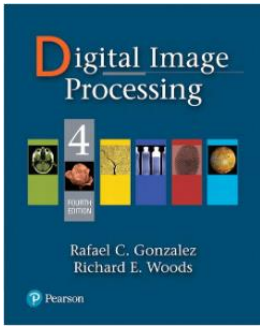


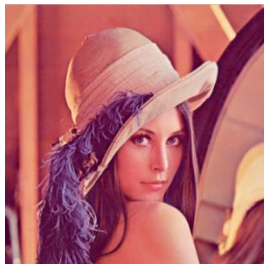
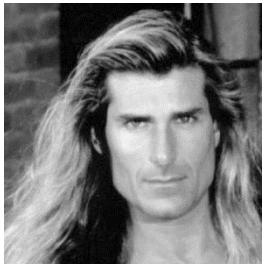
Digital Image Processing

Introduction of DIP

Dr. Tun-Wen Pai

1) Concept of a digital image
2) Historical understandings of DIP
3) Definition and scope of DIP
4) Fundamentals of electromagnetic spectrum for image generation
5) Basic processes/components involved in DIP

Digital Image Processing

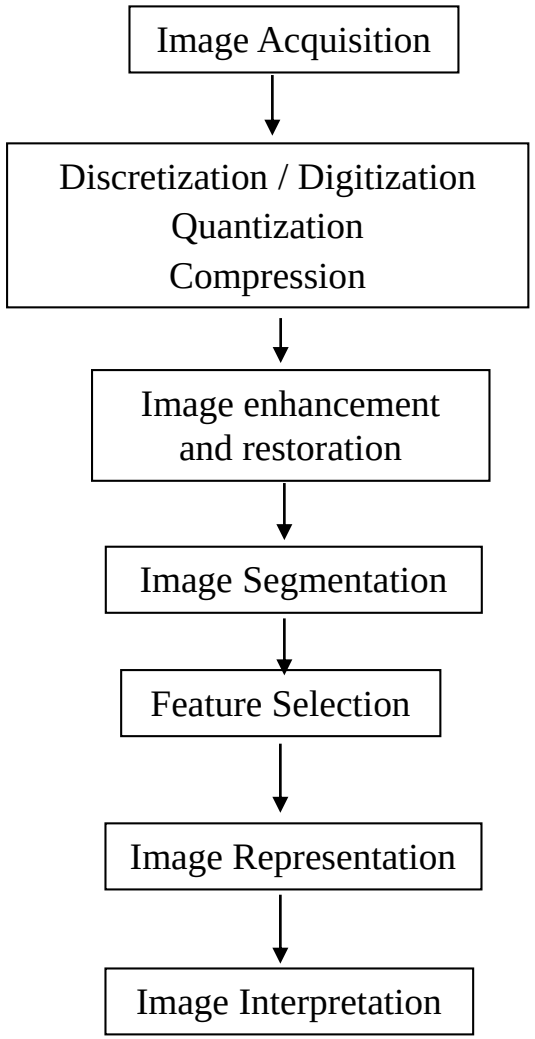




- What is an image?
  - Picture, Photograph
  - Visual data
  - Usually two- or three-dimensional
- What is a digital image?
  - An image which is “discretized” i.e., defined on a discrete grid (ex. scanner / digital camera)
  - Two-dimensional collection of light intensity values (or gray values)
  - Matrix, two-dimensional function → f(x,y)
- What is digital image processing?

  Digital image processing deals with the manipulation and analysis of pictures by a computer.

  - Improve pictorial information for better clarity (human interpretation).
  - Automatic machine processing of scene data (interpretation by a machine/non-human, storage, transmission).

Important steps in a typical image processing system



Capturing visual data by an imaging sensor

Convert data into discrete form
Compress for efficient storage/transmission

Improving image quality (low contrast, blur, noise)

Partition image into objects or constituent parts

Extracting pertinent features (or descriptors) from an image that are important for differentiating one class of objects from another

Assigning labels to an object based on information provided by descriptors

Assigning meaning to an ensemble of recognized objects

Important steps

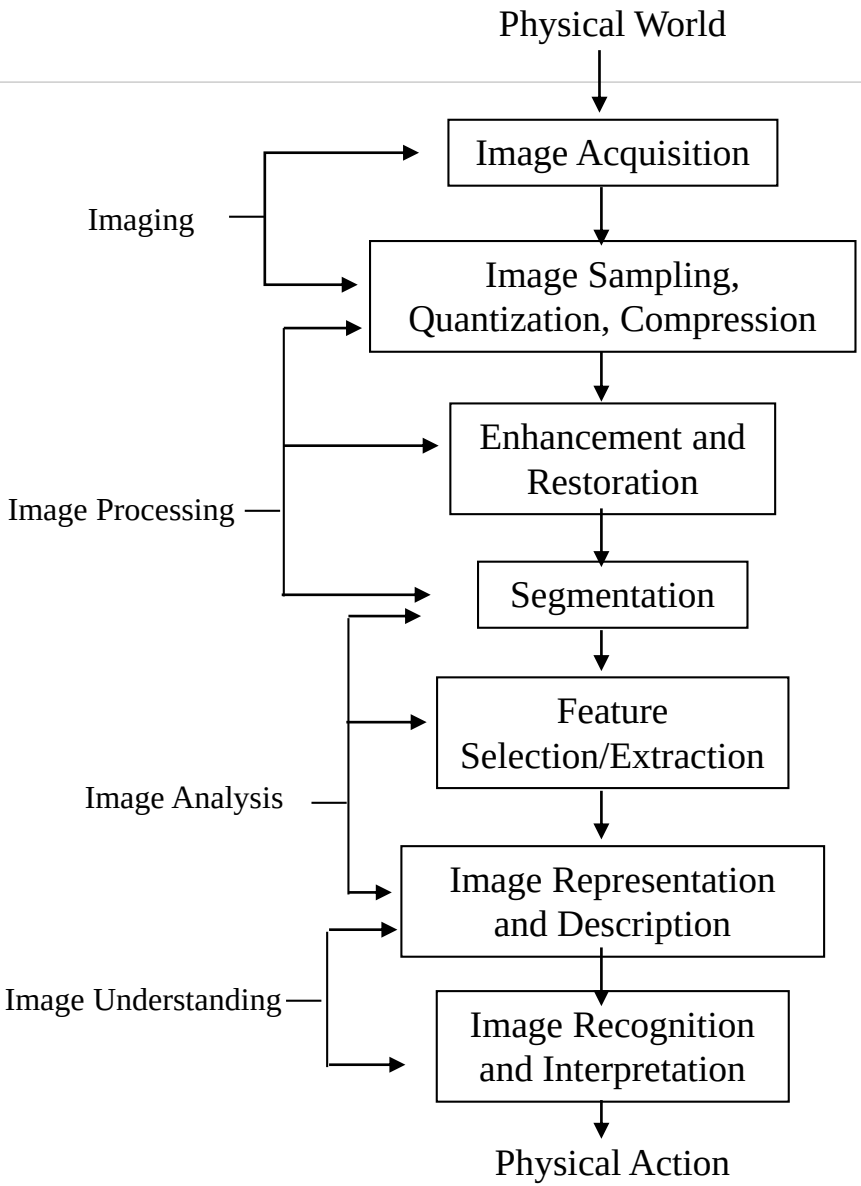


Image Processing and Analysis Transformations

- **Level 0:** Image representation (acquisition, sampling, quantization, compression)
- **Level 1:** Image-to-image transformations (enhancement, restoration, segmentation)
- **Level 2:** Image-to-parameter transformation (feature selection)
- **Level 3:** Parameter-to-decision transformation (recognition and interpretation)

Image Processing --- Levels 0 and 1
Image analysis --- Levels 1 and 2
Computer/Robot Vision --- Levels 2 and 3

- **Computer Graphics/Animation ?**

  This mainly involves “creating images” or “visual effects” from a given description.

  Image processing and analysis is mainly concerned with “interpreting ” a given image.

Chapter 1: Introduction

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

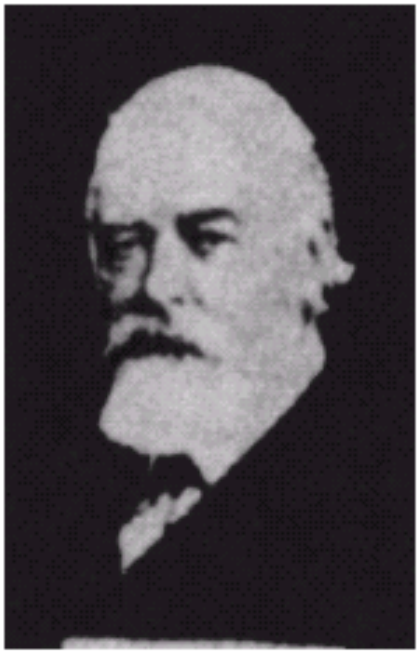


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals hand crossed the Atlantic twice. Some errors are visible. (McFarlane.)

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.)

Chapter 1: Introduction

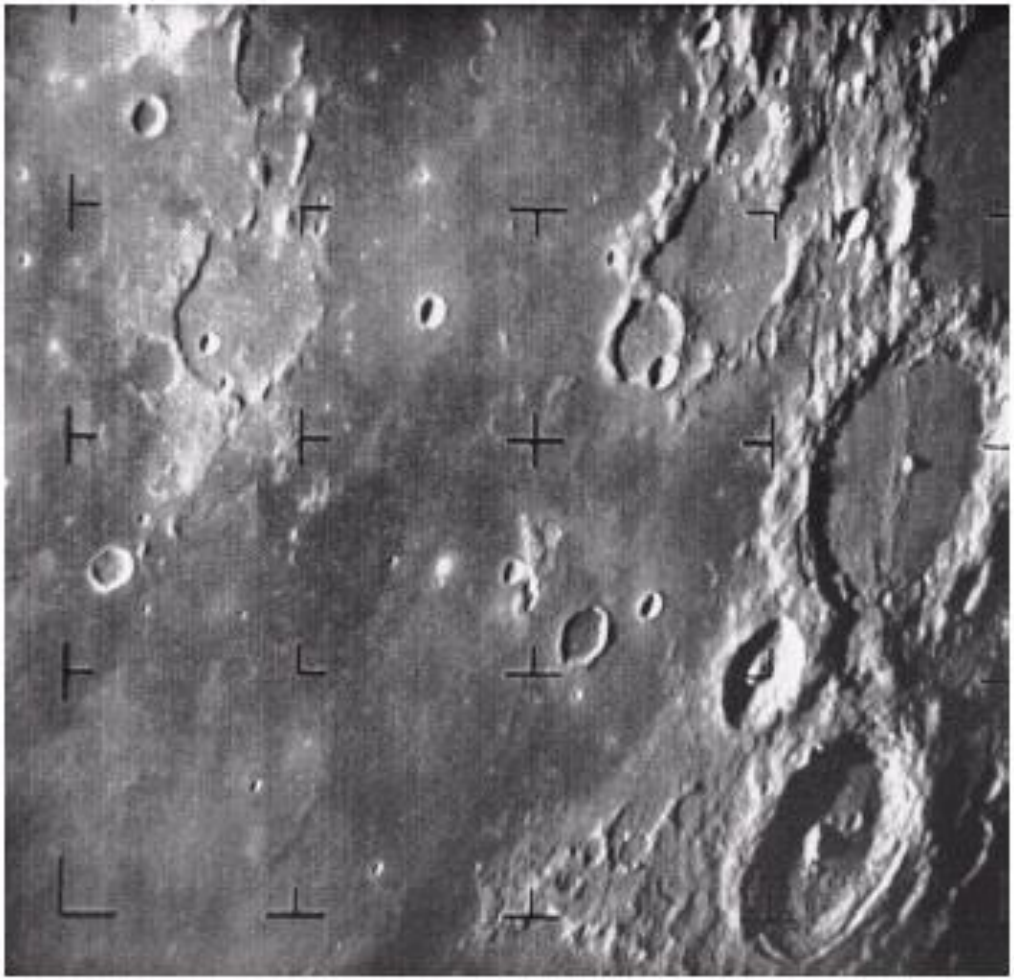


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. Ranger 7 took this image on July 31, 1964 at 9:09 A.M EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

Chapter 1: Introduction

Photon energy is the energy carried by a single photon.

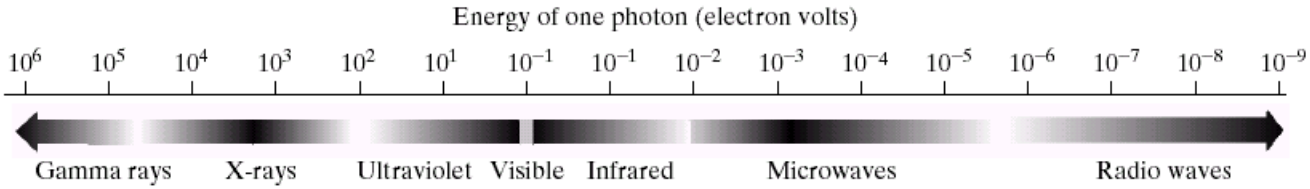
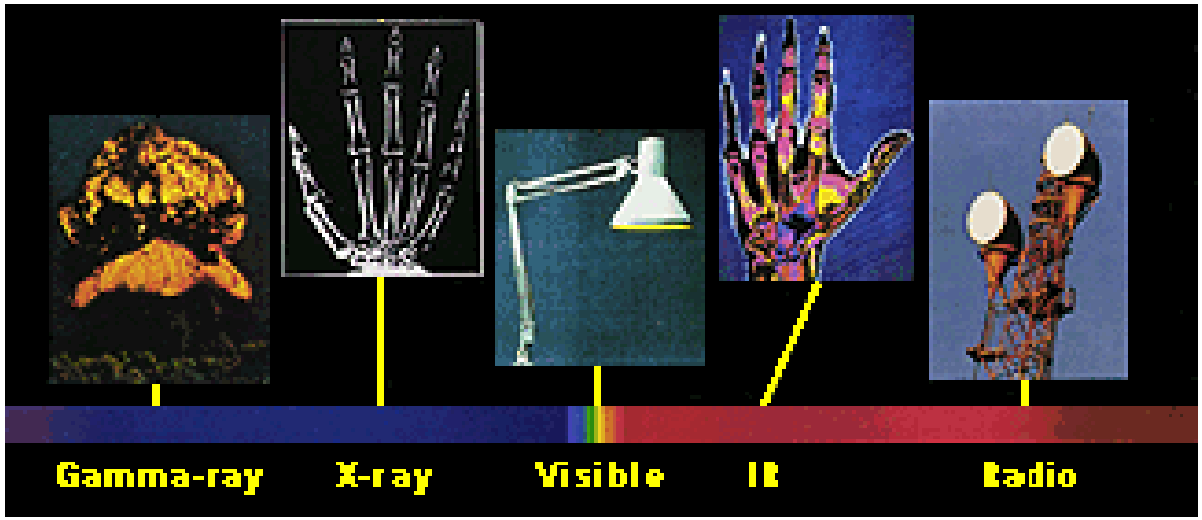
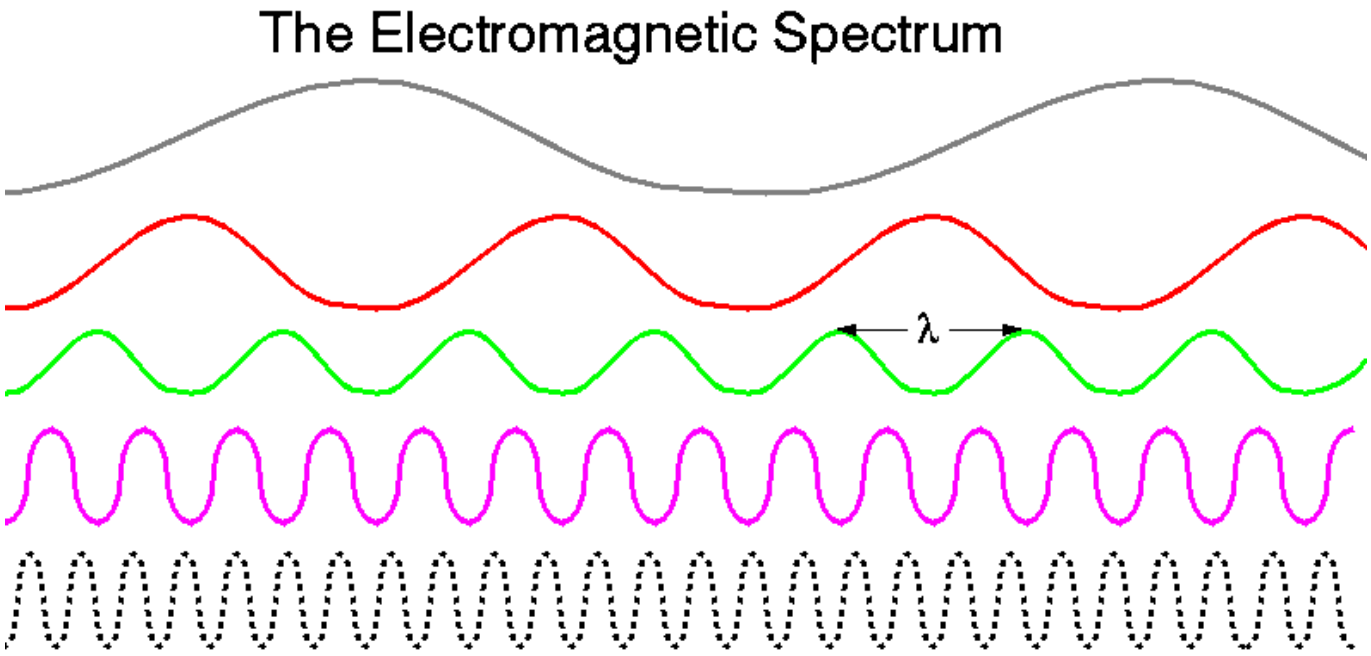


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.



https://ecuip.lib.uchicago.edu/multiwavelength-astronomy/infrared/index.html

Chapter 1: Introduction



speed = wavelength x frequency

$$c = \lambda f$$

$$\text{Energy of photon} = hf = \frac{hc}{\lambda}$$

where h is Planck's constant

Chapter 1: Introduction

- The **electromagnetic (EM) spectrum** is just a name that scientists give a bunch of types of radiation when they want to talk about them as a group.
- **Radiation** is energy that travels and spreads out as it goes-- visible light that comes from a lamp in your house or radio waves that come from a radio station are two types of electromagnetic radiation. Other examples of EM radiation are microwaves, infrared and ultraviolet light, X-rays and gamma-rays.

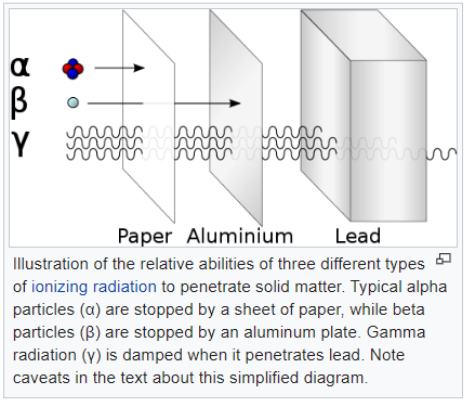


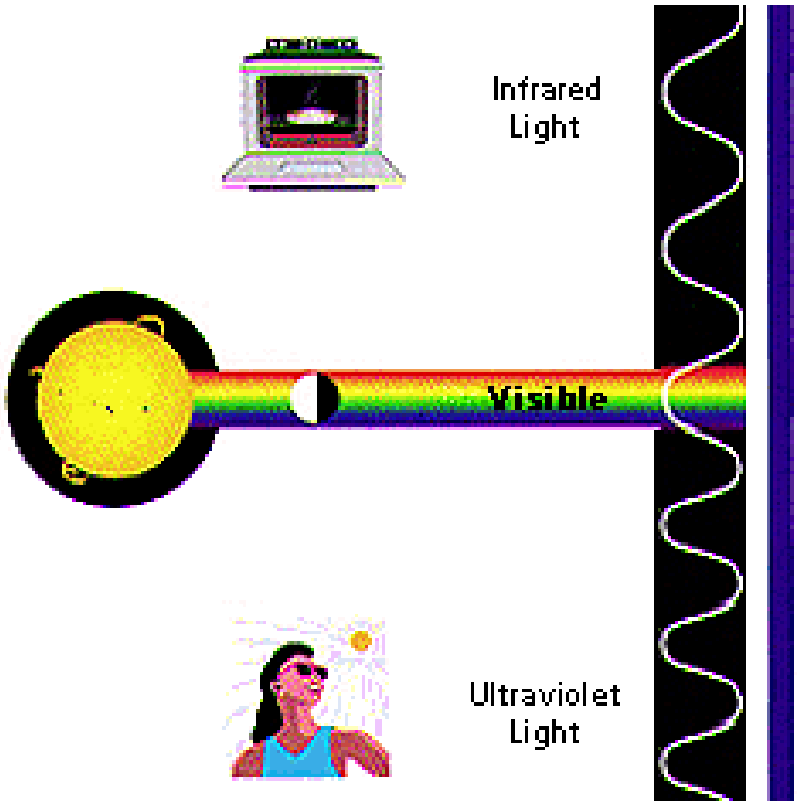
Illustration of the relative abilities of three different types of ionizing radiation to penetrate solid matter. Typical alpha particles (α) are stopped by a sheet of paper, while beta particles (β) are stopped by an aluminum plate. Gamma radiation (γ) is damped when it penetrates lead. Note caveats in the text about this simplified diagram.

Chapter 1: Introduction

- Radio: yes, this is the same kind of energy that radio stations emit into the air for your boom box to capture and turn into your favorite Mozart or Madonna tunes. But radio waves are also emitted by other things ... such as stars and gases in space.
- Microwaves: they will cook your popcorn in just a few minutes! In space, microwaves are used by astronomers to learn about the structure of nearby galaxies,

  including our own Milky Way!

Chapter 1: Introduction



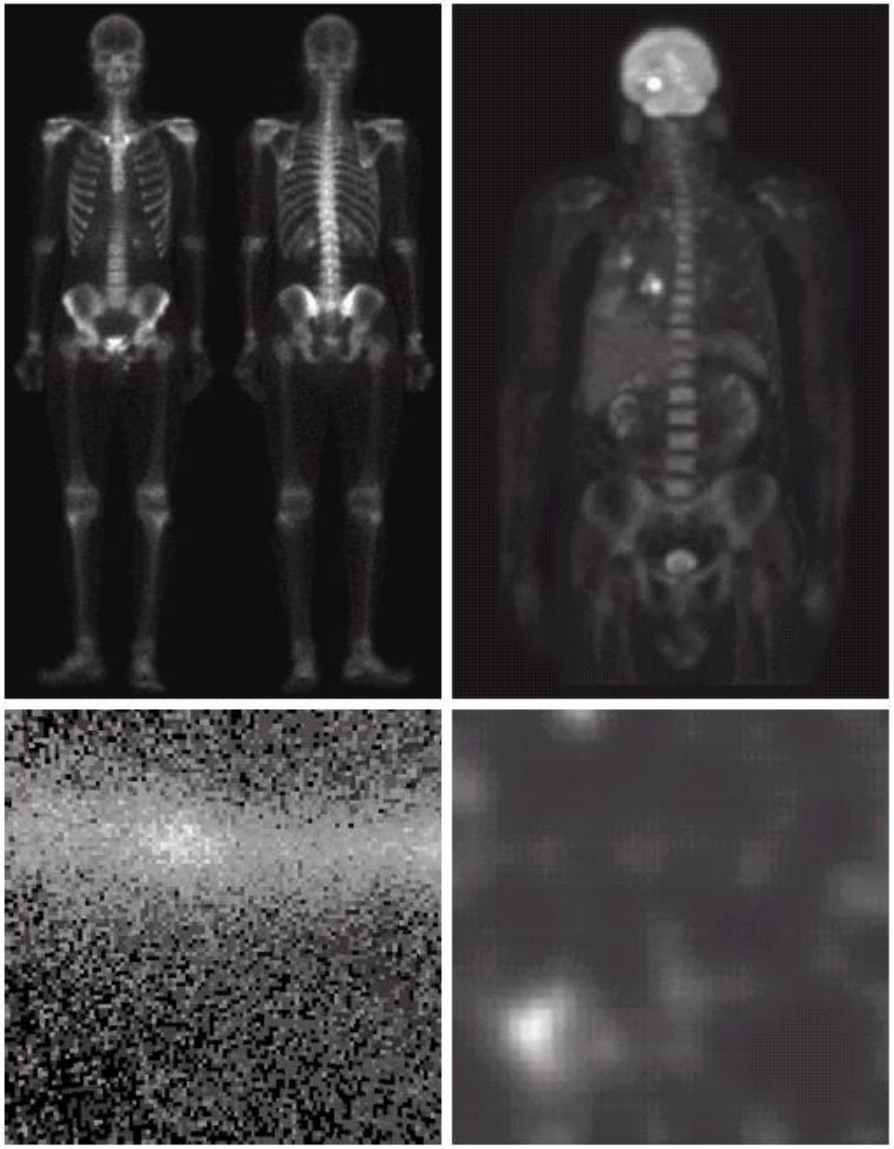
- Infrared: we often think of this as being the same thing as 'heat', because it makes our skin feel warm. In space, IR light maps the dust between stars.
- Visible: yes, this is the part that our eyes see. Visible radiation is emitted by everything from fireflies to light bulbs to stars ... also by fast-moving particles hitting other particles.
- Ultraviolet: we know that the Sun is a source of ultraviolet (or UV) radiation, because it is the UV rays that cause our skin to burn! Stars and other "hot" objects in space emit UV radiation.

Chapter 1: Introduction

- X-rays: your doctor uses them to look at your bones and your dentist to look at your teeth. Hot gases in the Universe also emit X-rays .

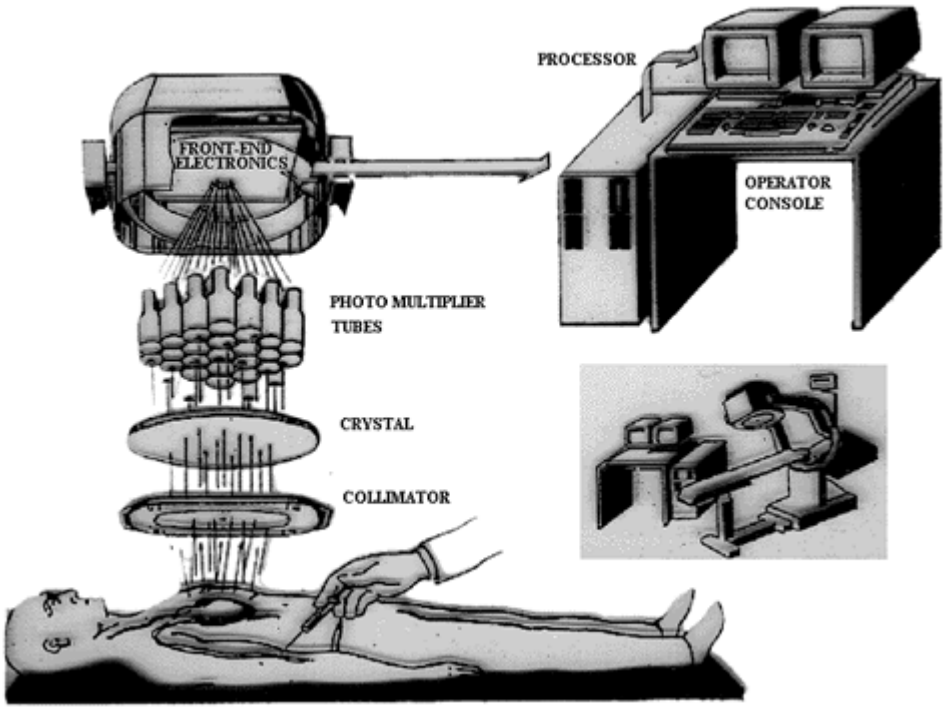
- Gamma-rays: radioactive materials (some natural and others made by man in things like nuclear power plants) can emit gamma-rays. Big particle accelerators that scientists use to help them understand what matter is made of can sometimes generate gamma-rays. But the biggest gamma-ray generator of all is the Universe! It makes gamma radiation in all kinds of ways.

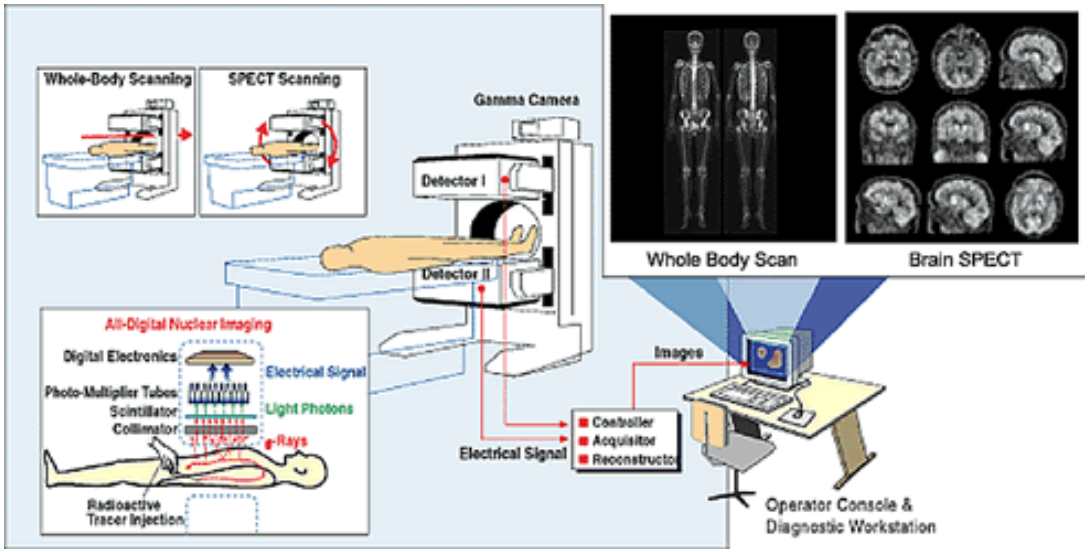
Chapter 1: Introduction



a b
c d

FIGURE 1.6
Examples of gramma-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.)


PROCESSOR
FRONT-END ELECTRONICS
OPERATOR CONSOLE
PHOTO MULTIPLIER TUBES
CRYSTAL
COLLIMATOR

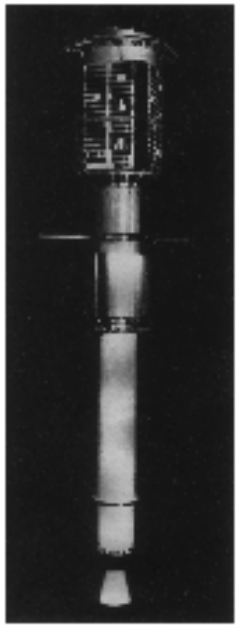

Whole-Body Scanning
SPECT Scanning
Gamma Camera
Detector I
Detector II
All-Digital Nuclear Imaging
Digital Electronics
Photo-Multiplier Tubes
Scintillator
Collimator
Electrical Signal
Light Photons
γ-Rays
Radioactive Tracer Injection
Electrical Signal
Controller
Acquisitor
Reconstructor
Images
Operator Console & Diagnostic Workstation
Whole Body Scan
Brain SPECT

Chapter 1: Introduction

PET 是 Positron Emission Tomography之簡稱，中文稱之為正子斷層掃描。可以做射入(Transmission)及射出 (Emission)掃描，兩者皆可做動態(Dynamic)、靜態(Static)、及全身(Whole body)掃描方式。檢查部位最主要包括:**腦部、心臟，及全身檢查**。

利用放射性核種會產生原子核衰變而釋放出正子(Positron)之原理，故稱之為正子斷層掃描。當放射性藥物由靜脈注射進入人體後，立即在細胞內進行生化及代謝作用，放射性同位素所釋放出的正子會與外圍電子進行互毀(Annihilation)，並產生兩個511Kev之光子，約成180度的射出。經由PET系統將此光子對所產生的一致信號(Coincidence Events)收集，再由電腦軟體將訊號組成影像並且切成三個平面。

Chapter 1: Introduction



Gamma-rays coming from space are mostly absorbed by the Earth's atmosphere. So gamma-ray astronomy could not develop until it was possible to get our detectors above all or most of the atmosphere, using balloons or spacecraft. The first gamma-ray telescope carried into orbit, on the Explorer XI satellite in 1961, picked up fewer than 100 cosmic gamma-ray photons. These appeared to come from all directions in the Universe, implying some sort of uniform "gamma-ray background". Such a background would be expected from the interaction of cosmic rays (very energetic charged particles in space) with gas found between the stars.

https://skyview.gsfc.nasa.gov/current/help/skv_images_cygnus.html

Chapter 1: Introduction

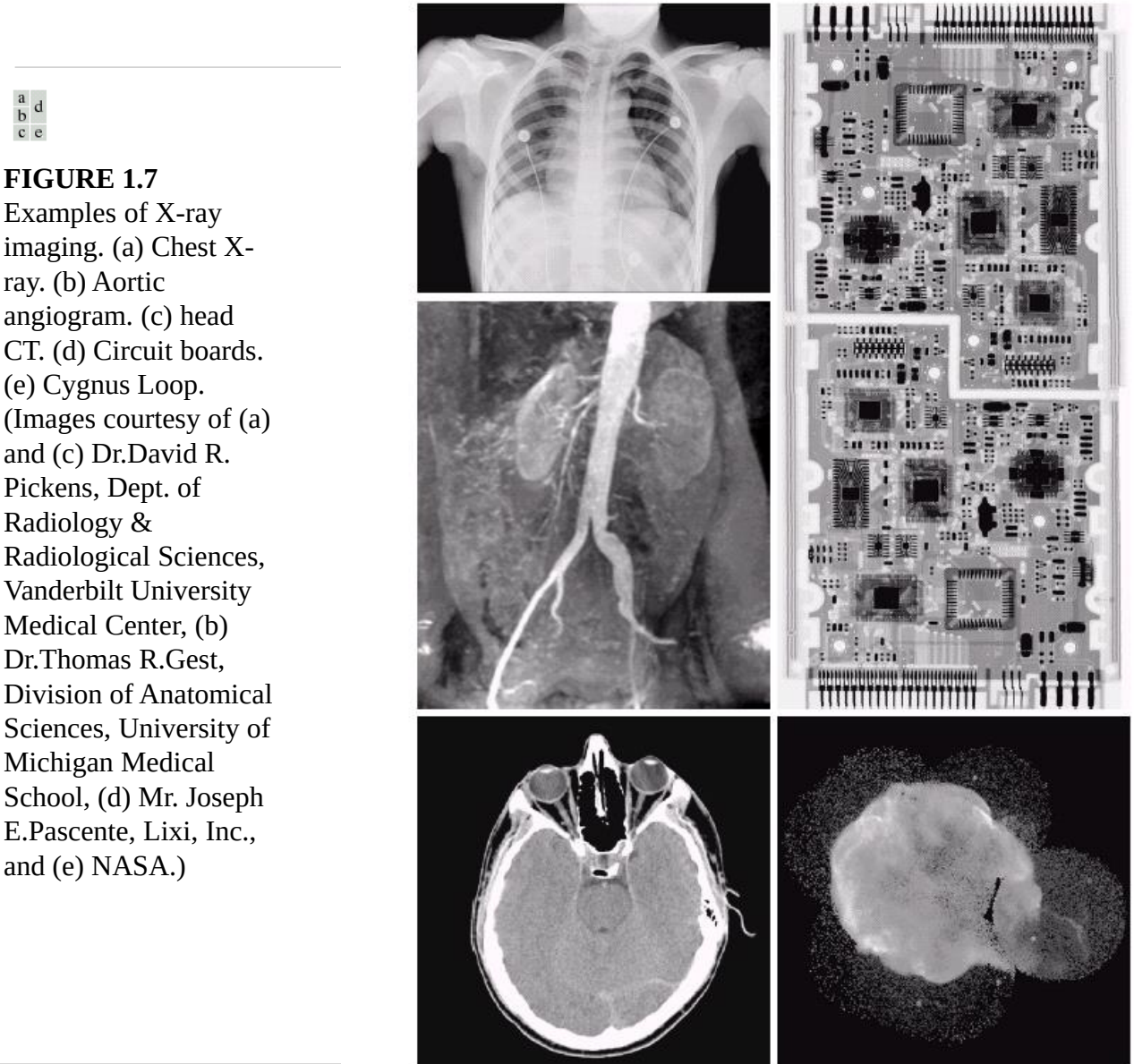
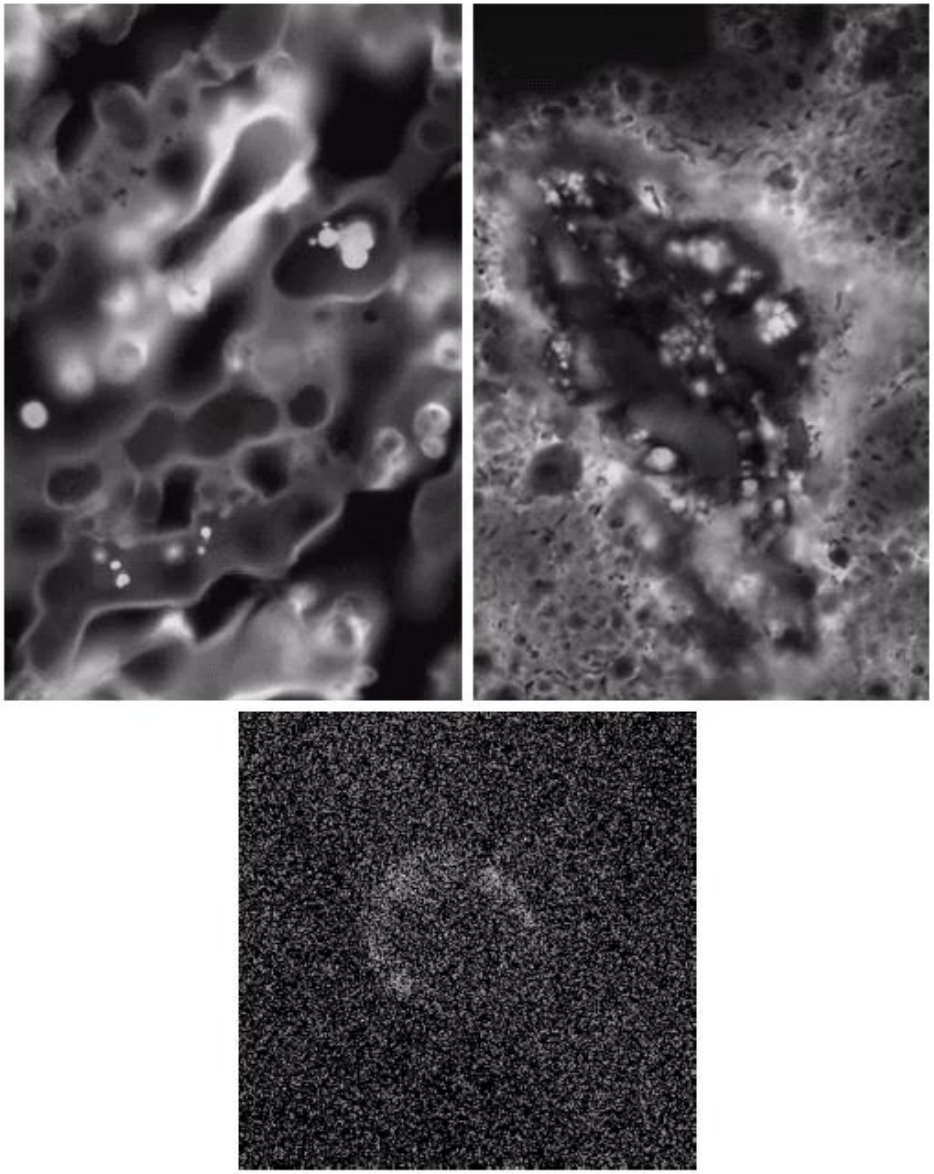


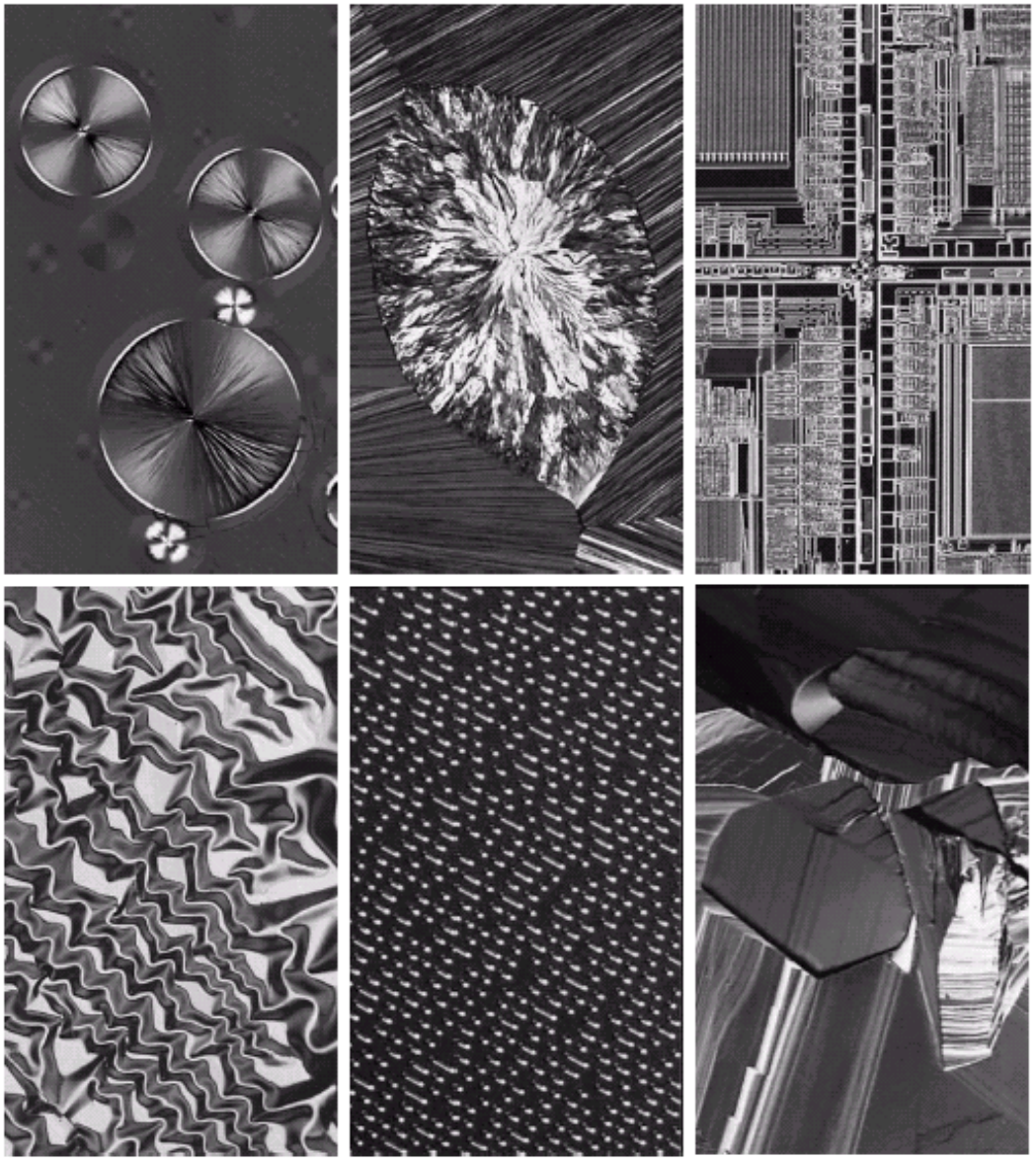
FIGURE 1.7
Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr.David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr.Thomas R.Gest, Division of Anatomical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



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.)

Chapter 1: Introduction



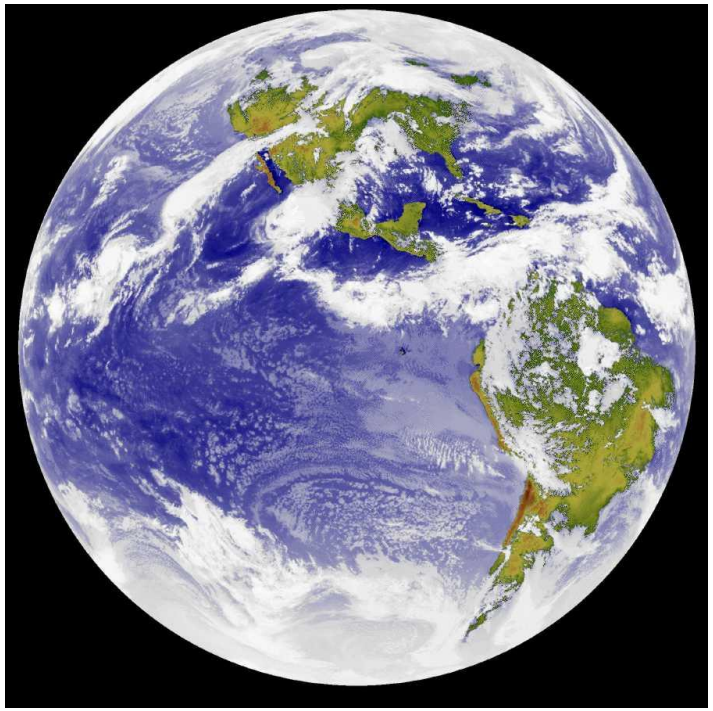
a b c
d e f

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

Chapter 1: Introduction

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



Chapter 1: Introduction

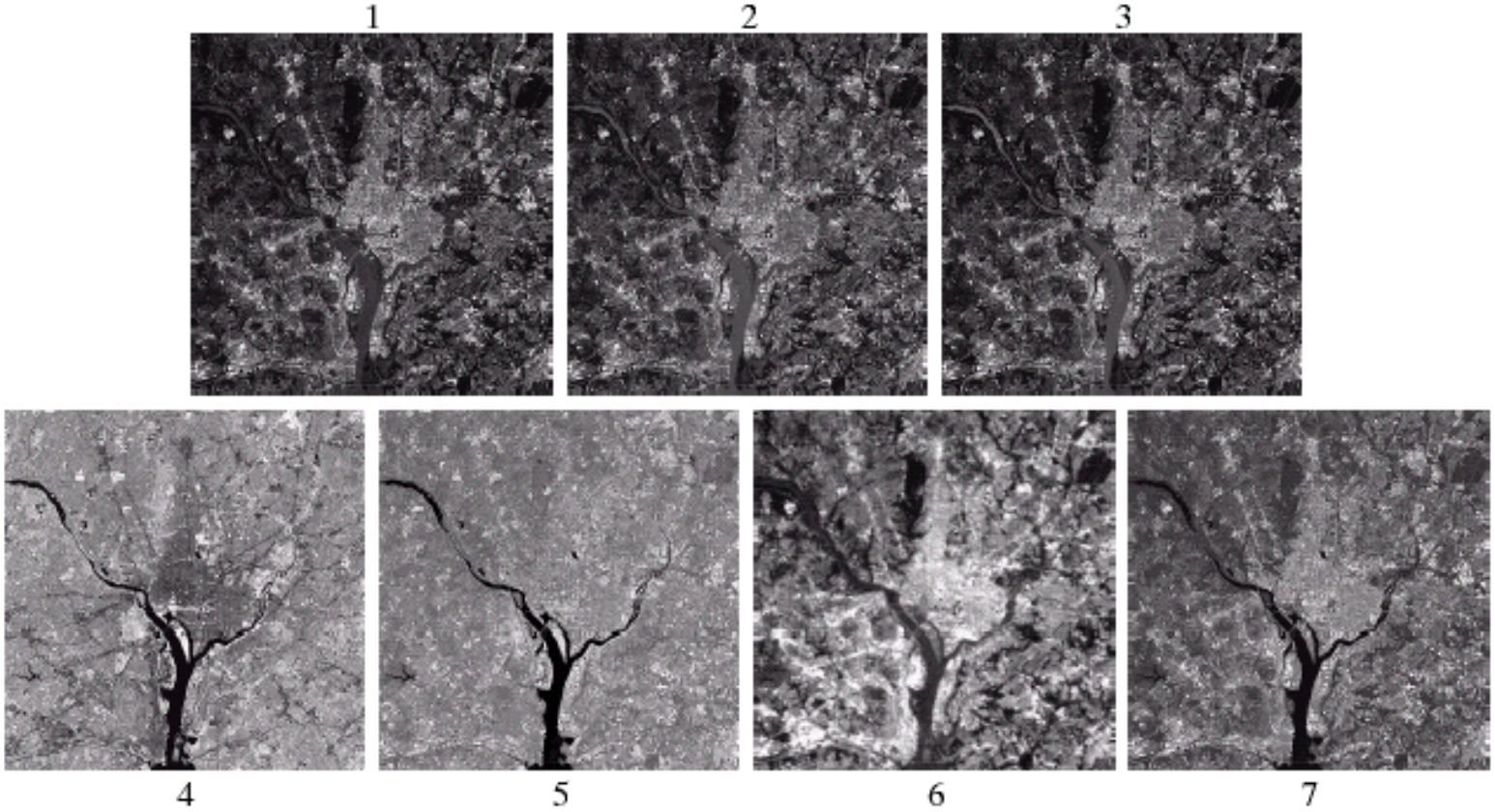


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Chapter 1: Introduction

TABLE 1.1 Thematic bands of 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	0.53–0.61	Measures plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.78–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content: soil/vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Short-wave infrared	2.09–2.35	Mineral mapping

Chapter 1: Introduction

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

Chapter 1: Introduction

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.)

Chapter 1: Introduction

a b
c d
e f

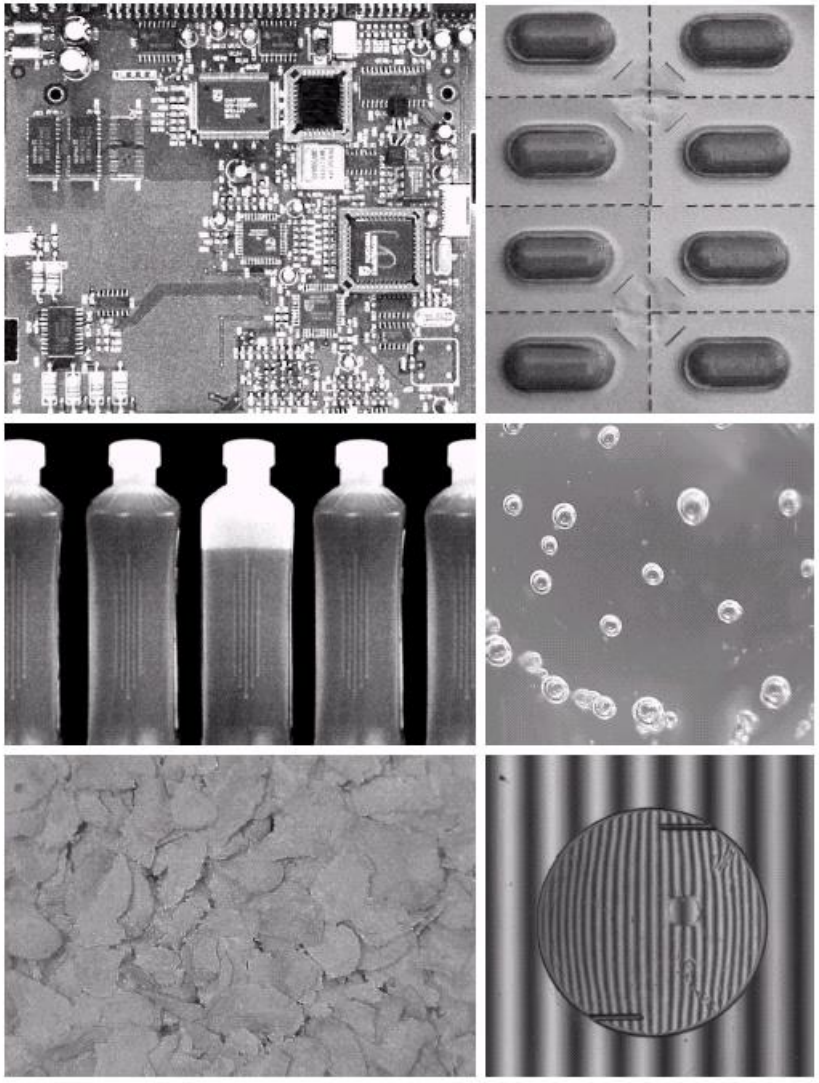
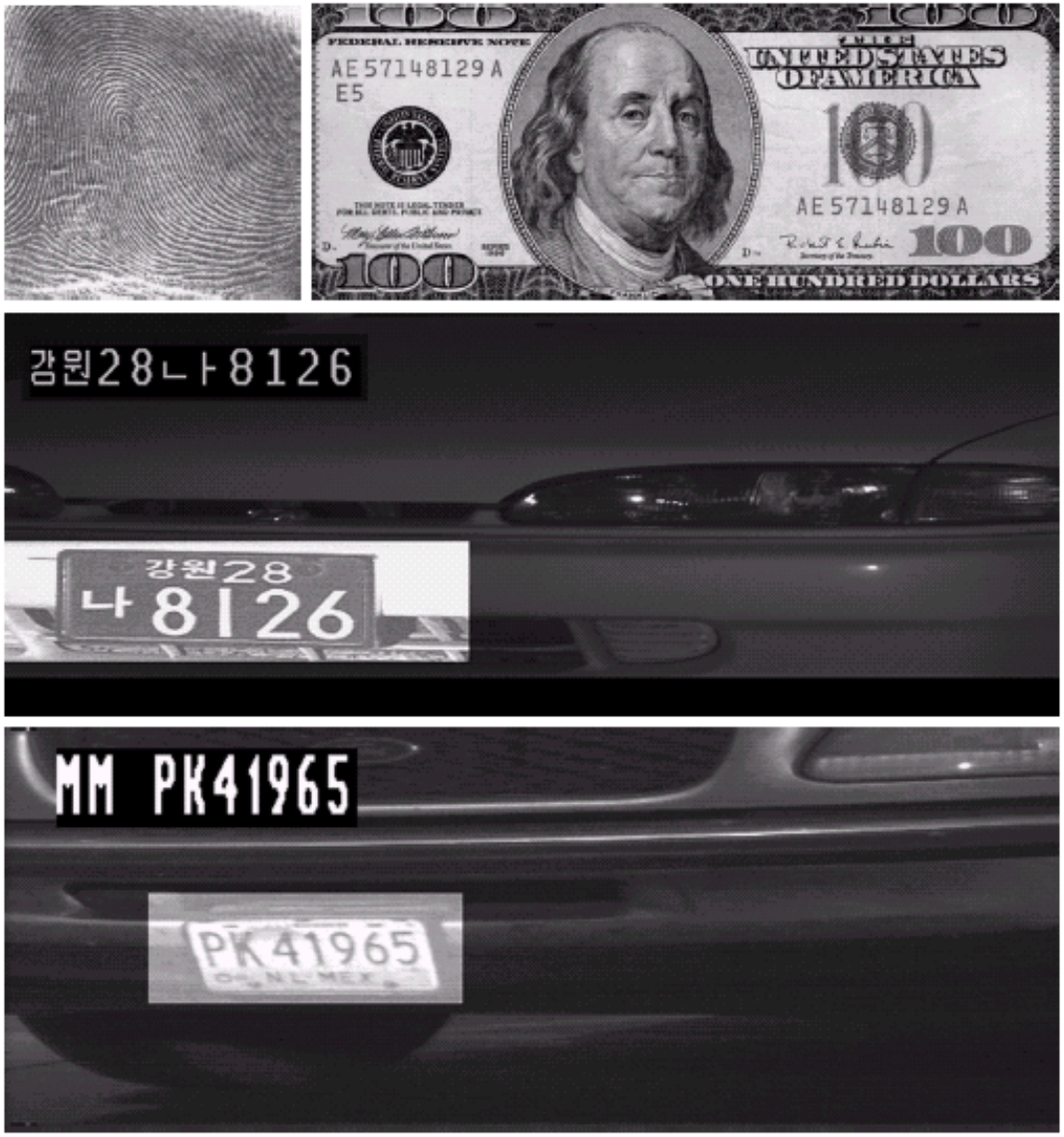


FIGURE 1.14
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Bubbles in clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr.Pete Sites, Perceptics Corporation.)

Chapter 1: Introduction



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.)

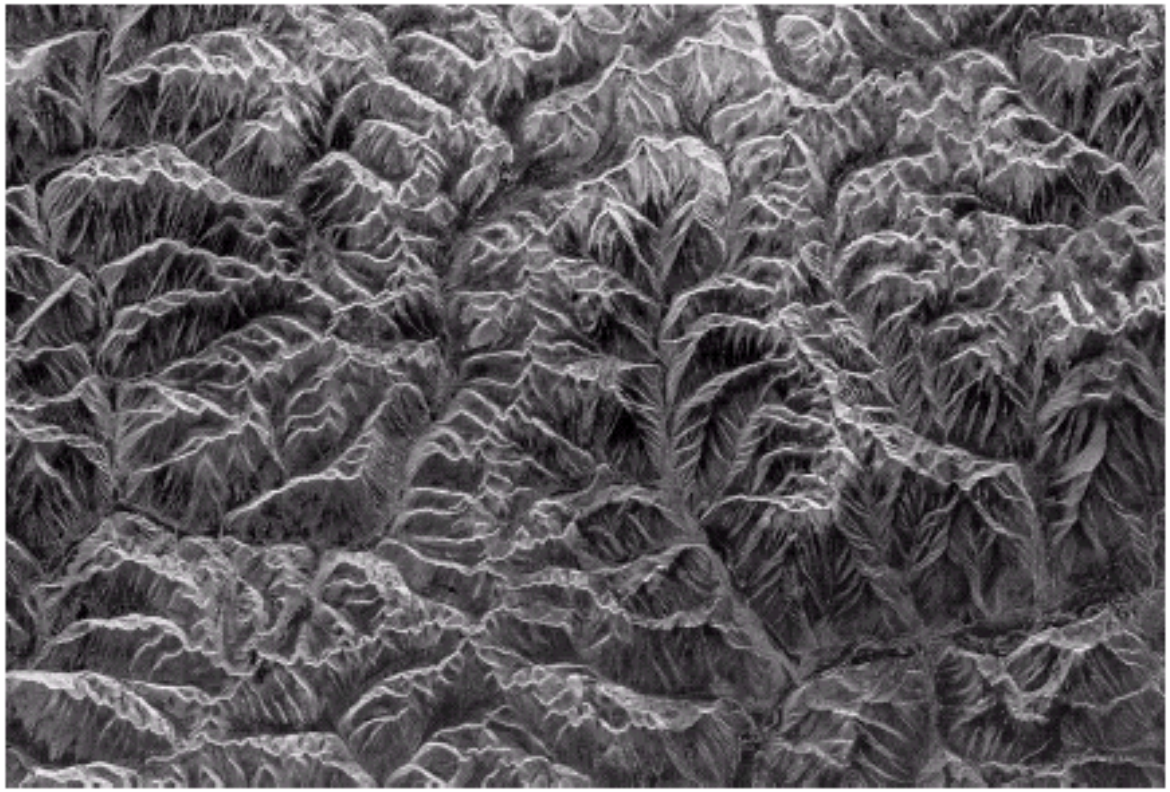
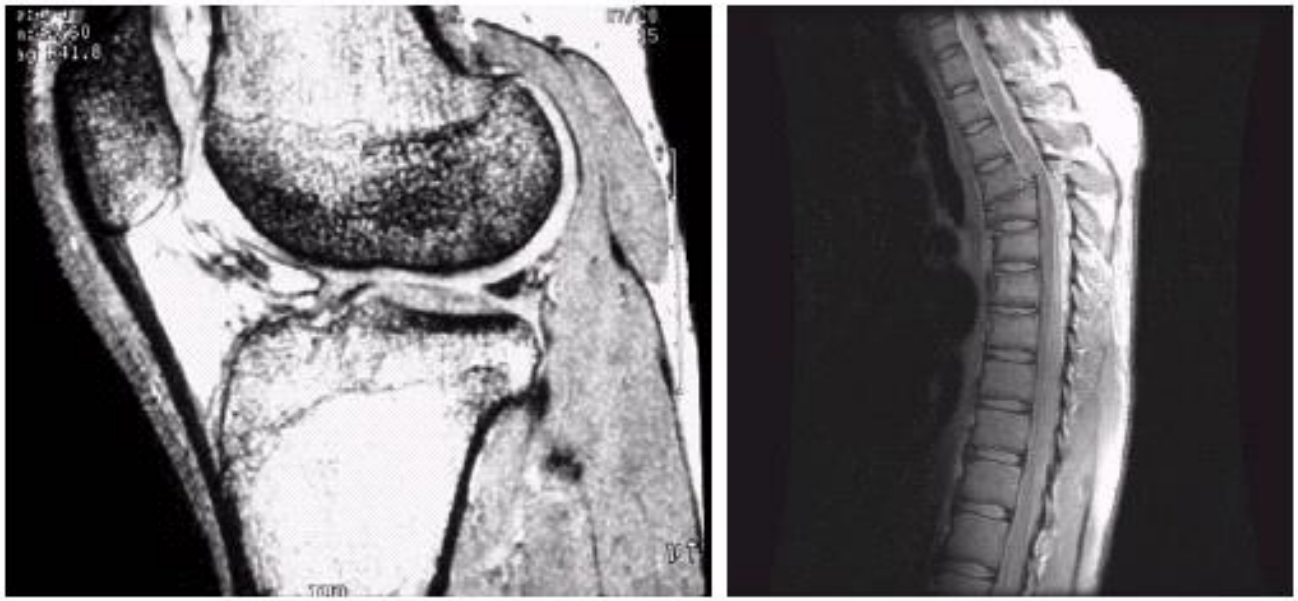


FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

Chapter 1: Introduction



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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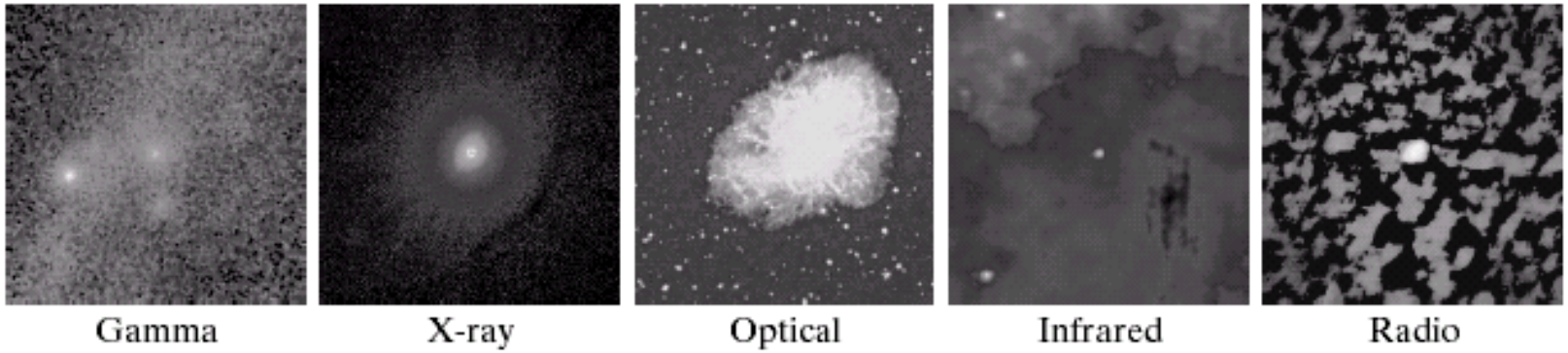


FIGURE 1.18 Image of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

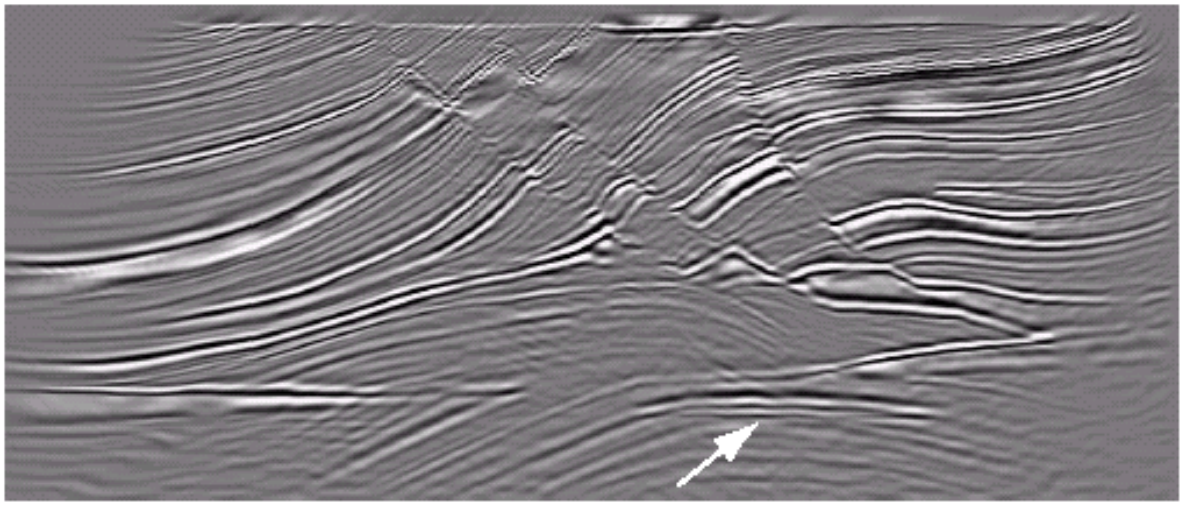
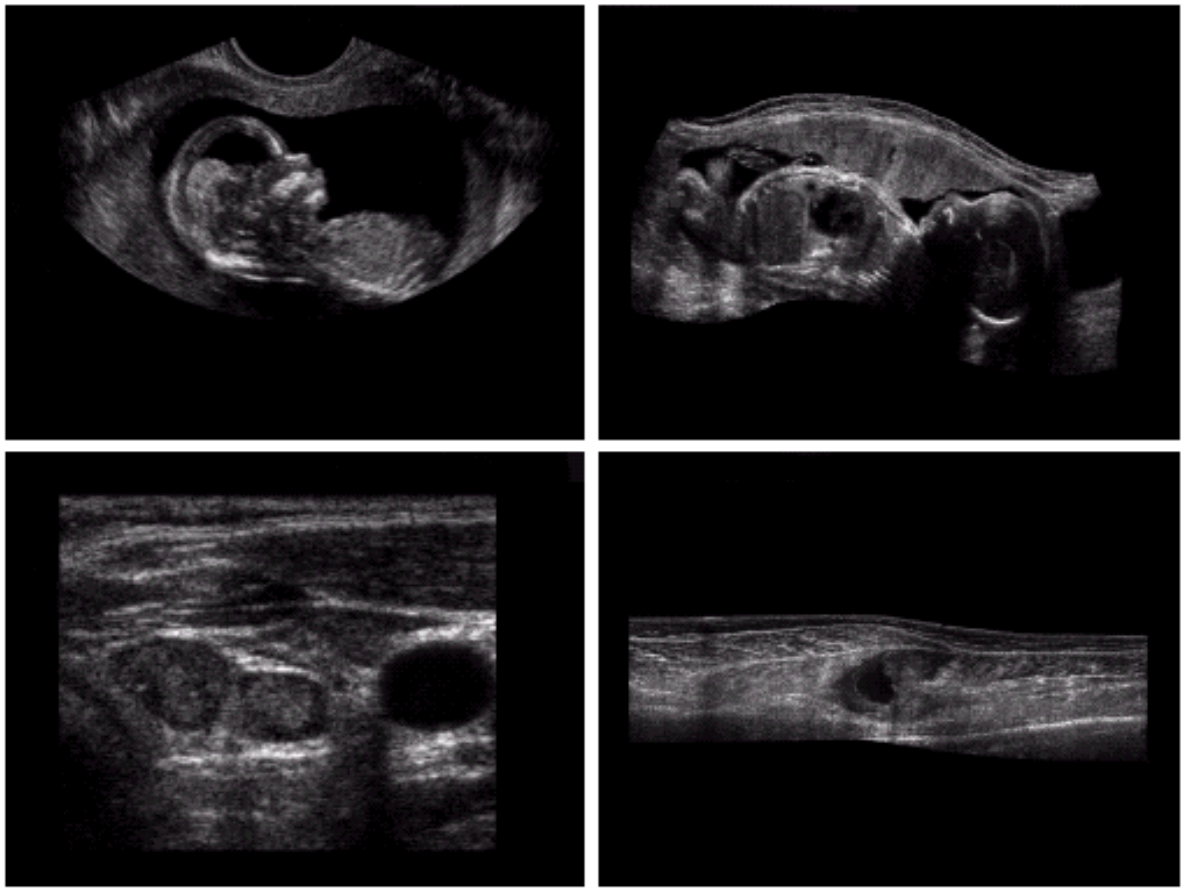


FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

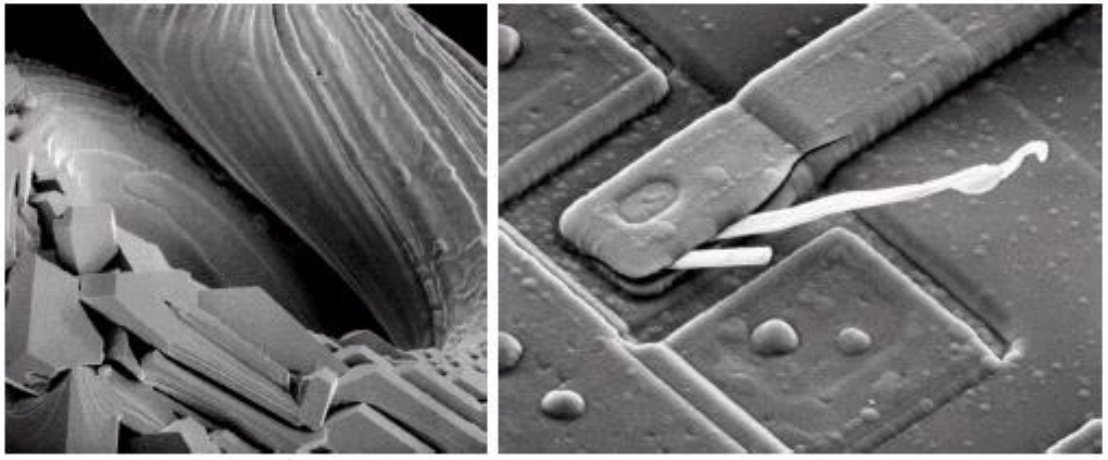
Chapter 1: Introduction



a b
c d

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

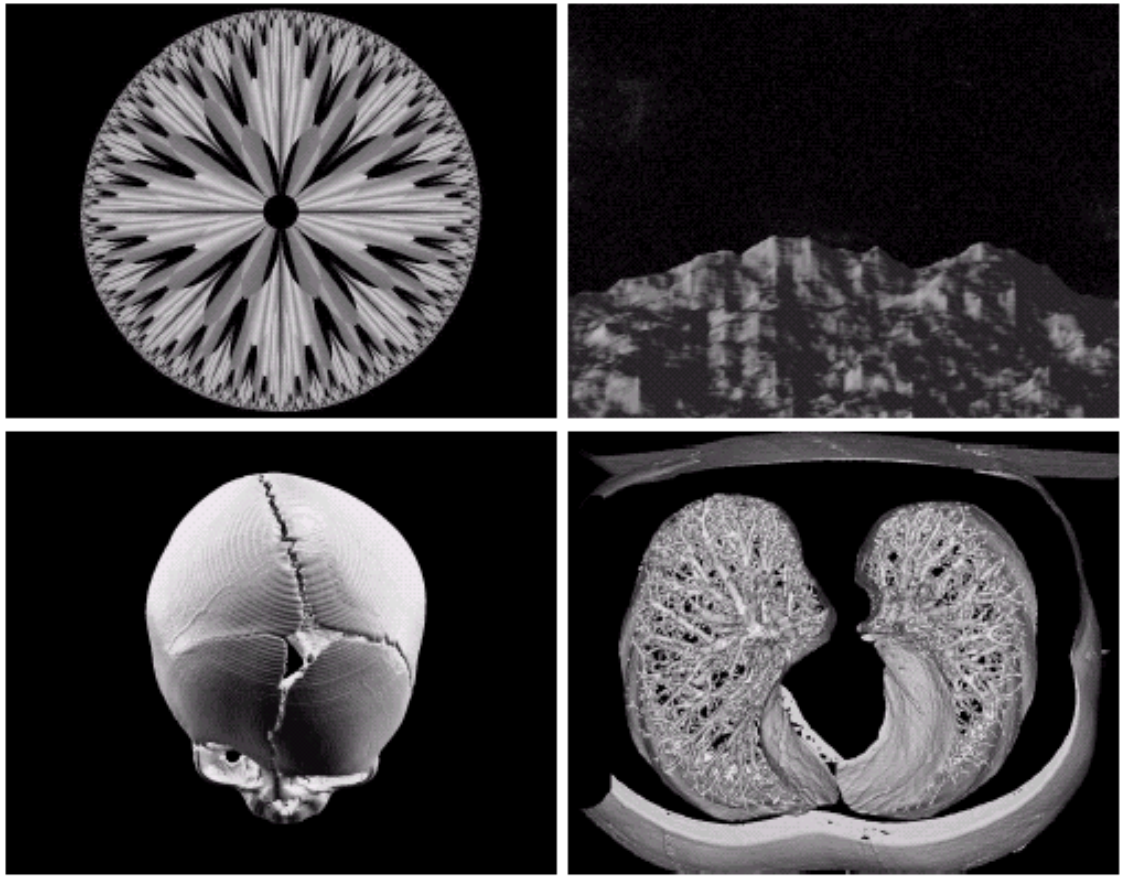
Chapter 1: Introduction



a b

FIGURE 1.21 (a) 250xSEM image of a tungsten filament following thermal failure. (b) 2500xSEM 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.)

Chapter 1: Introduction

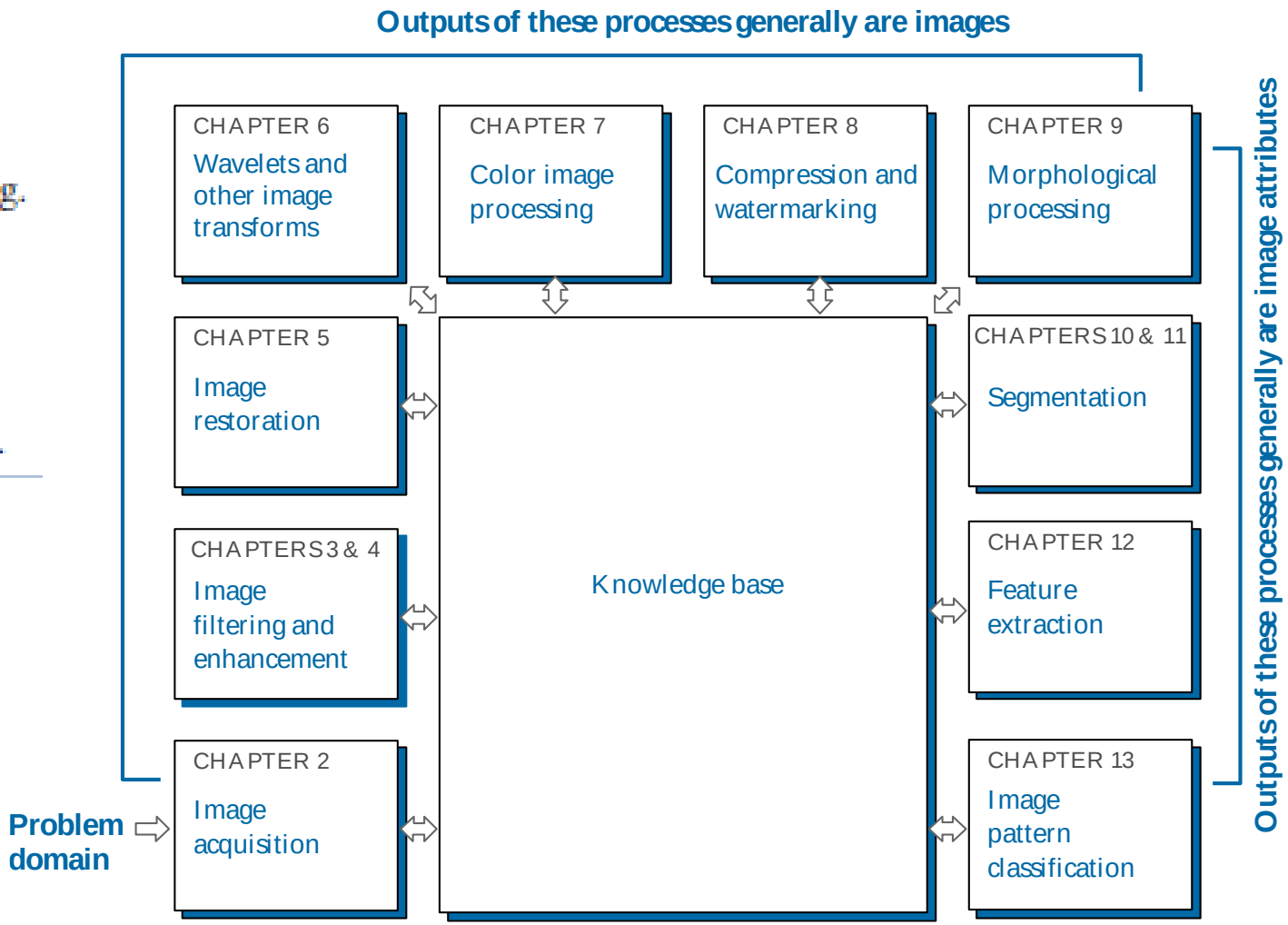


a b
c d

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.)

Chapter 1: Introduction

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.



Chapter 1: Introduction

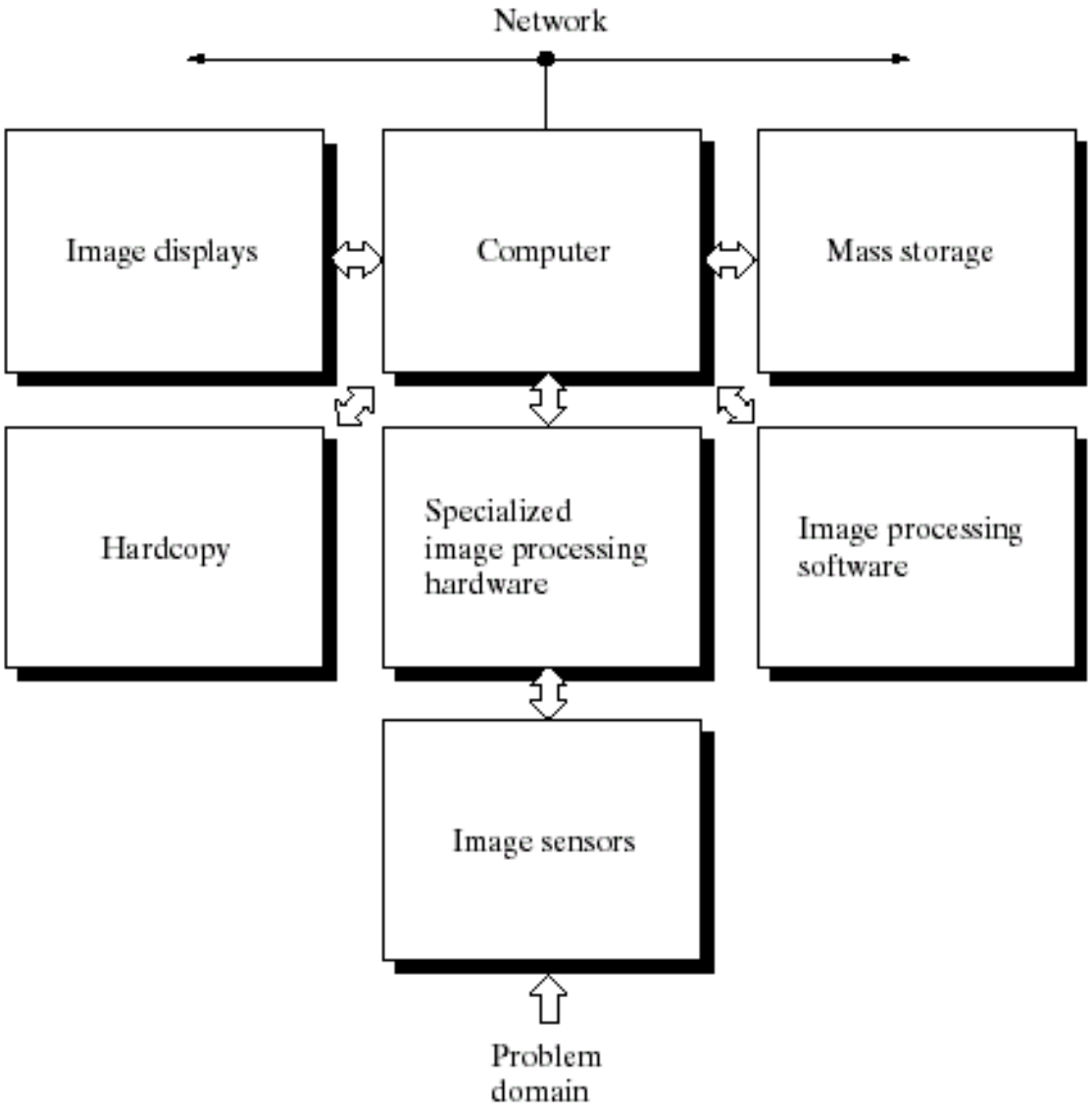


FIGURE 1.24
Components of a general-purpose image processing system.