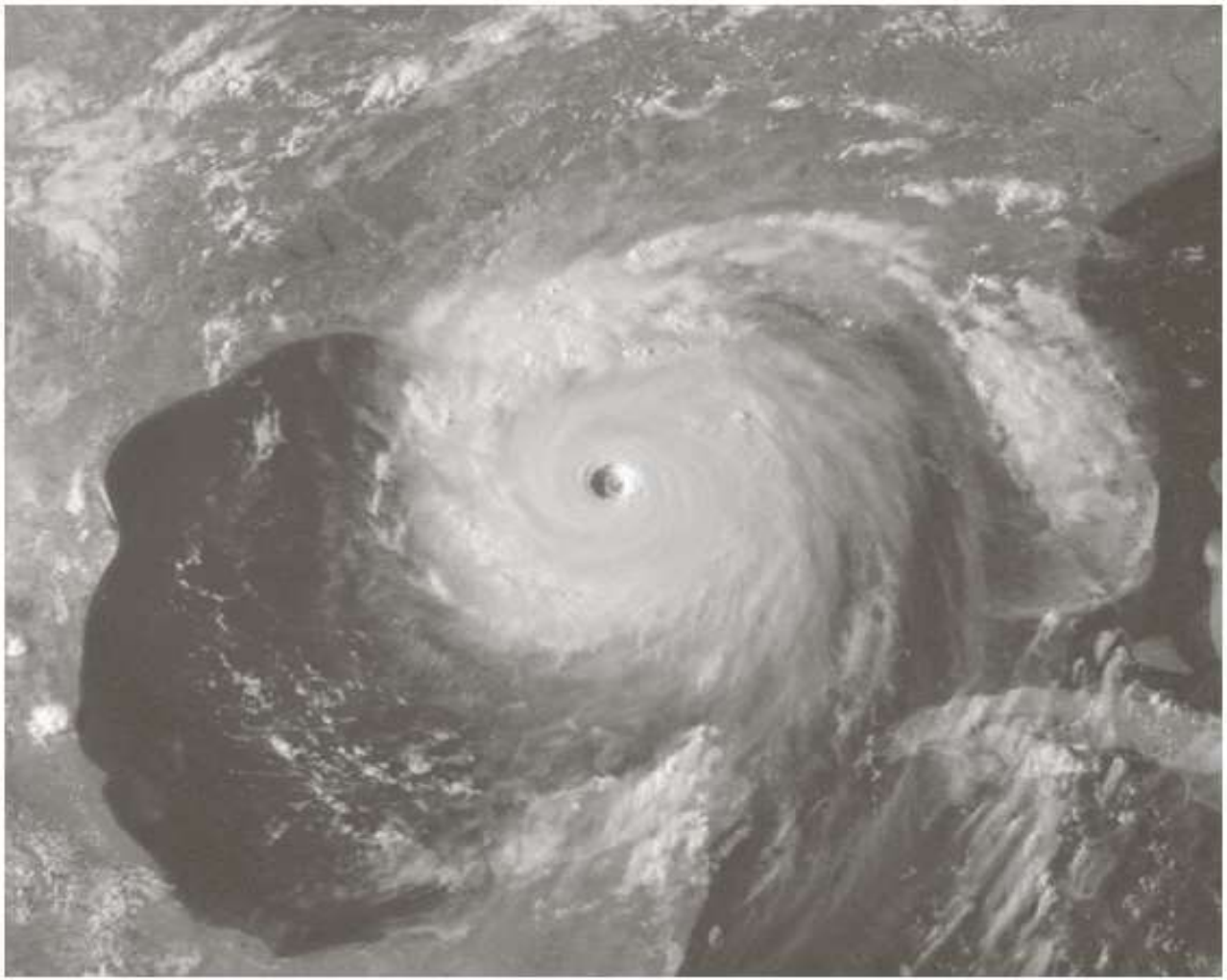


FIGURE 1.11
Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

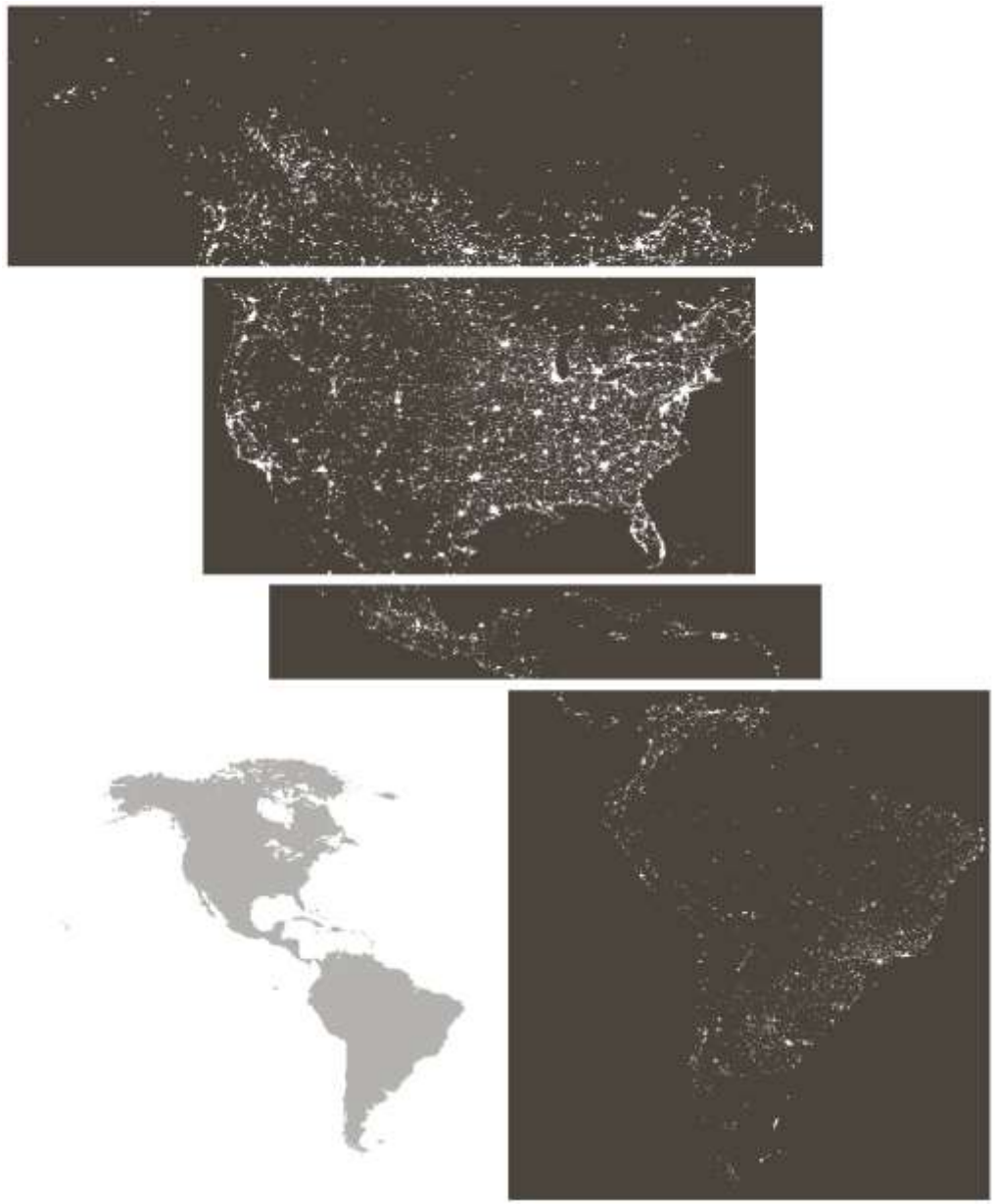
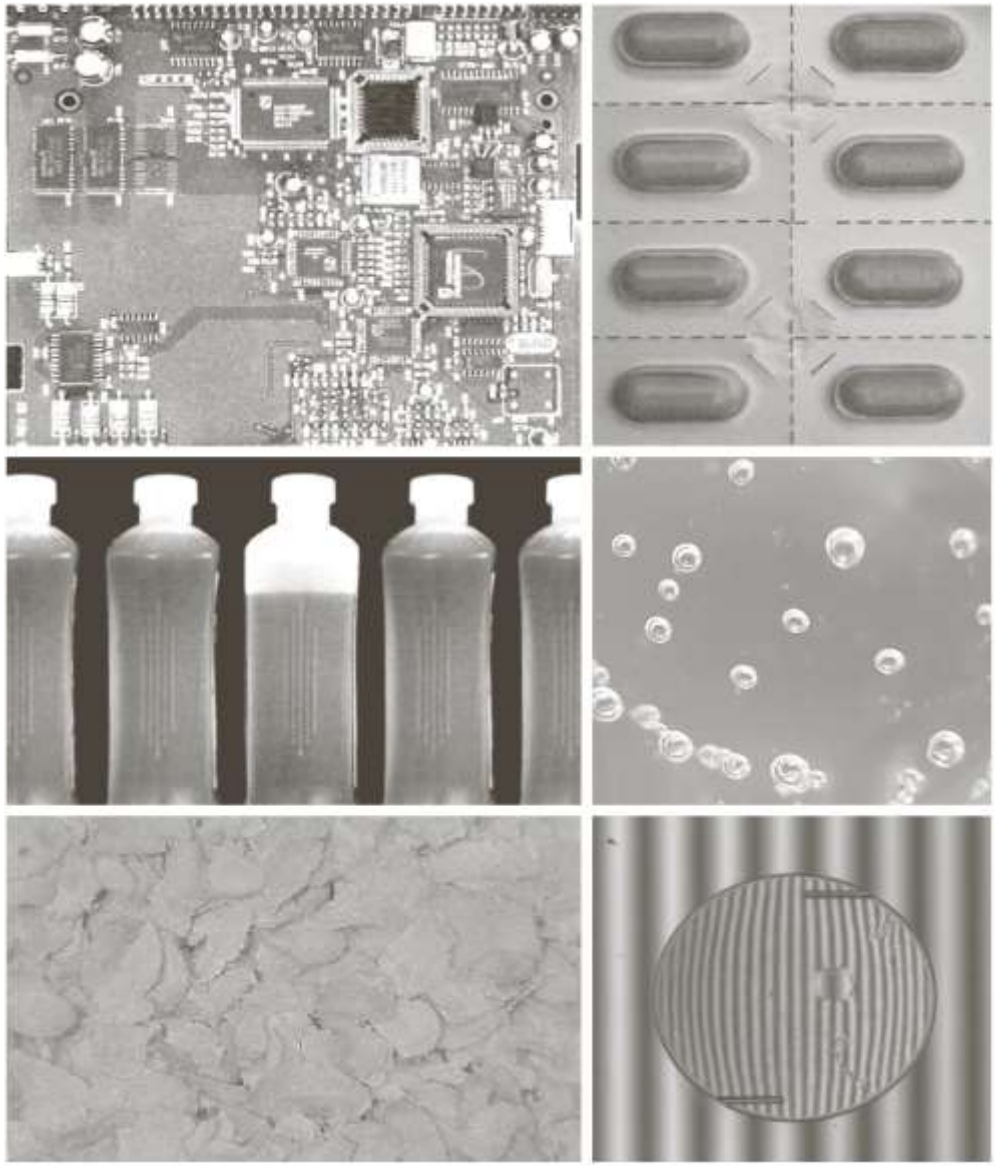


FIGURE 1.12
Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)

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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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.)

a b
c
d

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.)

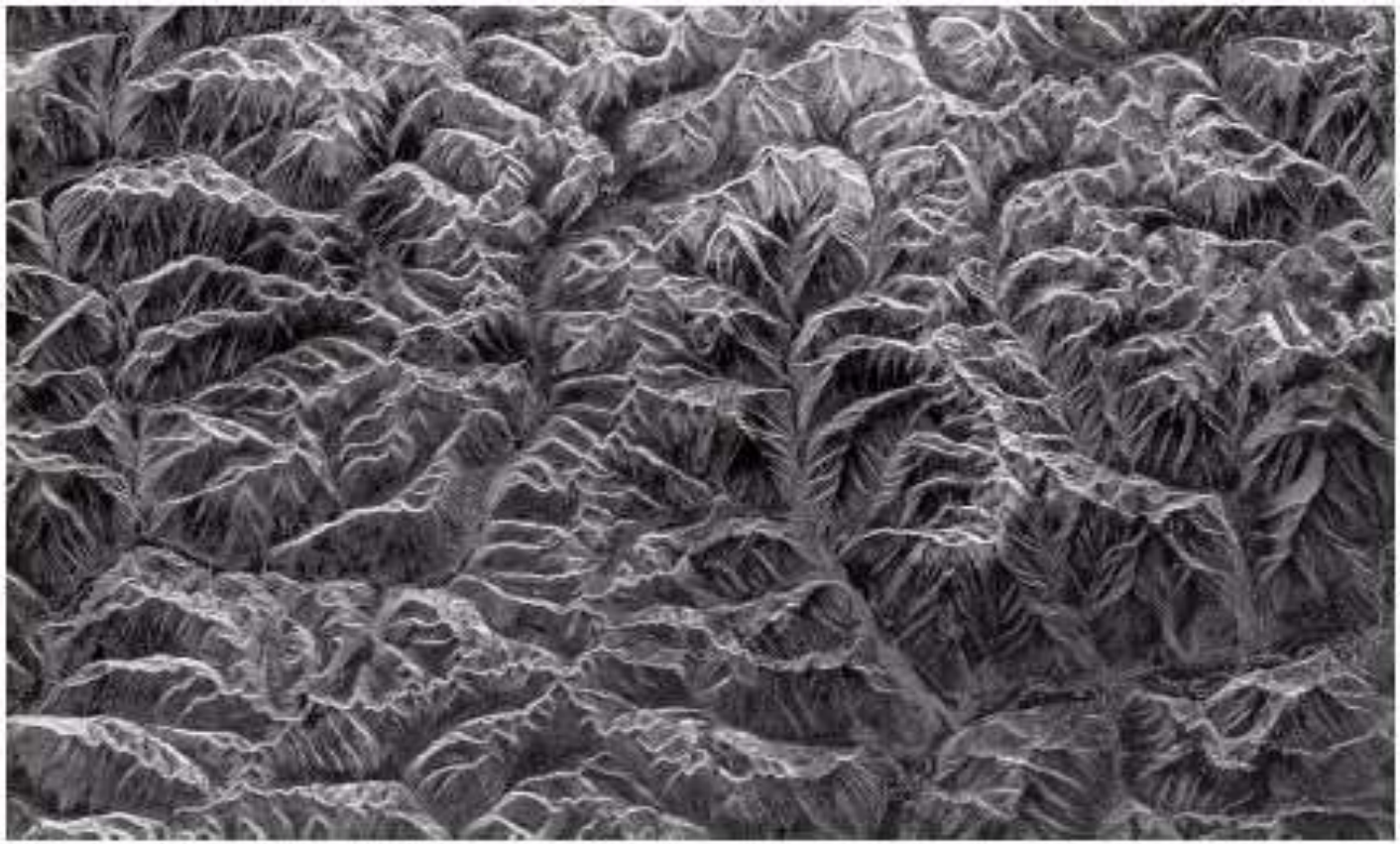

FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

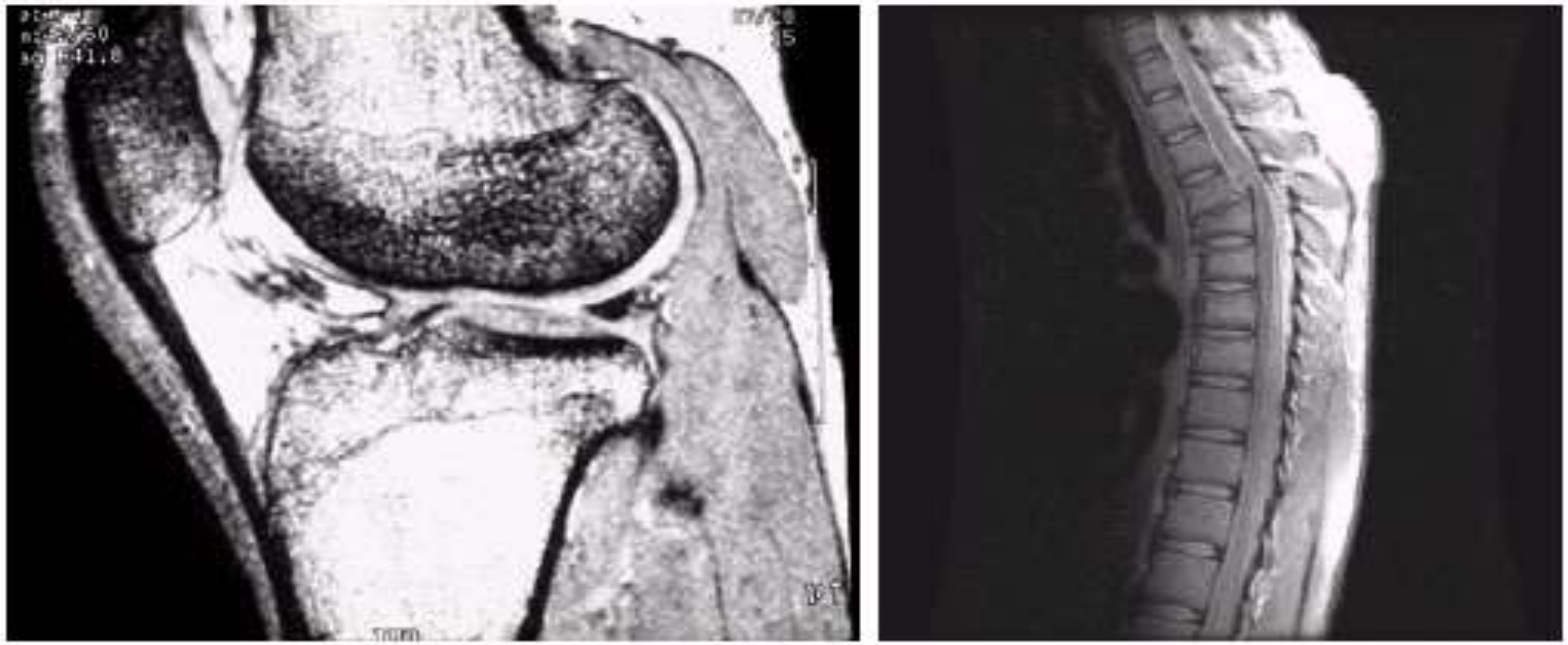

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FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences,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

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

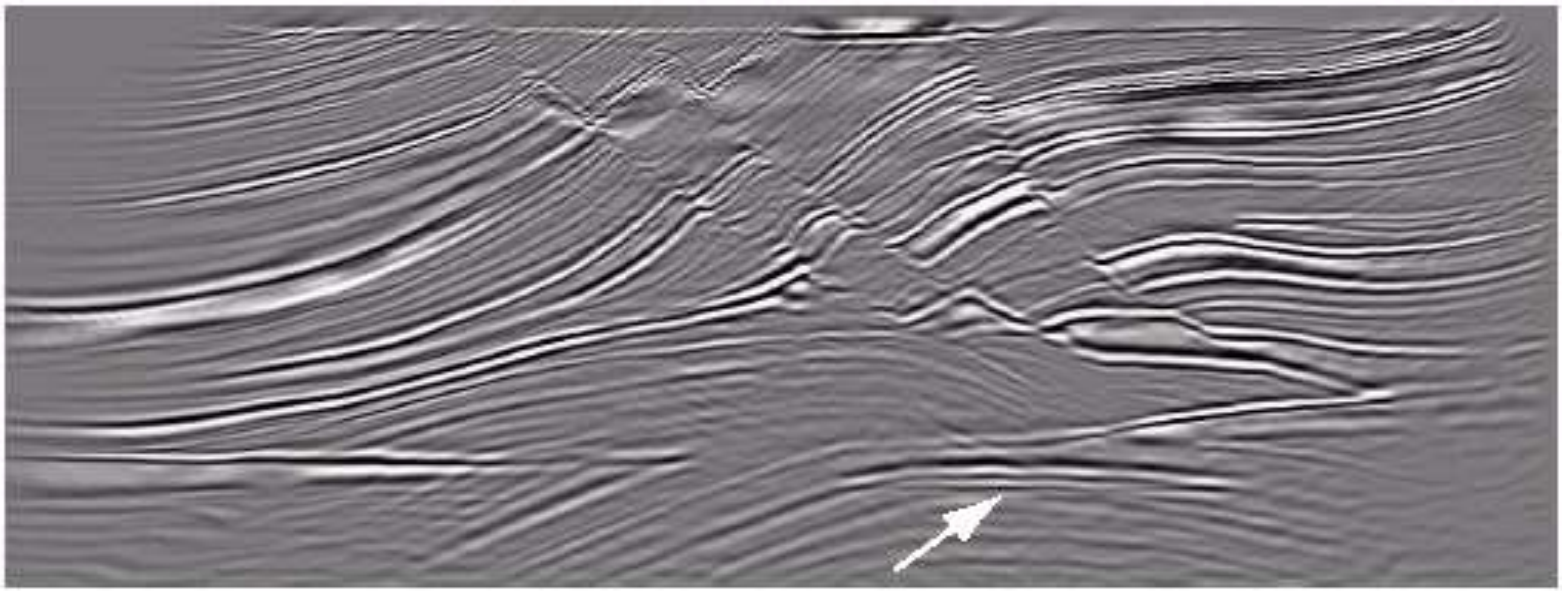

FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

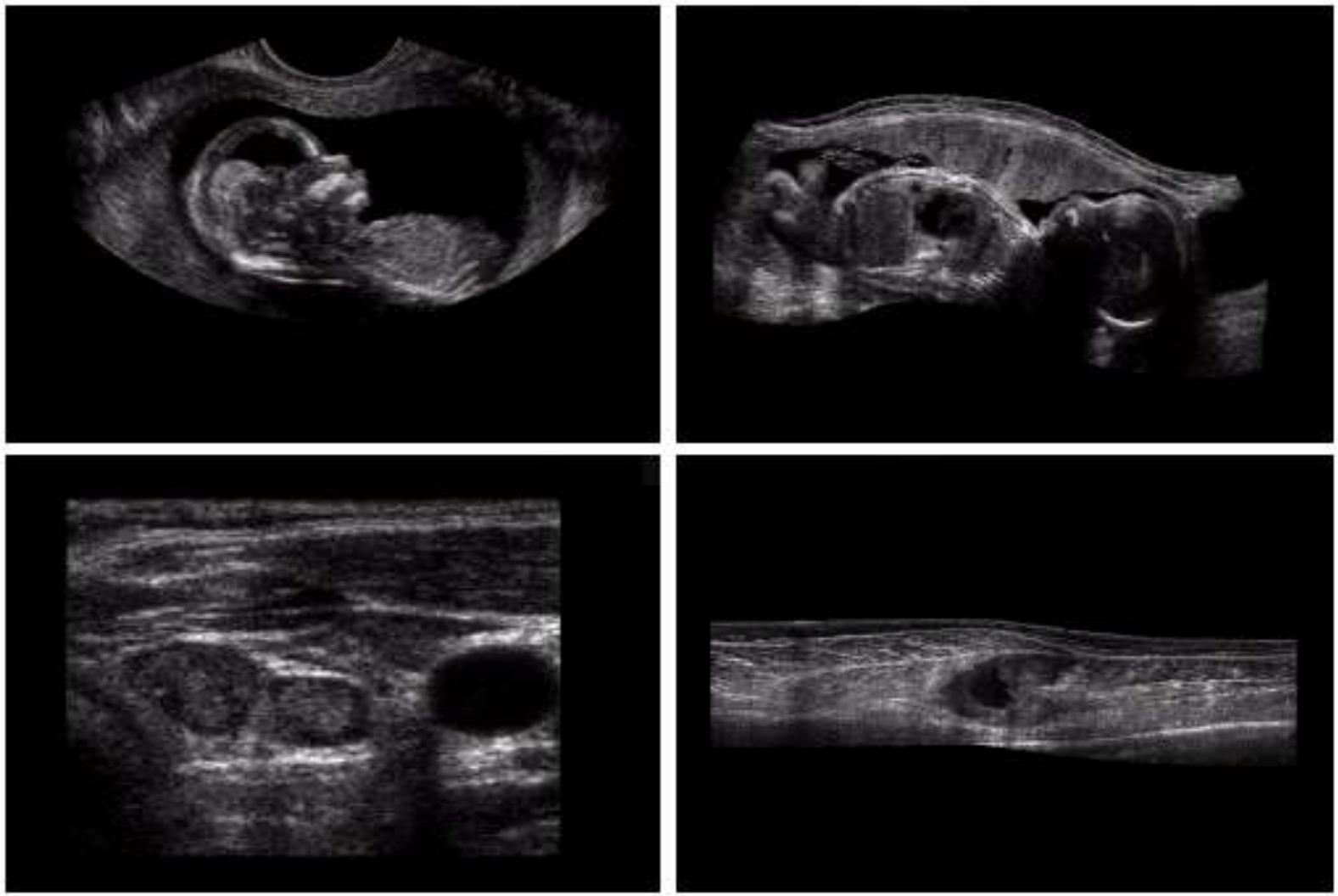

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FIGURE 1.20
Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

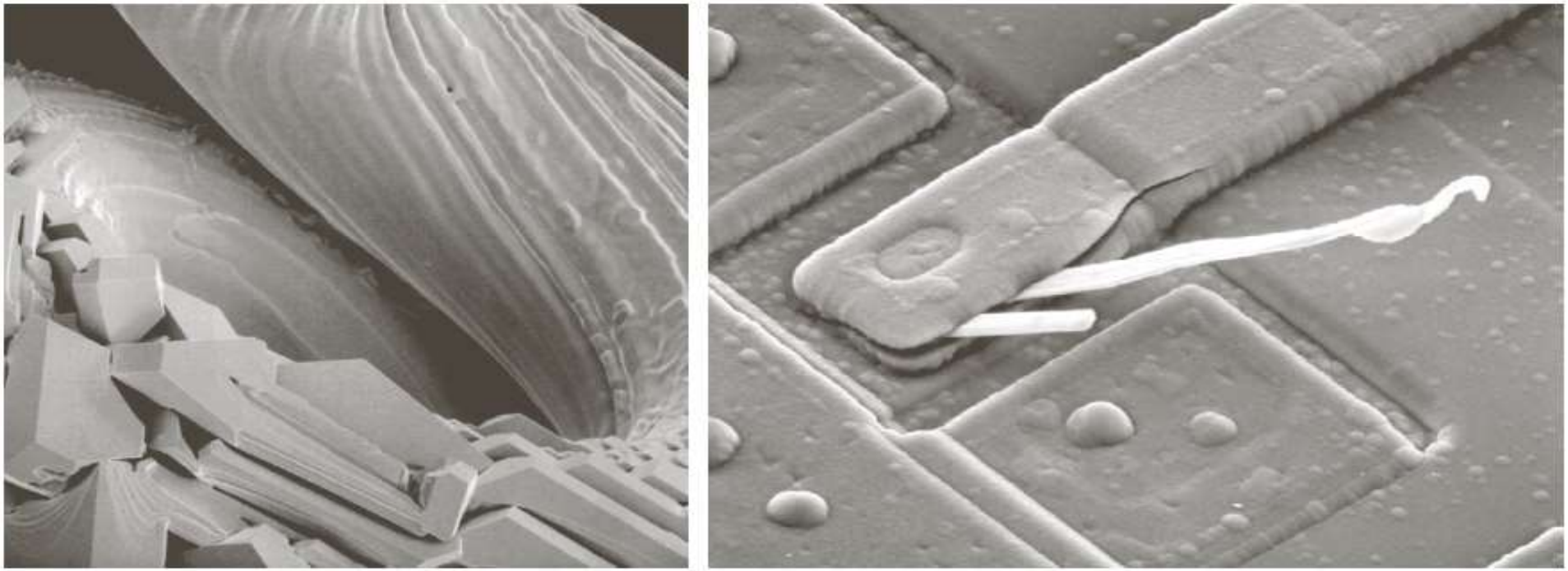

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FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (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.)

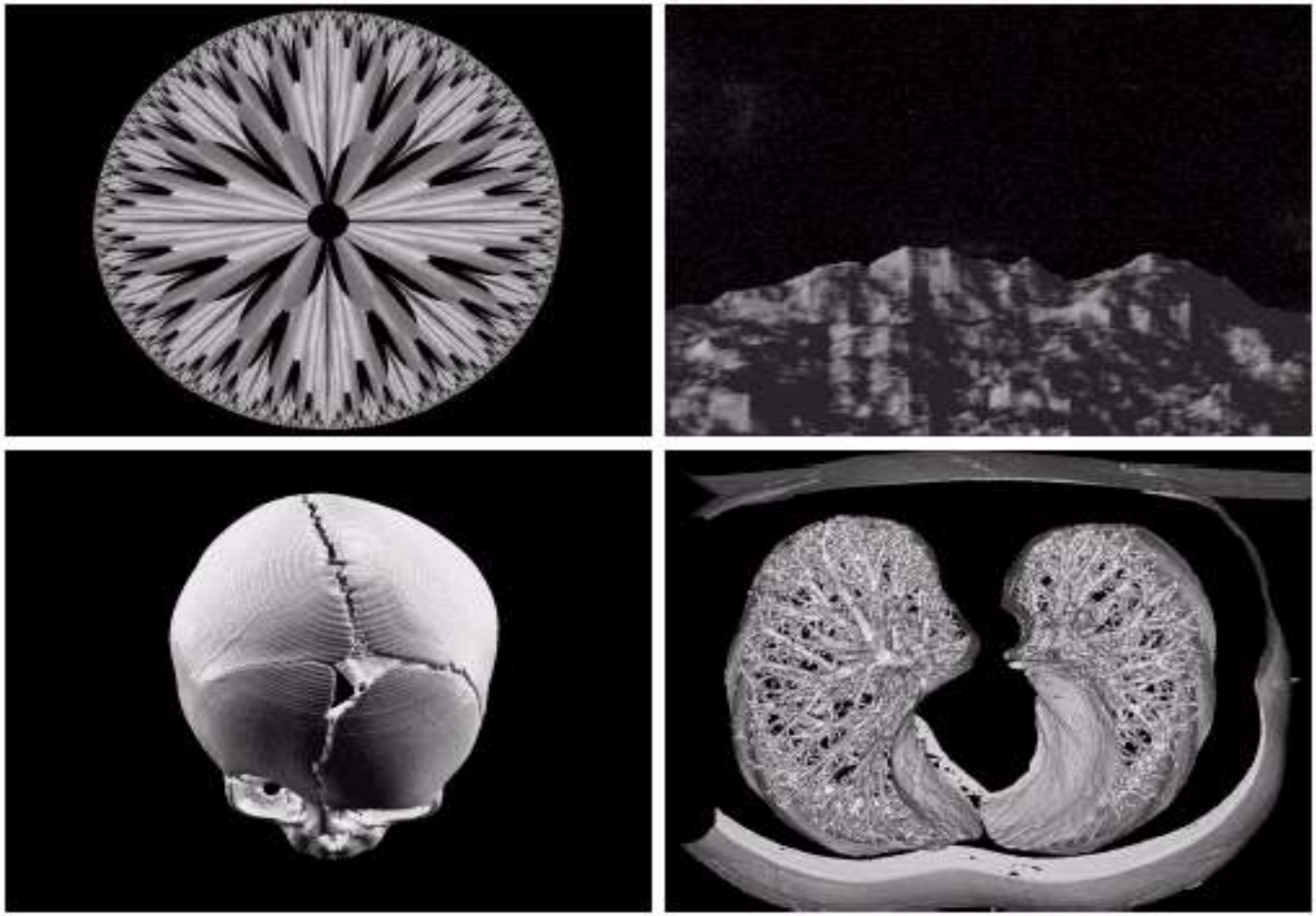

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FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

Fundamental steps in Digital Image Processing

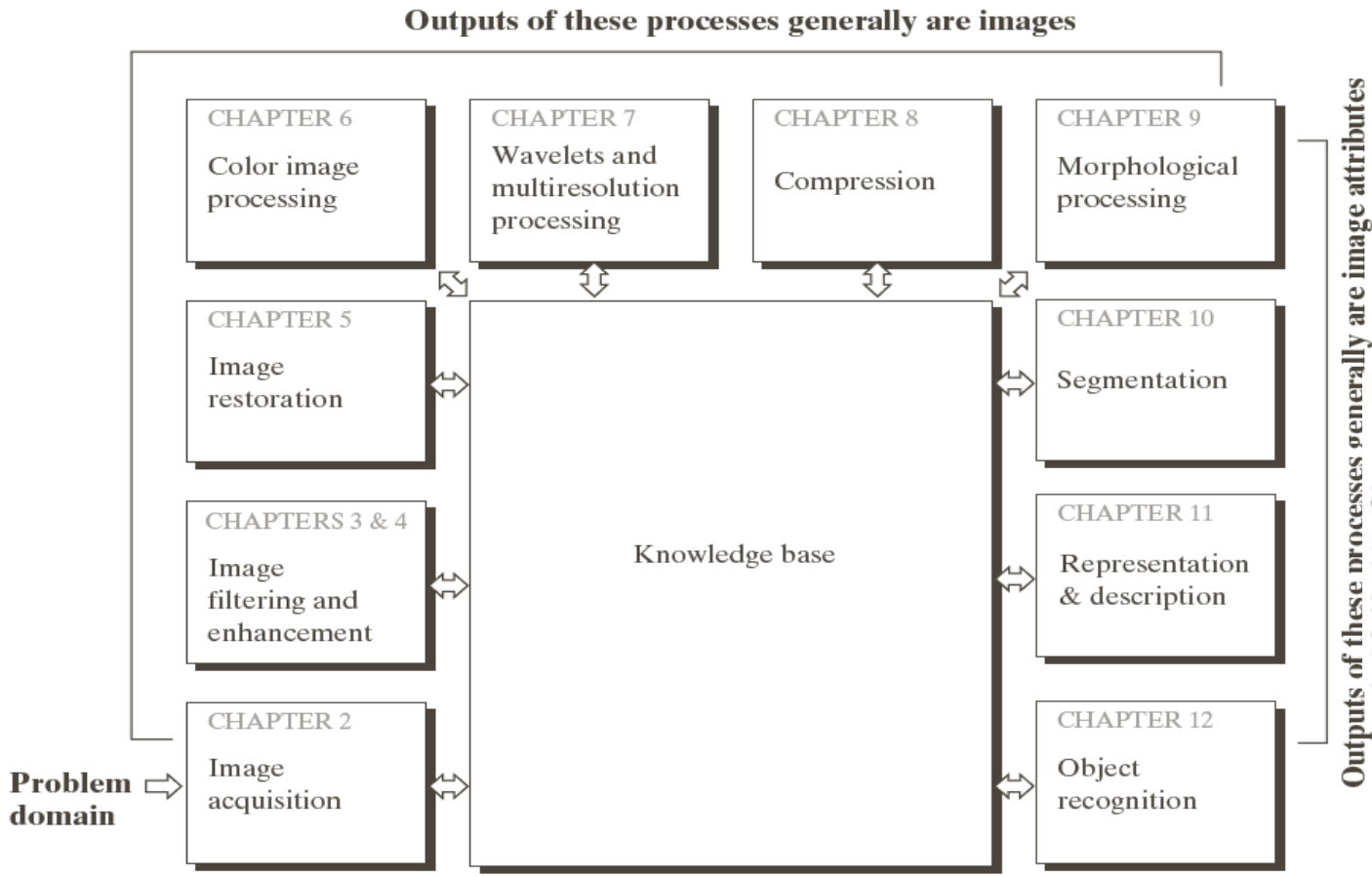

FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

Fundamental steps in Digital Image Processing

- Image acquisition
  - getting images in digital form and scaling
- Image enhancement
  - Improving the appearance of an image so that it is suitable for a specific application
  - Techniques may differ based on application
  - X-ray images enhancement techniques may not suit for satellite images taken in infrared band of EM waves.
  - subjective
- Image restoration
  - Improving the appearance of an image
  - Objective (based on mathematical or probabilistic models of image degradation)

- Color image processing
  - Modeling color
- Wavelets
  - Representing images in various degrees of resolution
  - Used for image data compression
  - Pyramidal representation(images are subdivided in to smaller regions)
- Compression
  - For reducing the storage required to save an image
  - For reducing the bandwidth required to transmit an image
- Morphological processing
  - Extracting image components that are useful in representing and description of shape
- Segmentation
  - Partition an image into its constituent parts or objects

- Representation and description
  - Output of segmentation is either region or boundary
  - Boundary representation
    - When focus is on external shape, such as corners and inflections
  - Region representation
    - When focus is on internal properties, such as texture or skeletal shape
  - Description, also called feature selection
    - Extracting attributes for differentiating one class of objects from another
- Recognition
  - Assigns a label to an object based on descriptors
- Knowledge base
  - Guide the operation of each processing module
    - Detailing regions of an image where the information of interest is located
    - Interrelated list of all major possible defects in a material inspection problem.
  - Controls the interaction between modules

Components of an Image Processing System

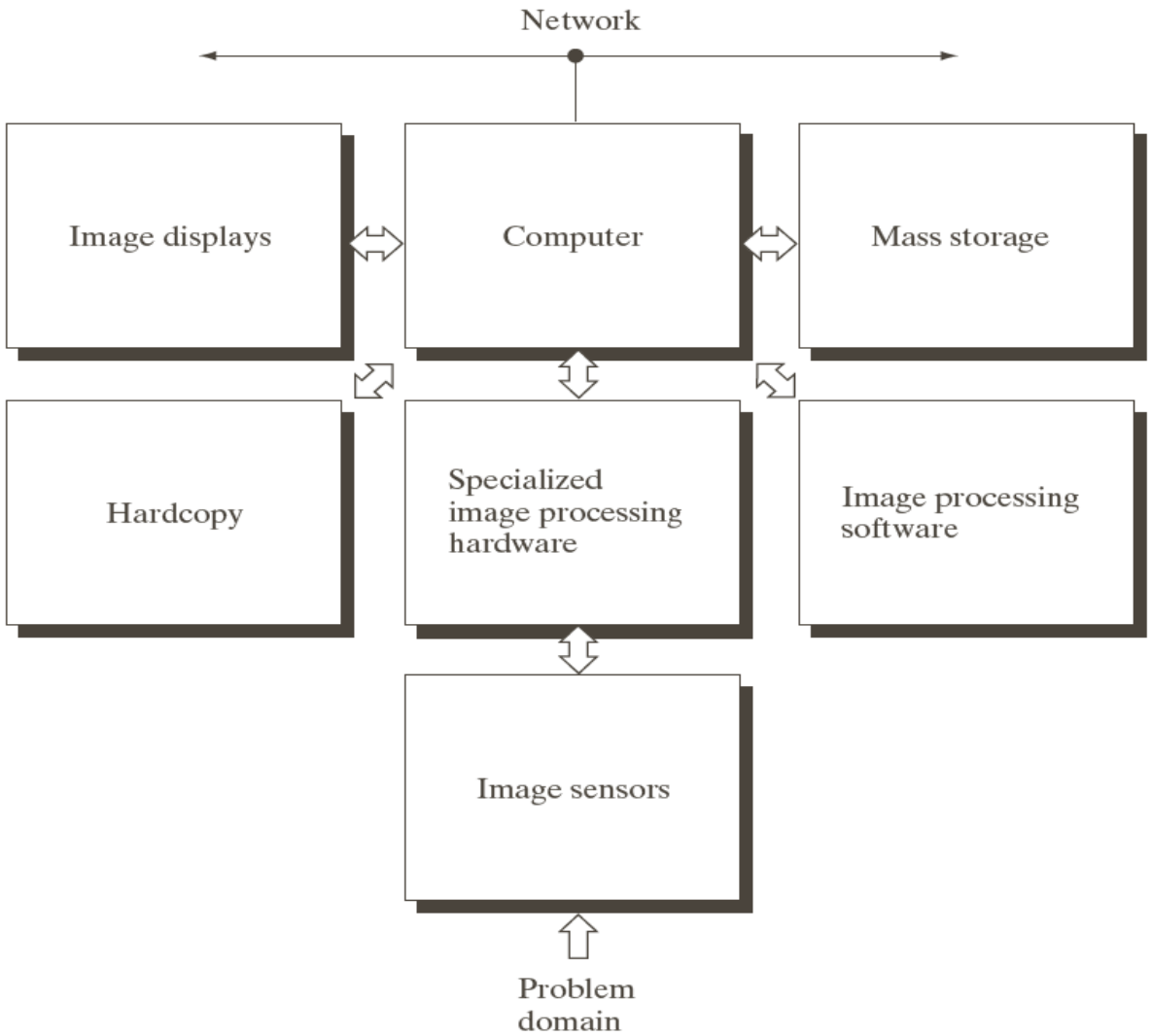

FIGURE 1.24 Components of a general-purpose image processing system.