



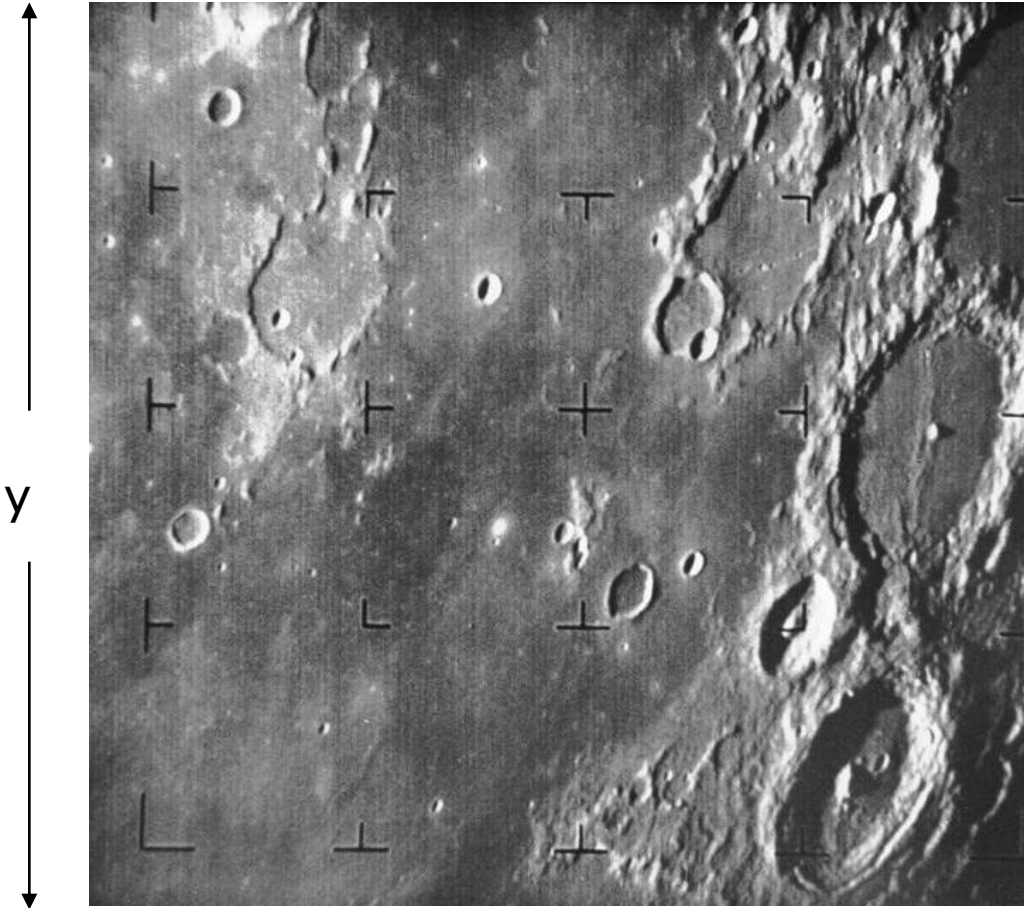
# Biomedical Image Processing

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## Introduction

# What Is Digital Image Processing?

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



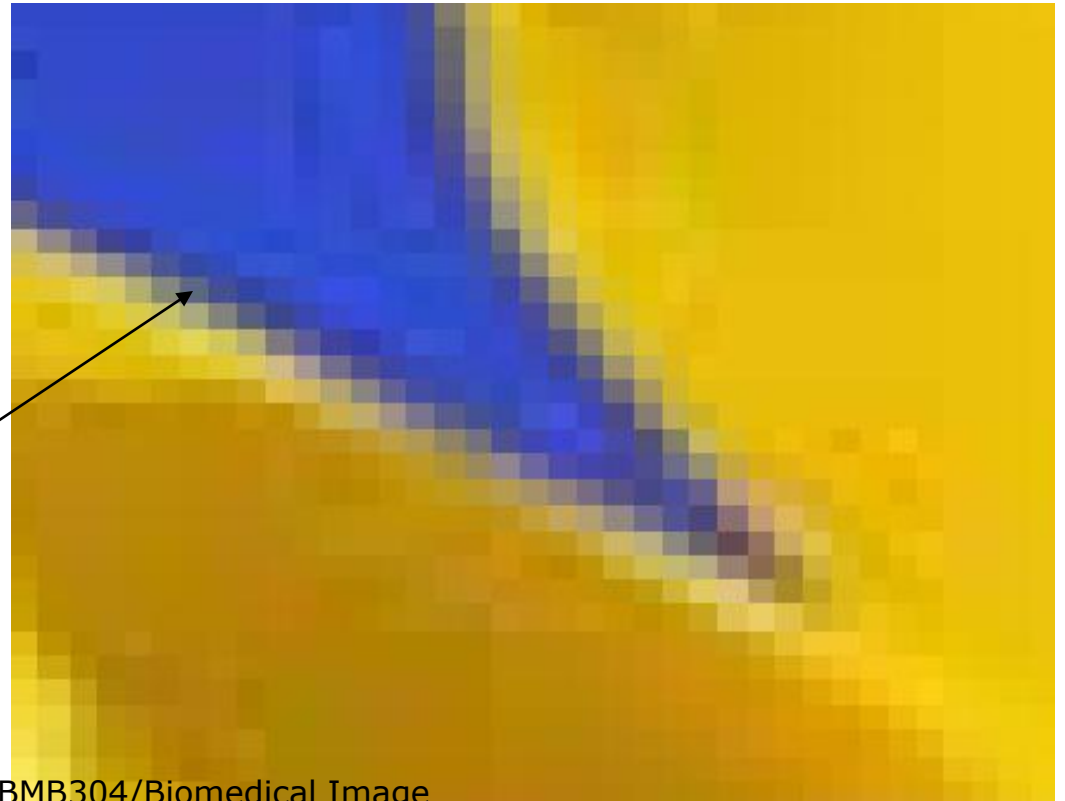
- 
- $f(x,y)$ : A two-dimensional function, where  $x$  and  $y$  are spatial coordinates, and the amplitude of  $f$  at any pair of coordinates  $(x,y)$  is called the intensity or gray level of the image at that point.
  - $x$  size: 662,  $y$  size: 640, gray levels: 256
  - Digital image:  $x$ ,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

- A sample color digital image,  $800 \times 600 \times 24$  bits



- 
- Pixel: The elements of a digital image.

Pixels





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○ Some applications

- **FUJIFILM**: Searching faces, [Fuji.htm](#)
- License plates, [Licence.htm](#)
- Tracking people, [Hand.htm](#)

# The Origins of Digital Image Processing

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- 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.)

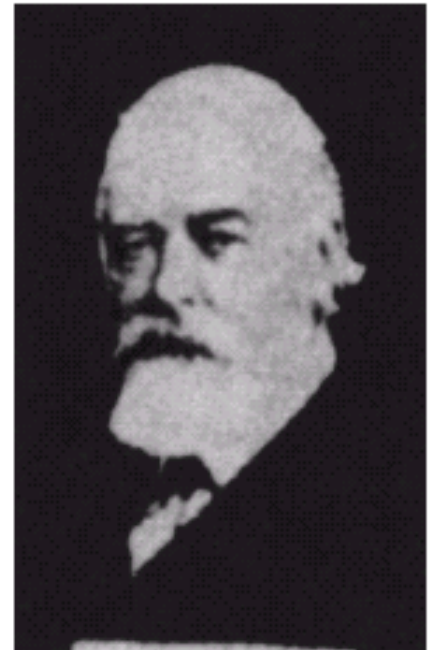
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- Better quality

**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.)

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- 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.)

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- 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.)

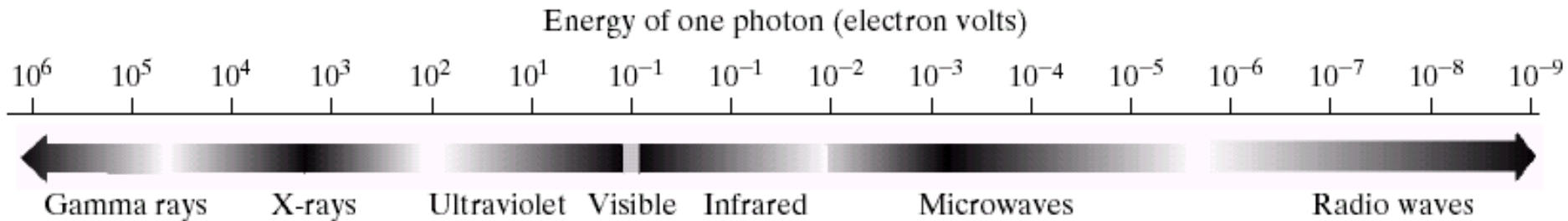
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- Medical imaging
  - Remote Earth resource observations
  - Astronomy
  - High-energy plasmas and electron microscopy

# Examples of Fields that Use Digital Image Processing

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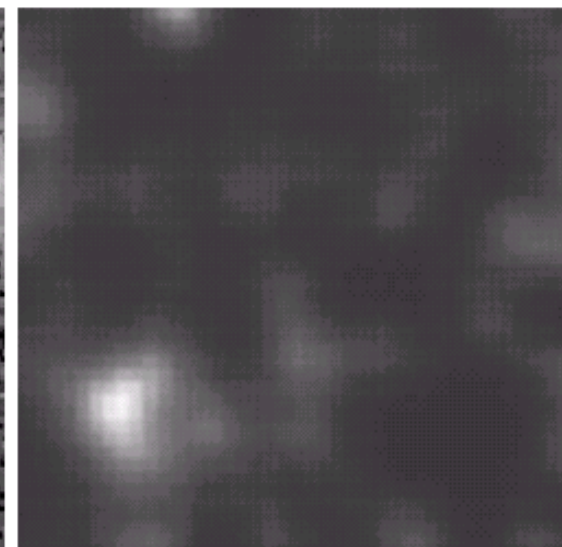
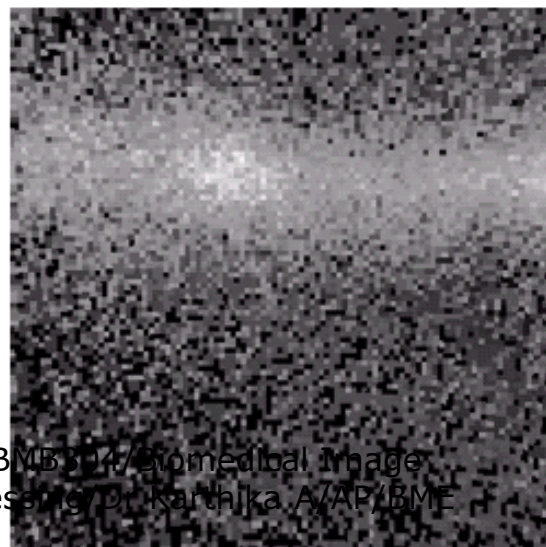
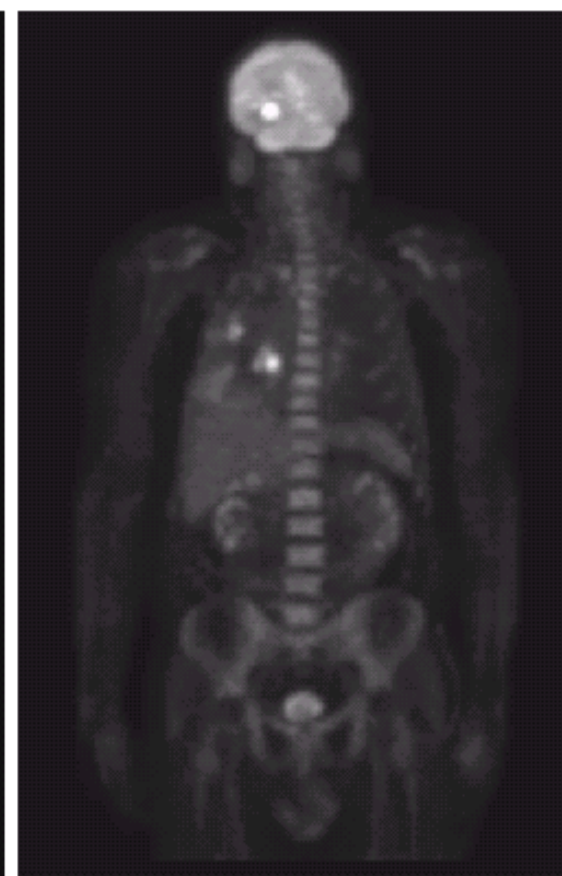
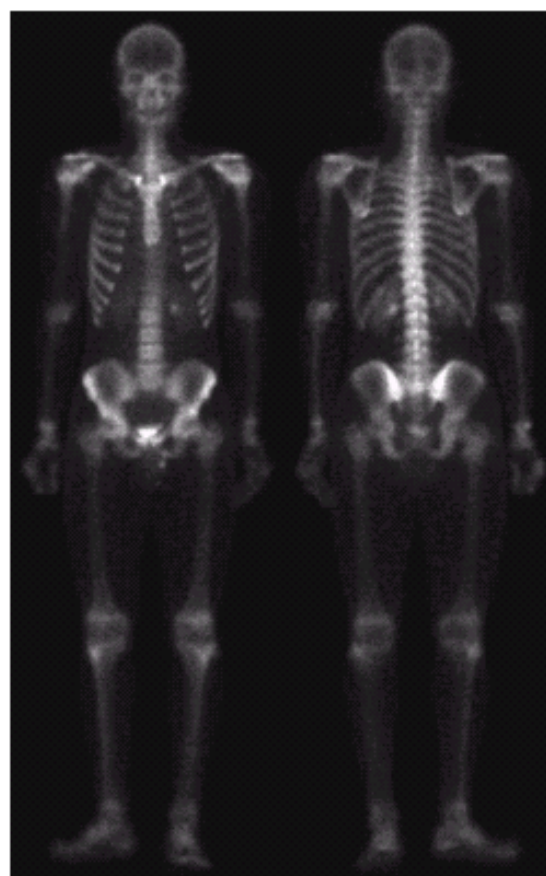
- Electromagnetic energy spectrum



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

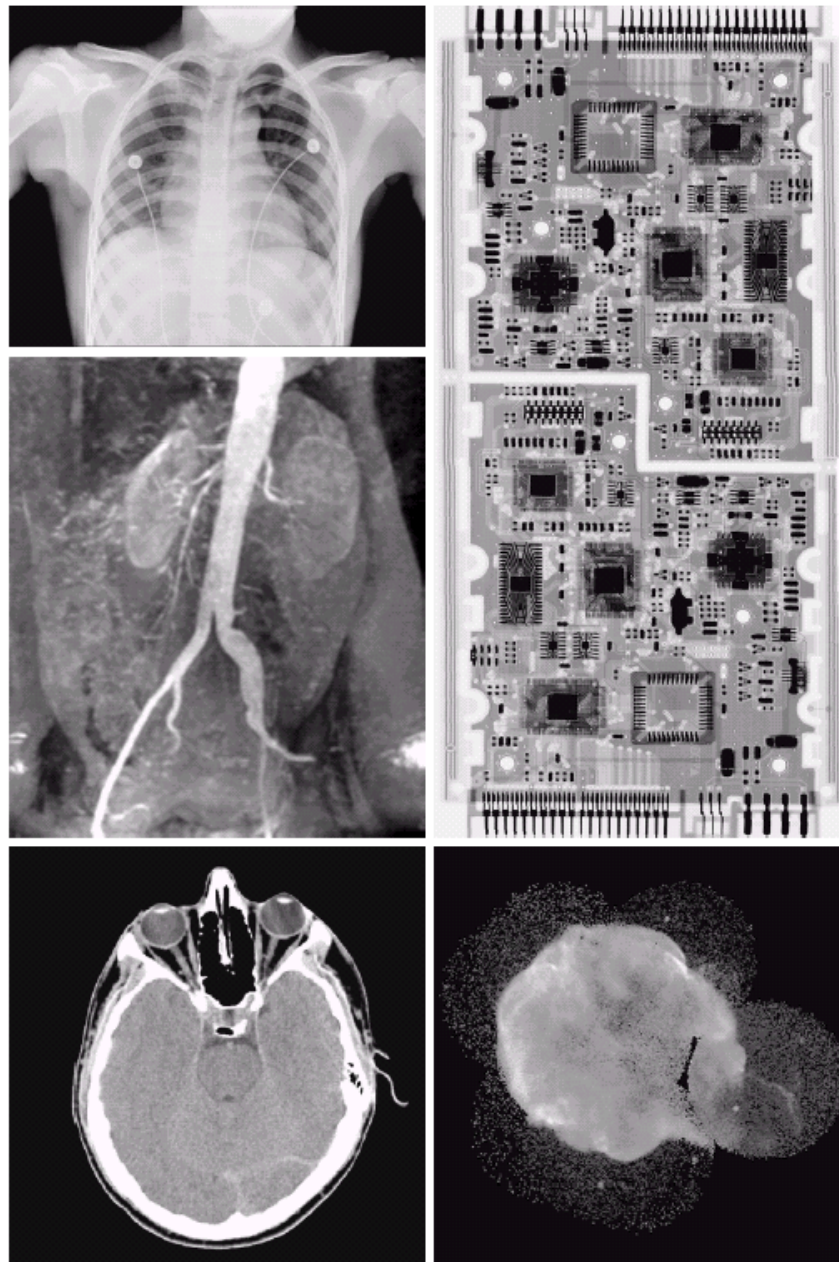
a b  
c d

**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



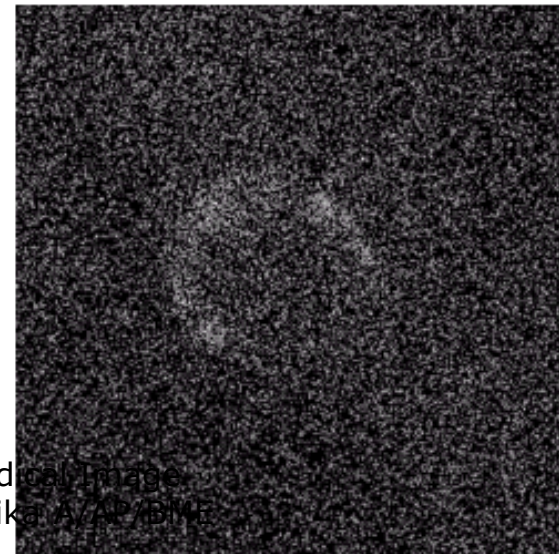
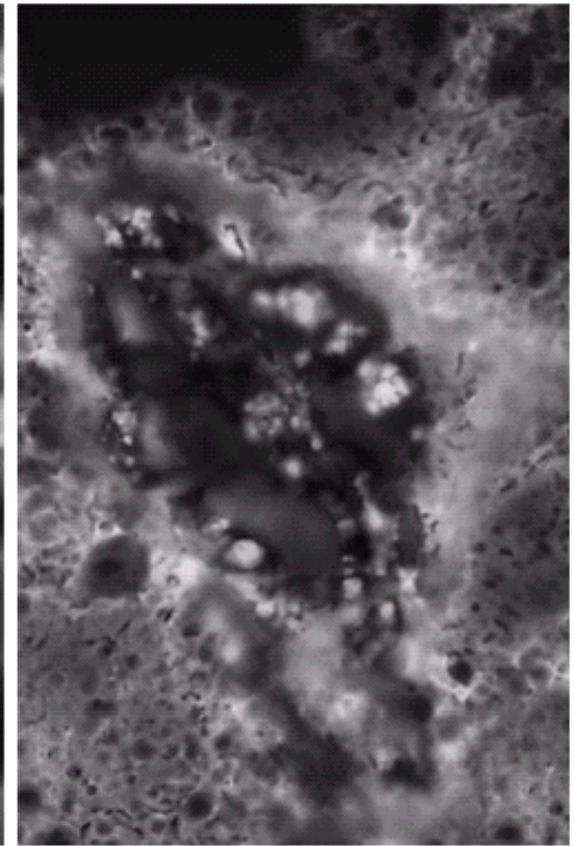
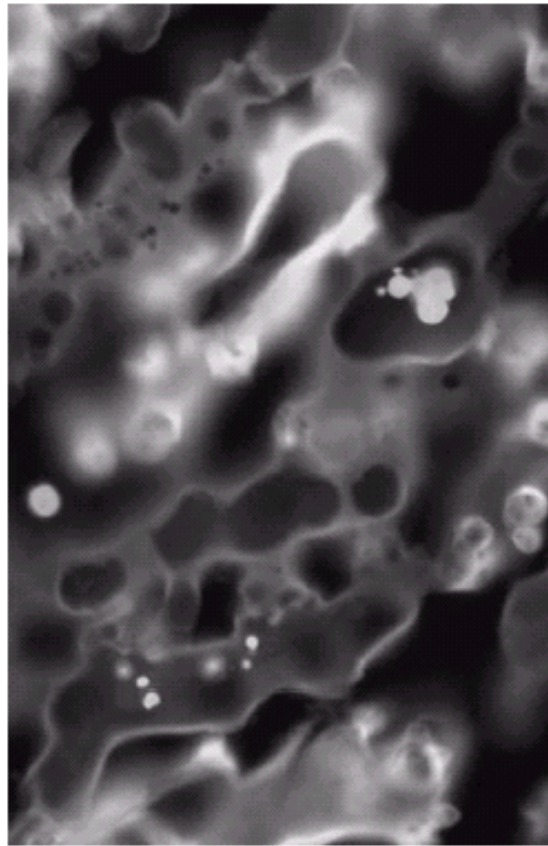
a  
b  
c

**FIGURE 1.7** Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit board. (e) Venus's Flytrap. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Joseph E. Pascente, Lixi, Inc.; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

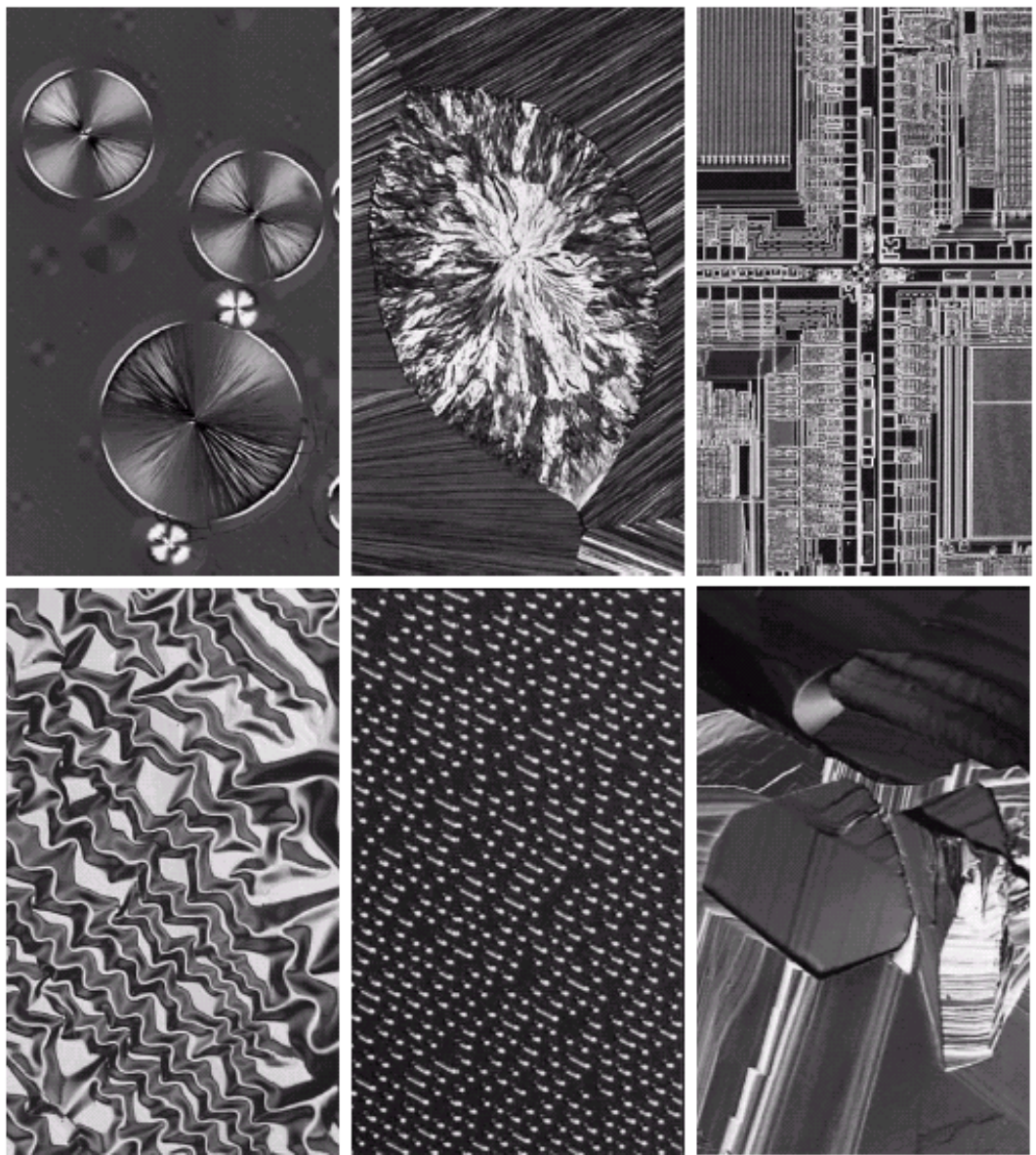
# Imaging in the Ultraviolet Band

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

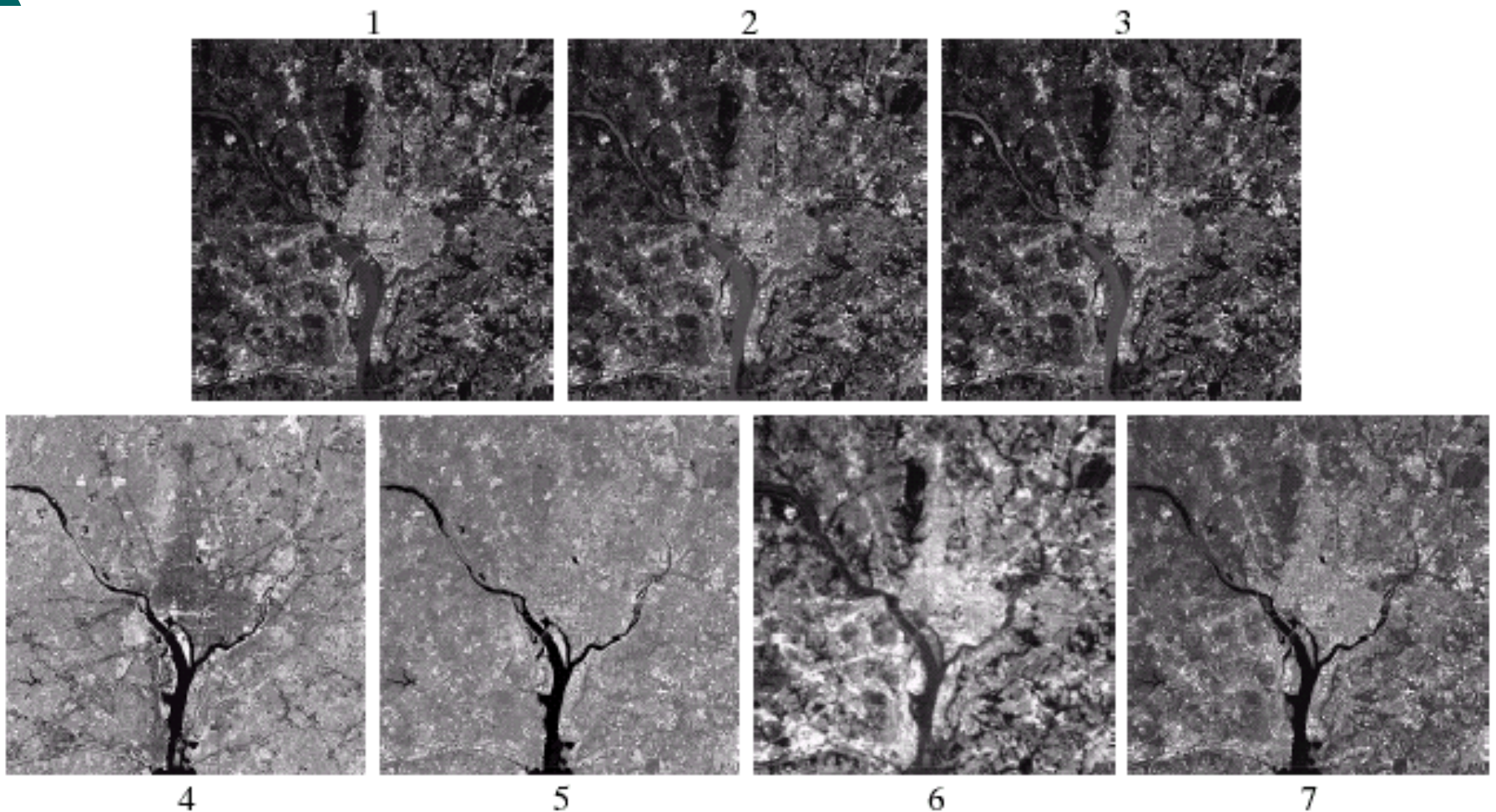
**FIGURE 1.9** Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 198 $\times$ . (b) Surface of audio CD—175 $\times$ . (c) Organic superconductor—450 $\times$ . (d) Nickel oxide thin film—600 $\times$ . (e) Surface of audio CD—175 $\times$ . (f) Organic superconductor—450 $\times$ . (Images courtesy of Dr. Michael W. Davidson, Florida State University.)



## ○ Remote sensing

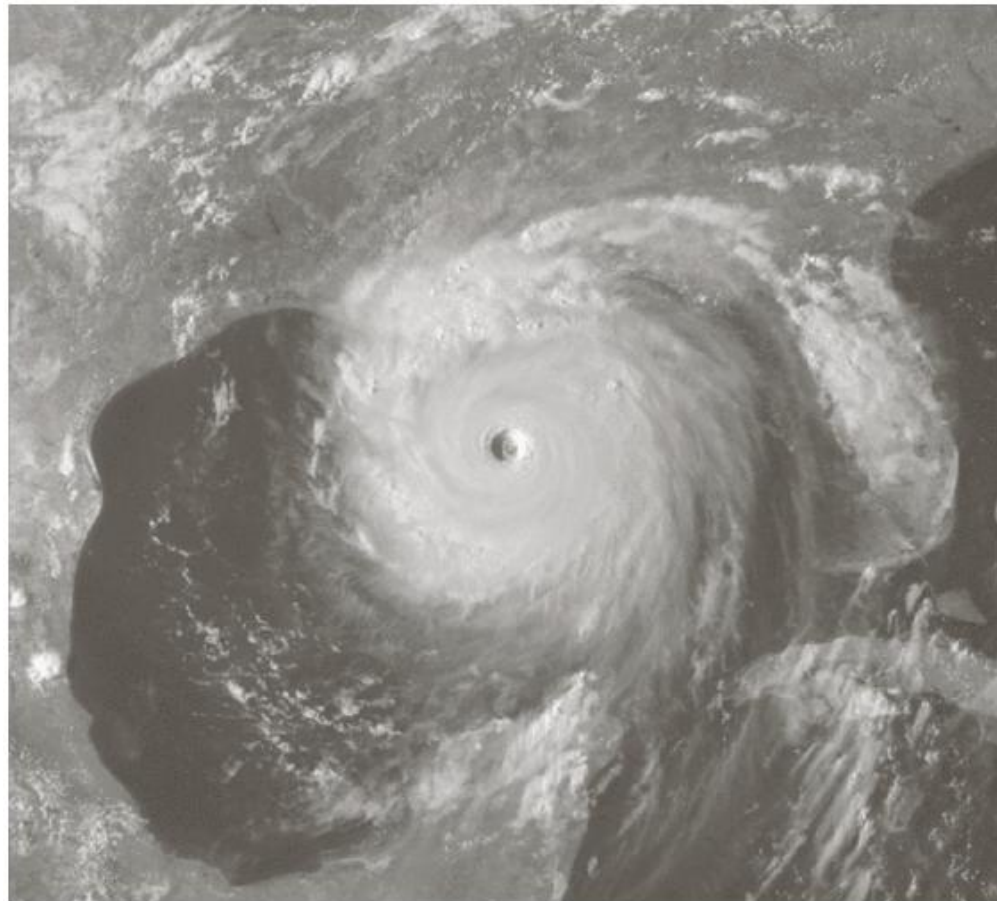
**TABLE 1.1**  
Thematic bands  
in NASA's  
LANDSAT  
satellite.

Band No.	Name	Wavelength ( $\mu\text{m}$ )	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



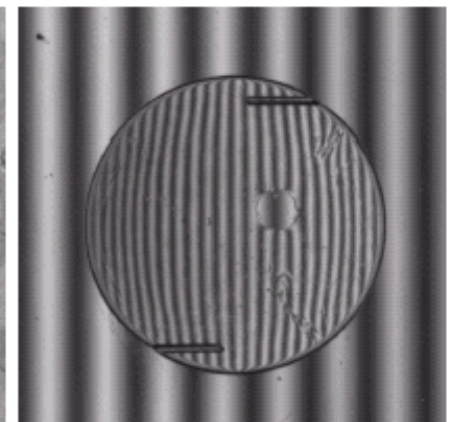
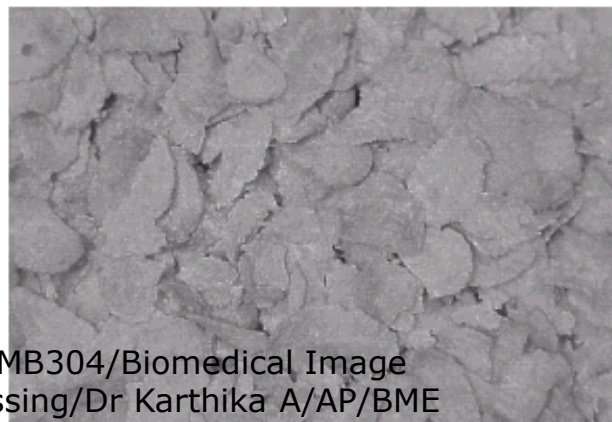
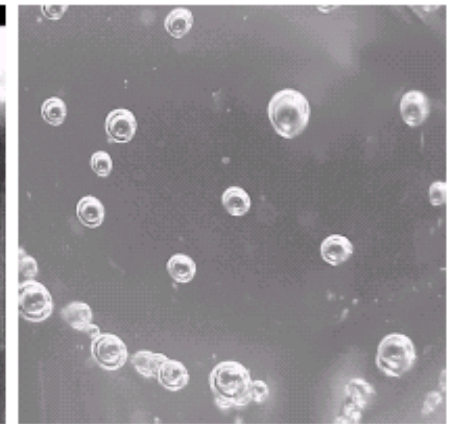
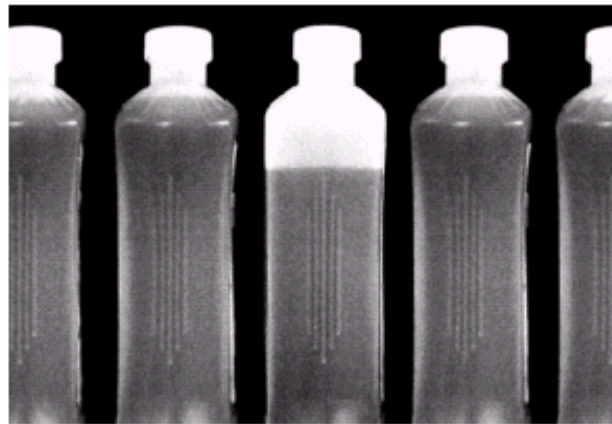
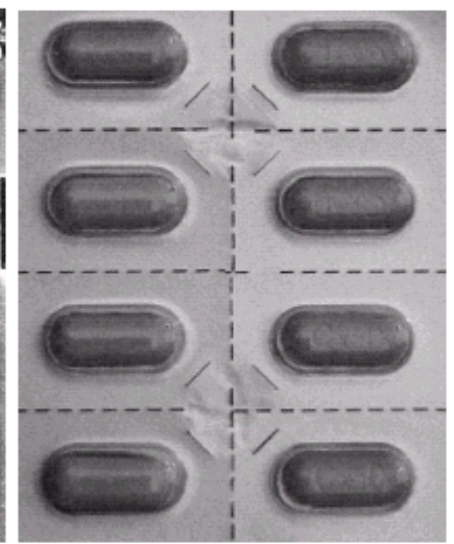
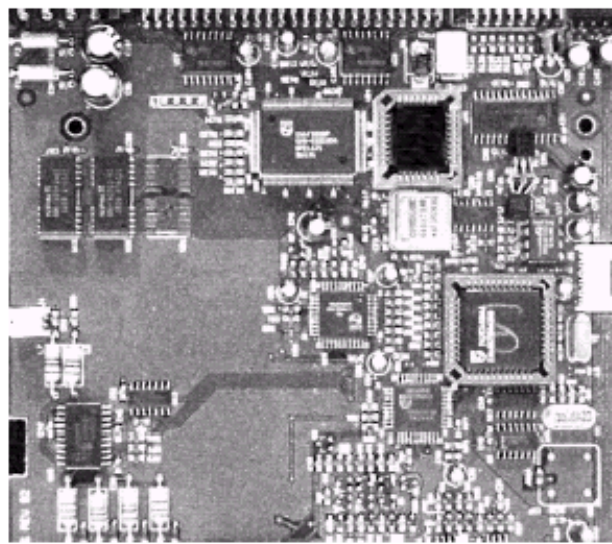
**FIGURE 1.13**  
Infrared satellite  
images of the  
remaining  
populated part of  
the world. The  
small gray map is  
provided for  
reference.  
(Courtesy of  
NOAA.)

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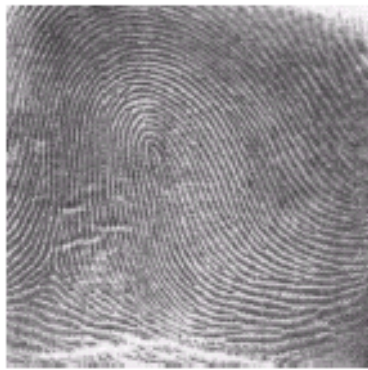


a b  
c d  
e f

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



# Automated visual inspection



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.)

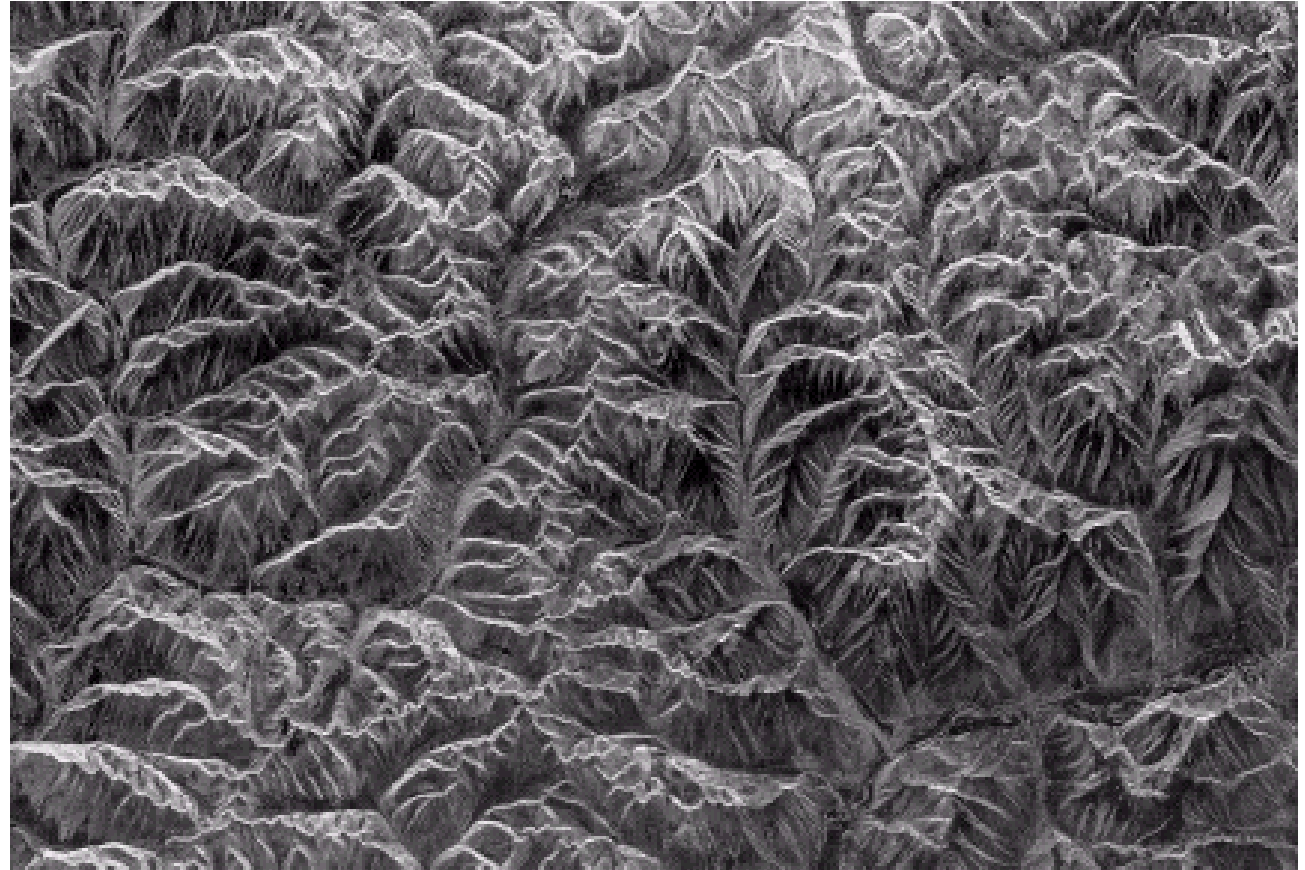


# Imaging in the Microwave Band

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

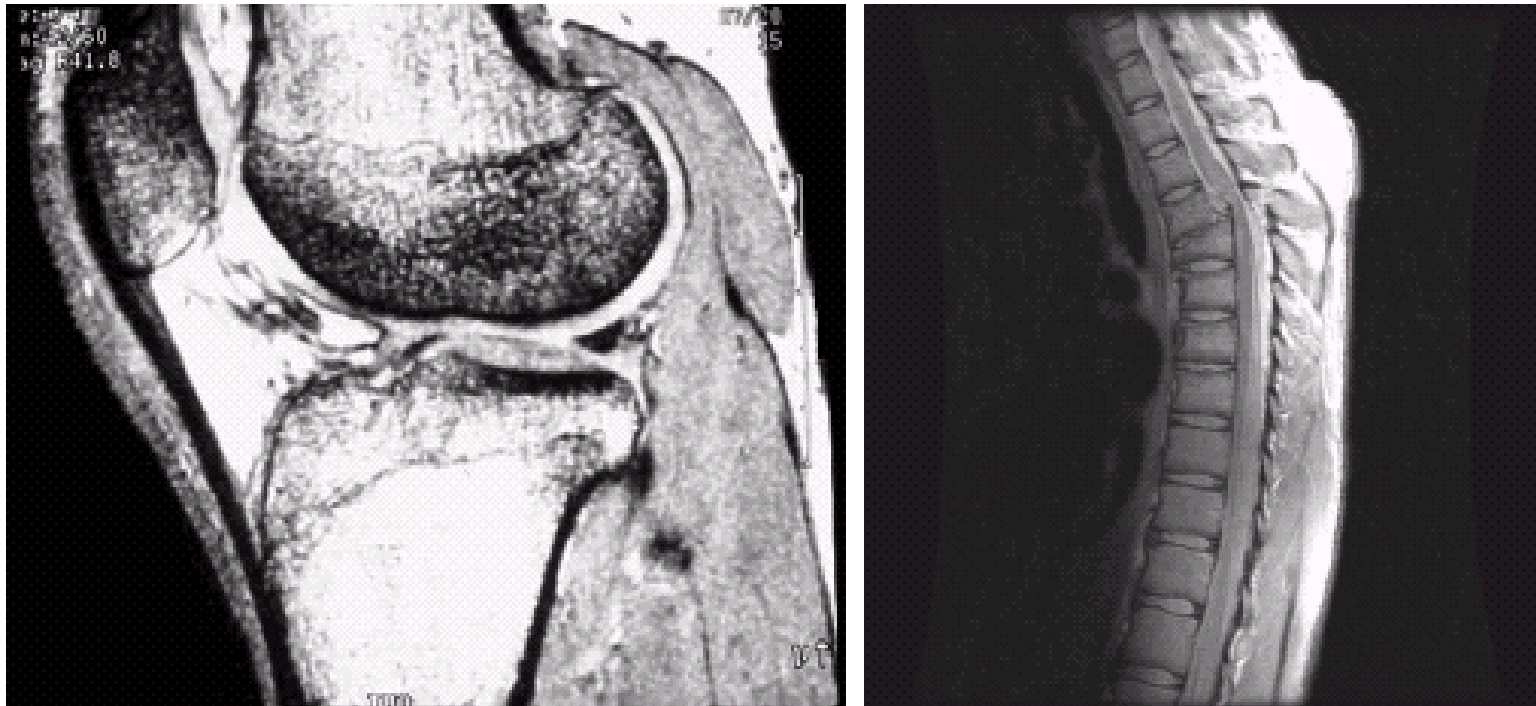
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# Imaging in the Radio Band

## ○ MRI

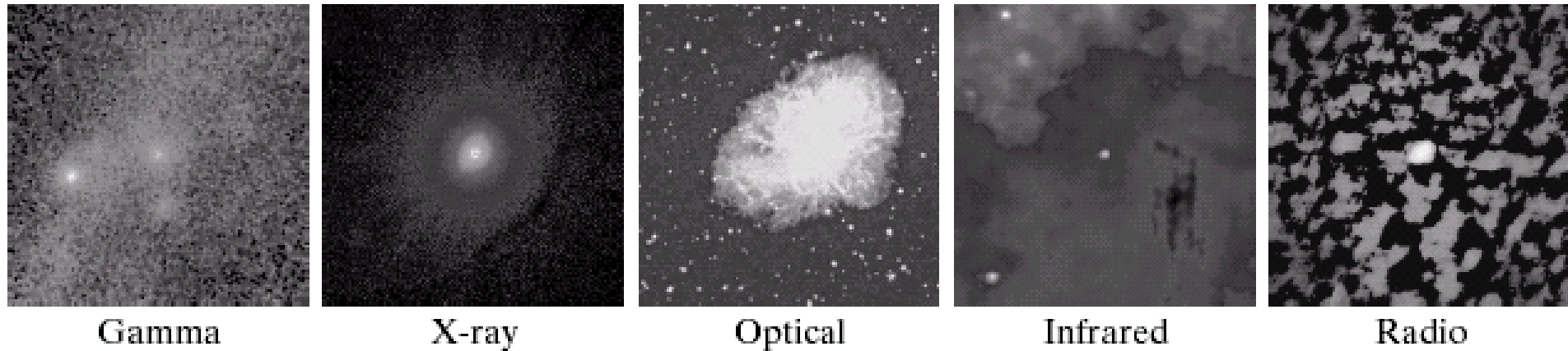


a b

**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.)

19BMB304/Biomedical Image

Processing/Dr Karthika A/AP/BME



Gamma

X-ray

Optical

Infrared

Radio

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

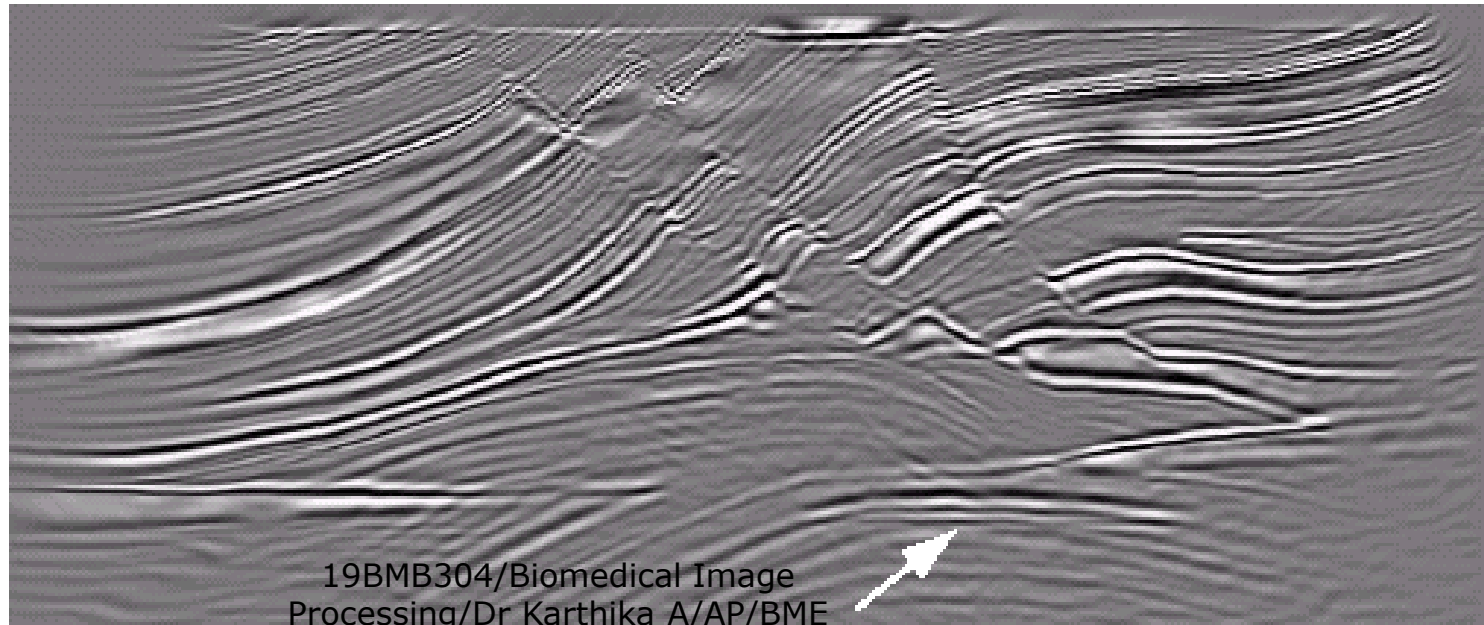
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# Examples in which Other Imaging Modalities Are Used

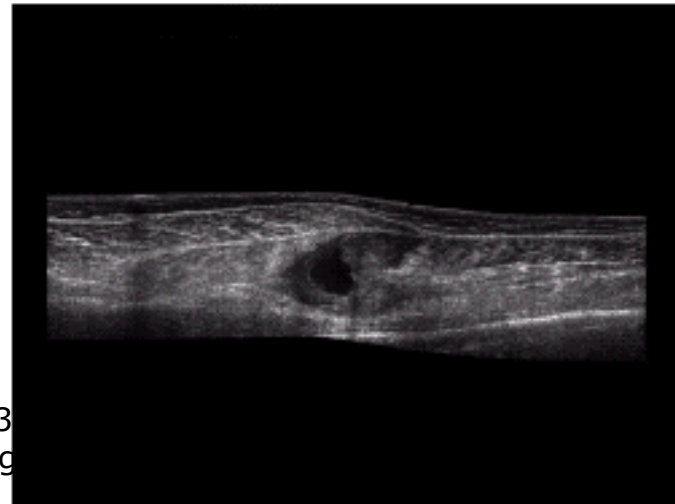
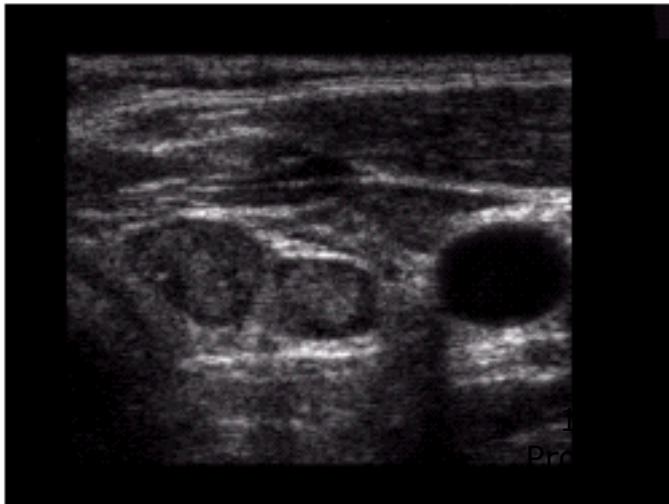
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- Sound

**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.)



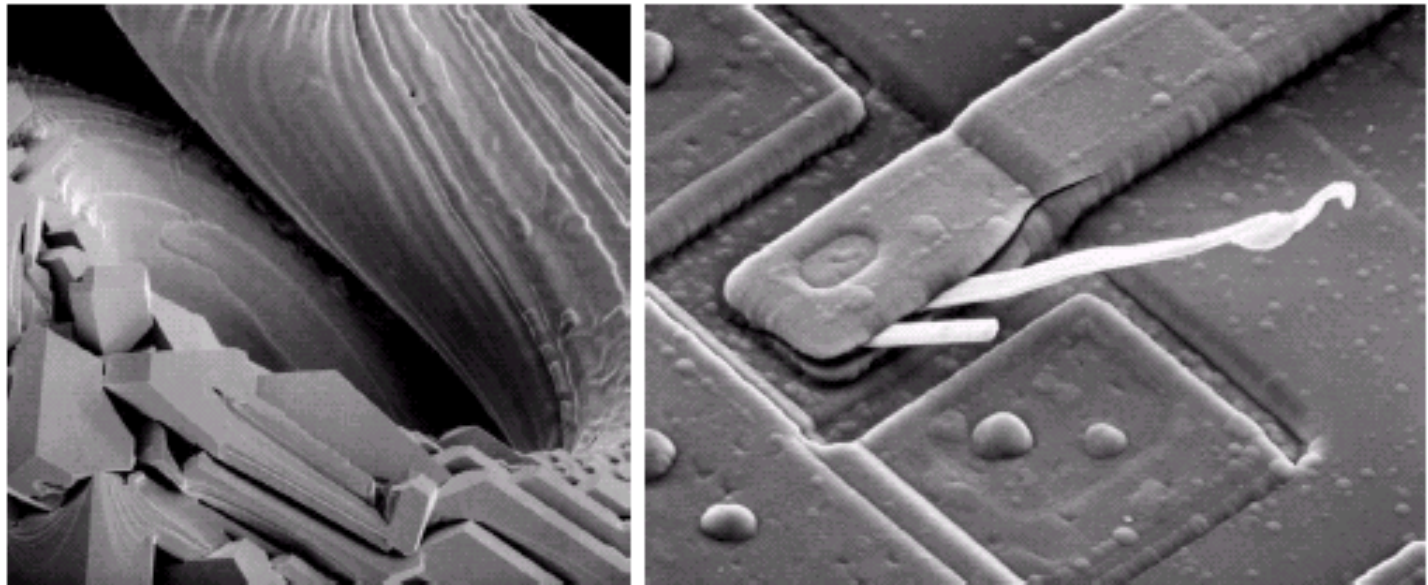
# ○ Ultrasound



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.)

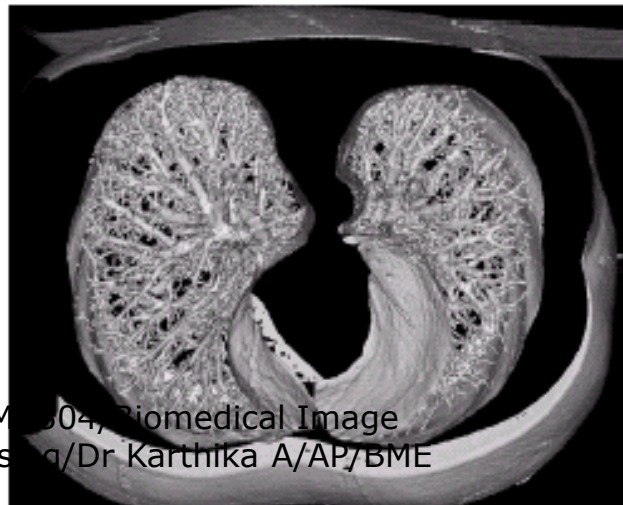
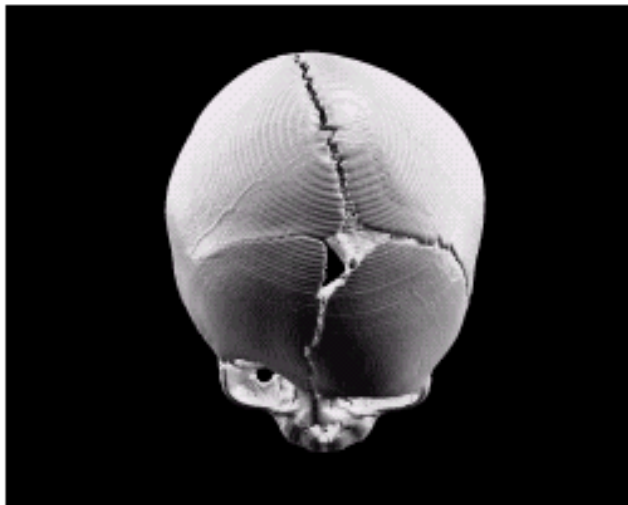
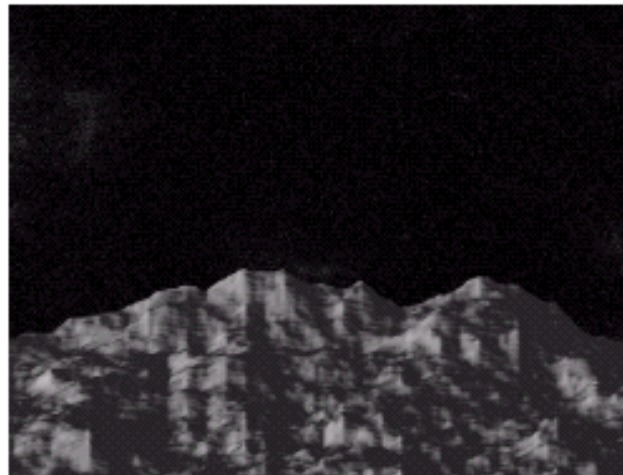
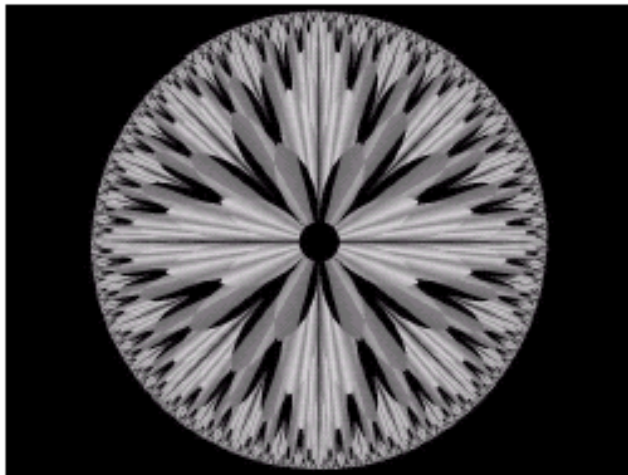
## ○ Electron Microscope



a b

**FIGURE 1.21** (a)  $250\times$  SEM image of a tungsten filament following thermal failure. (b)  $2500\times$  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



a	b
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.)

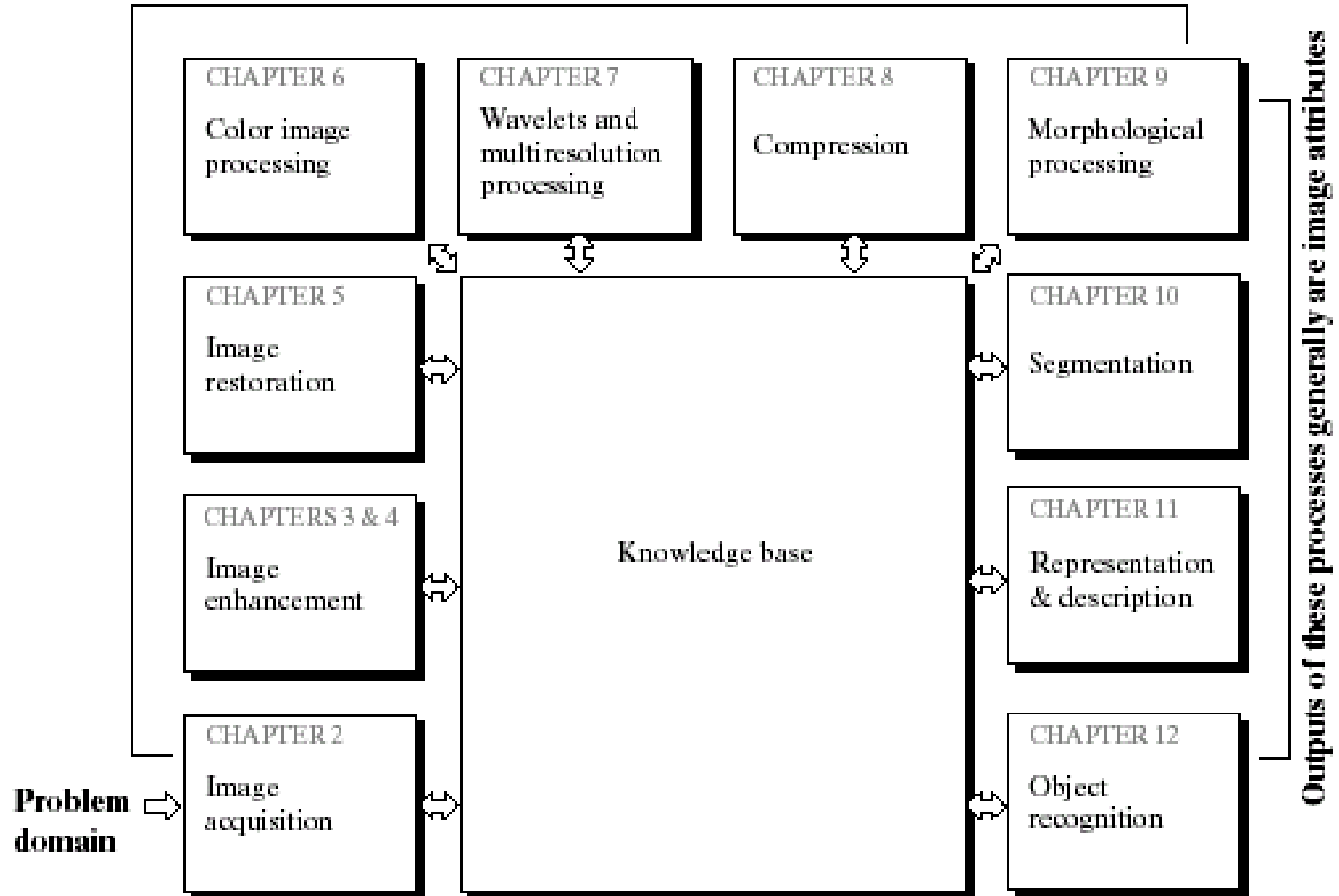
# Fundamental Steps in Digital Image Processing

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- Methods whose input and output are images
- Methods whose outputs are attributes extracted from those images

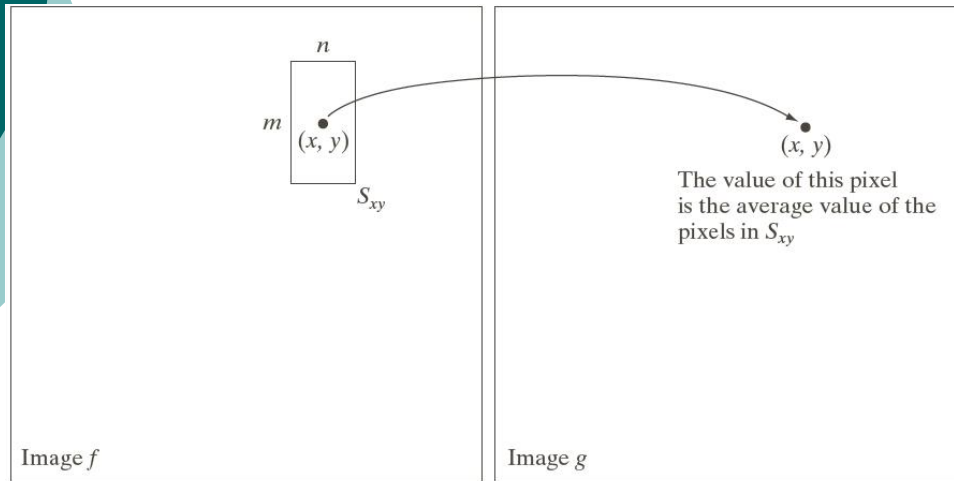
**FIGURE 1.23**  
Fundamental  
steps in digital  
image processing.

Outputs of these processes generally are images





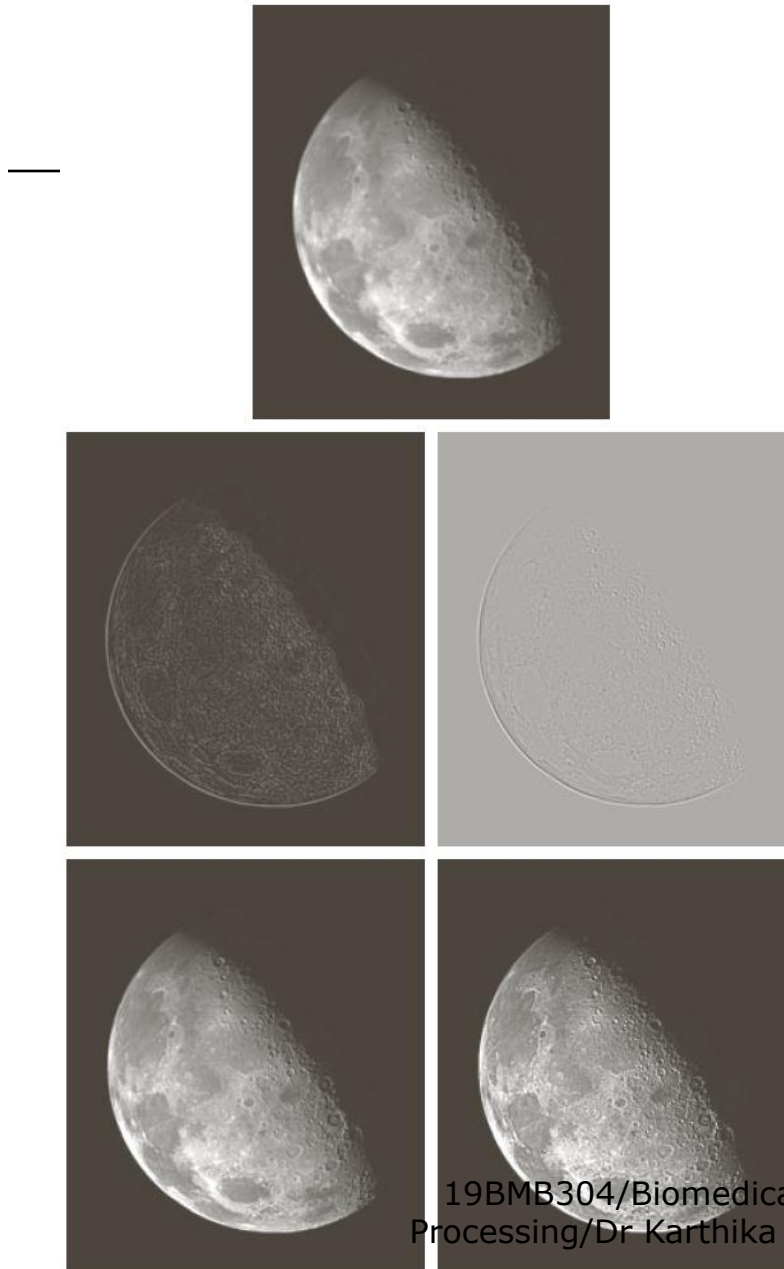
# ○ Image operations



a	b
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  $790 \times 686$  pixels.

# ○ Spatial filtering



a  
b c  
d e

**FIGURE 3.38**

(a) Blurred image of the North Pole of the moon.

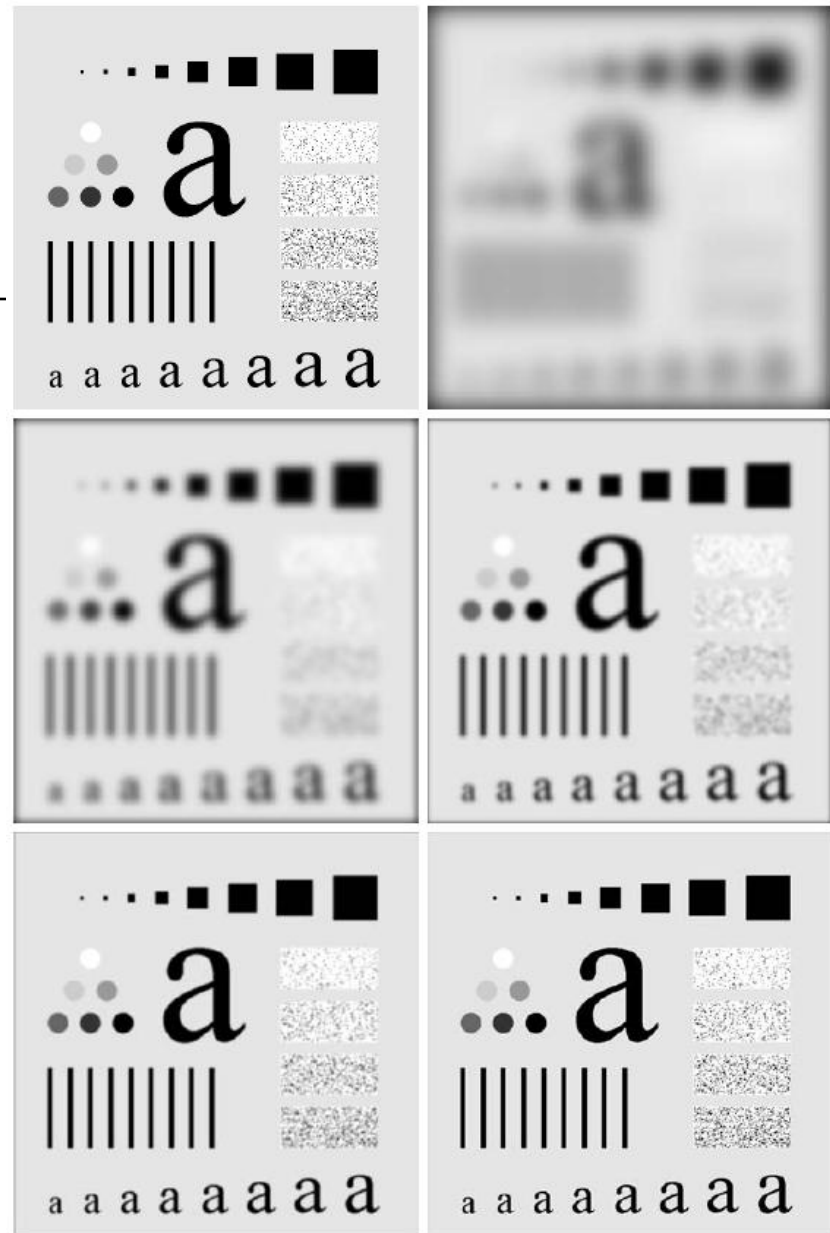
(b) Laplacian without scaling.

(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.)

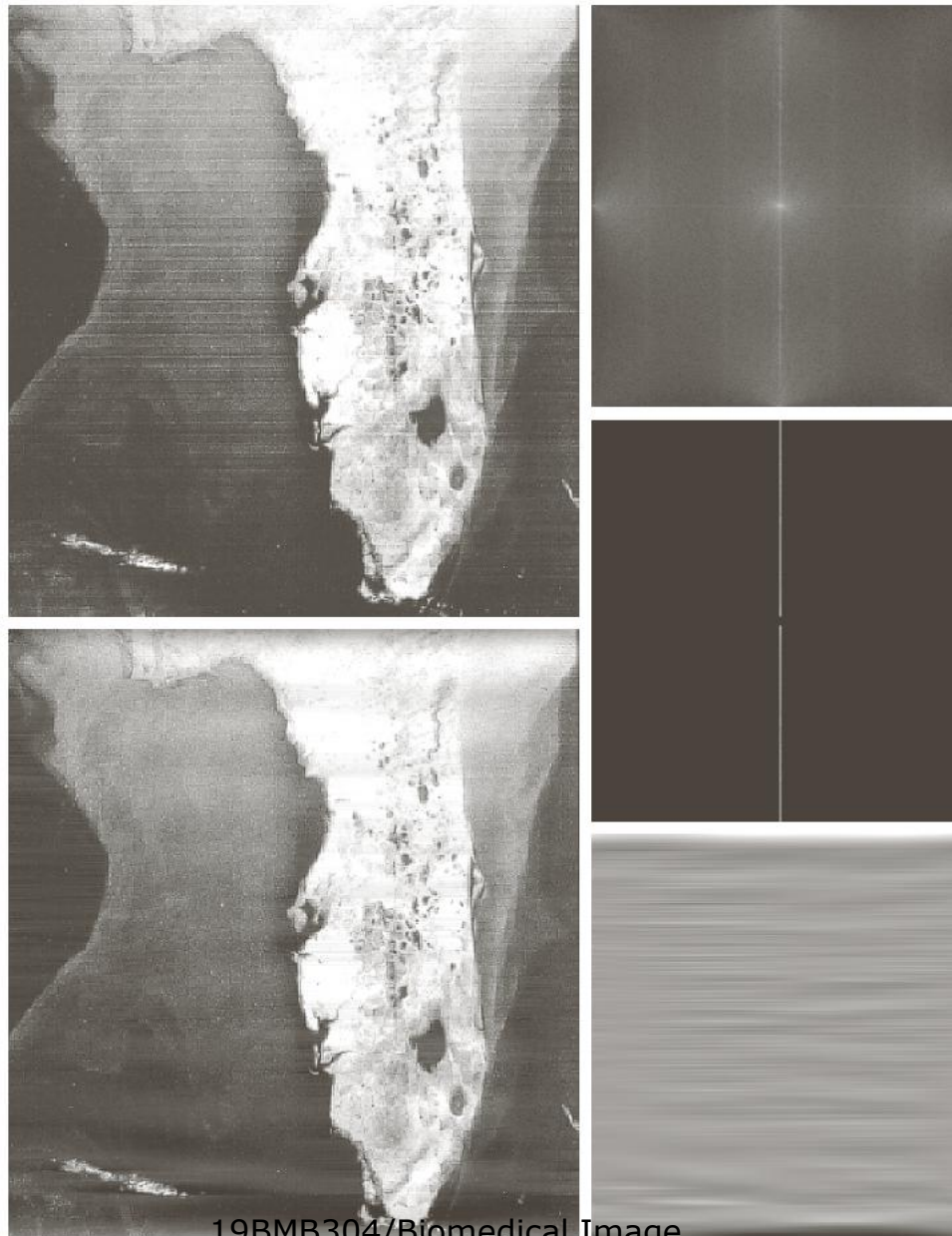
○ Filtering in the frequency domain



a b  
c d  
e f

19BMB304/Biomedical Image Processing/Dr Karthika A/AP/BME  
 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.

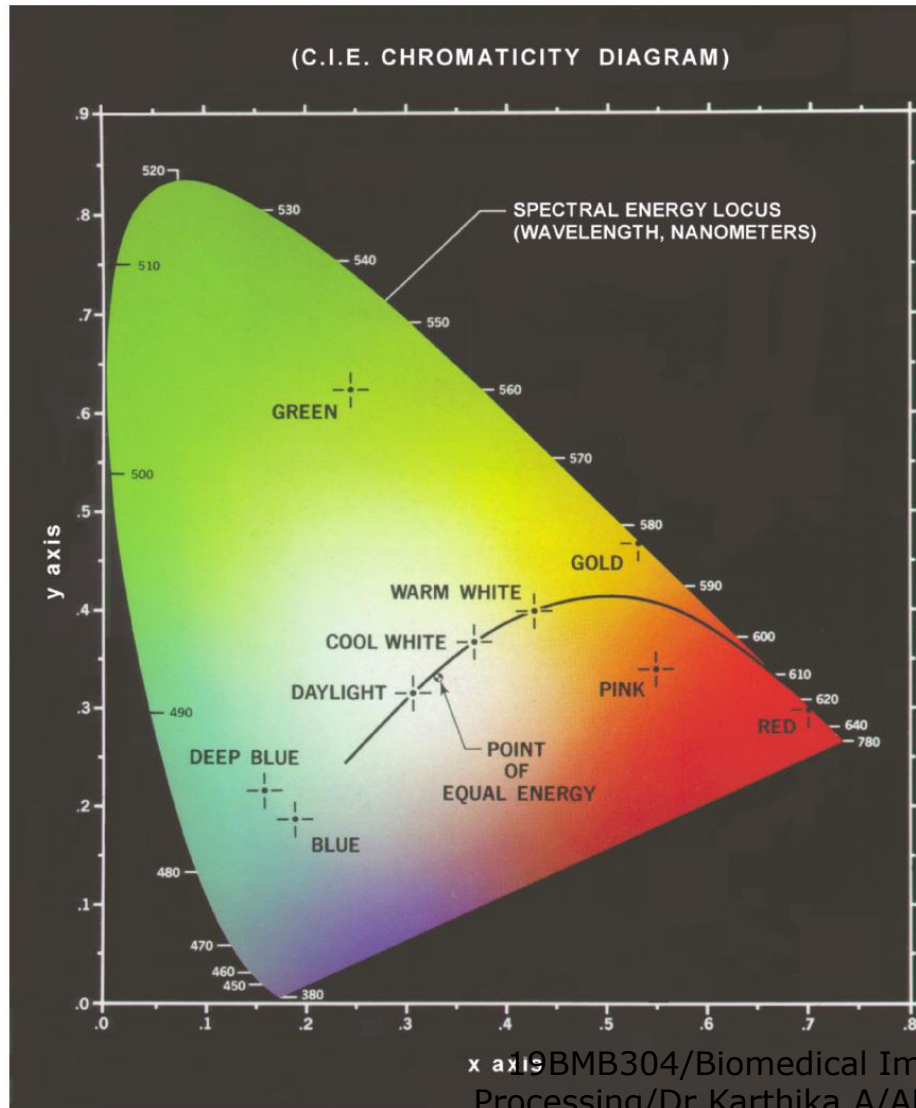
# Image restoration



a	b
c	d
e	

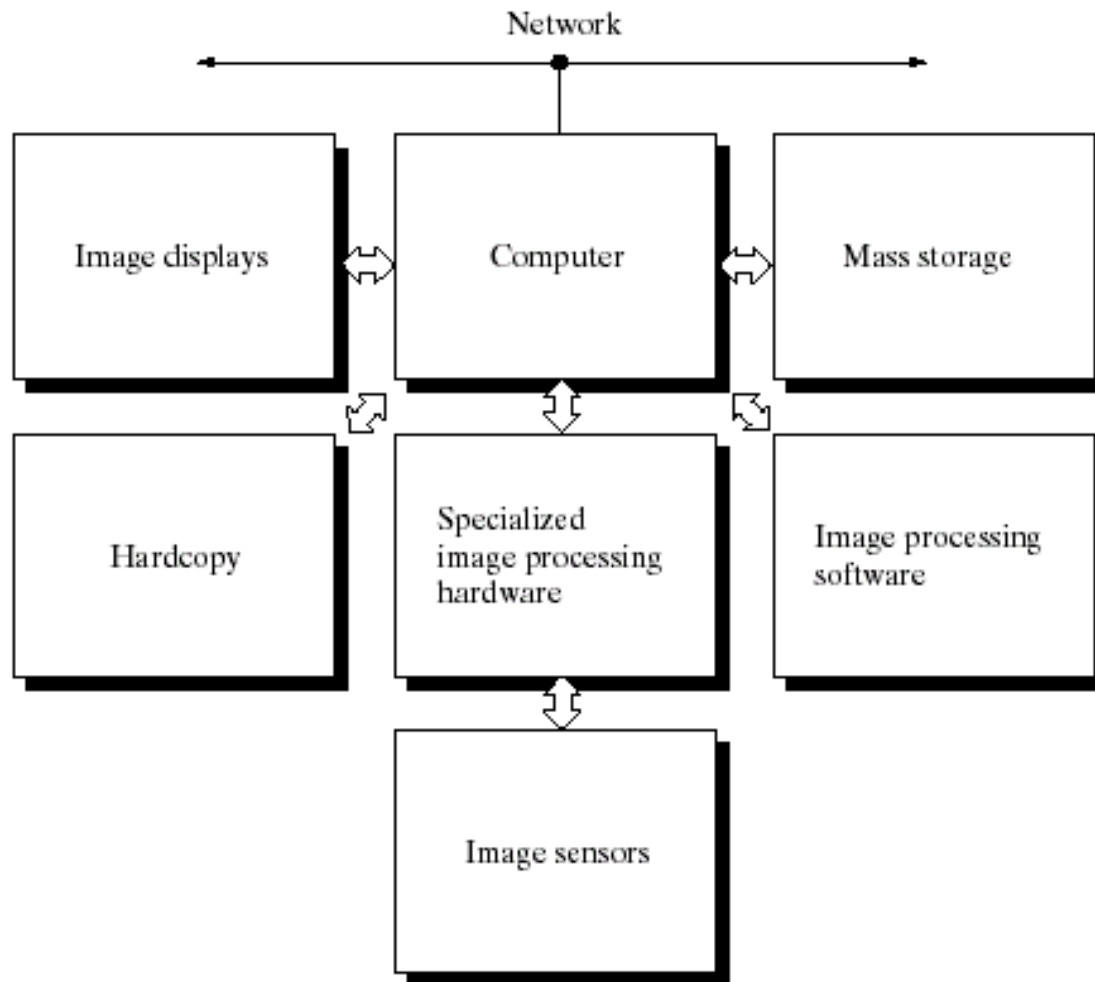
**FIGURE 5.19**  
(a) Satellite image of Florida and the Gulf of Mexico showing horizontal scan lines. (b) Spectrum. (c) Notch pass filter superimposed on (b). (d) Spatial noise pattern. (e) Result of notch reject filtering. (Original image courtesy of NOAA.)

# ○ Color image processing



**FIGURE 6.5**  
Chromaticity diagram.  
(Courtesy of the General Electric Co., Lamp Business Division.)

# Components of an Image Processing System



**FIGURE 1.24**

Components of a general-purpose image processing system.