CSA 4702: Digital Image Processing

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Semester 2021/2021 II Schedule

Tuesday: 1200 – 1300 (Webex Online)

Thursday: 0900 – 1100 (Webex Online)

Link: https://umt.webex.com/meet/suzuri

Course Content & Schedule

Week 1	Chapter 1: Introduction to Digital Image Processing
Week 2 & 3	Chapter 2: Digital Image Fundamentals
Week 4 & 5	Chapter 3: Image Enhancement in Spatial Domain
Week 6	Chapter 4: Image Enhancement in Frequency Domain Midterm Test
Week 7&8	Chapter 6: Color Image Processing

Course Content & Schedule (cont.)

Week 9&10	Chapter 9: Morphological Image Processing
Week 11&12	Chapter 10: Image Segmentation
Week 13&14	Chapter 11: Representation and Description

Note: The schedule may be changed from time to time when necessary.

References

- Rafael C. Gonzalez and Richard E. Woods, "Digital Image Processing", Prentice Hall 2002.
- Rafael C. Gonzalez, Richard E. Woods and Steven L. Eddins, "Digital Image Processing using MATLAB", Prentice Hall 2004.
- Milan Sonka, Vaclav Hlavac and Roger Boyle, "Image Processing Analysis and Machine Vision", PWS Publishing, 1998.
- Maria Petrou & Panagiota Bosdogianni, "Image Processing: The Fundamentals", John Wiley

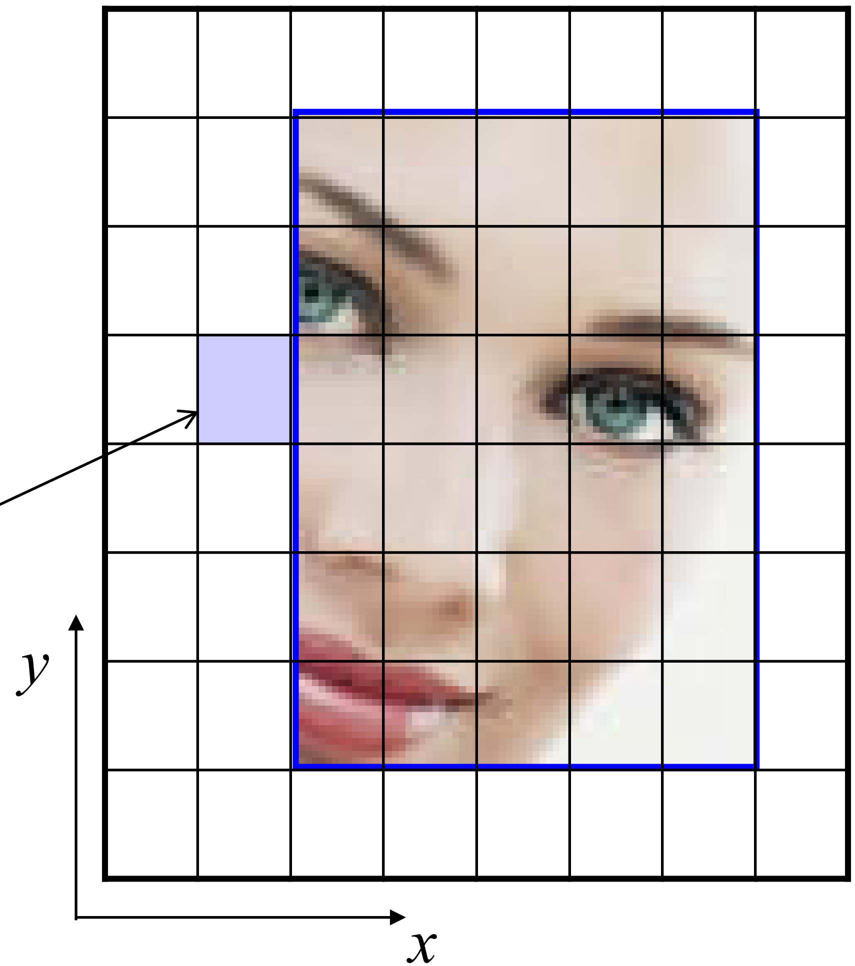
Chapter 1: Introduction to Digital Image Processing (DIP)

Chapter Overview:

- ✓ To define DIP and its scope
- ✓ To provide brief historical overview of DIP (self-reading)
- ✓ To give an idea of state of art of DIP application areas
- ✓ To discuss briefly principles approaches in DIP
- ✓ To give an overview of general components in DIP

What is Digital Image Processing (DIP) ?

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 any pair of coordinates (*x*,*y*) is called the ***intensity*** or ***gray level*** of the image at that point.



picture elements, image elements, pels or pixels

Human Vision vs Computer Vision

- Limited to visual band of the electromagnetic (EM) spectrum

- Could cover almost the entire electromagnetic (EM) spectrum, from gamma to radio waves

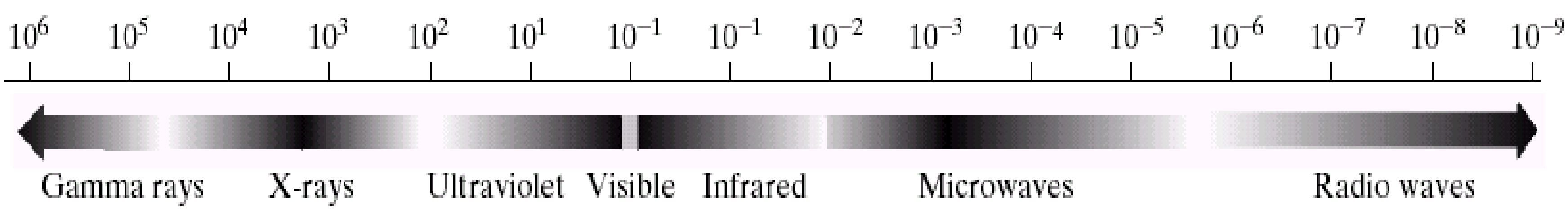
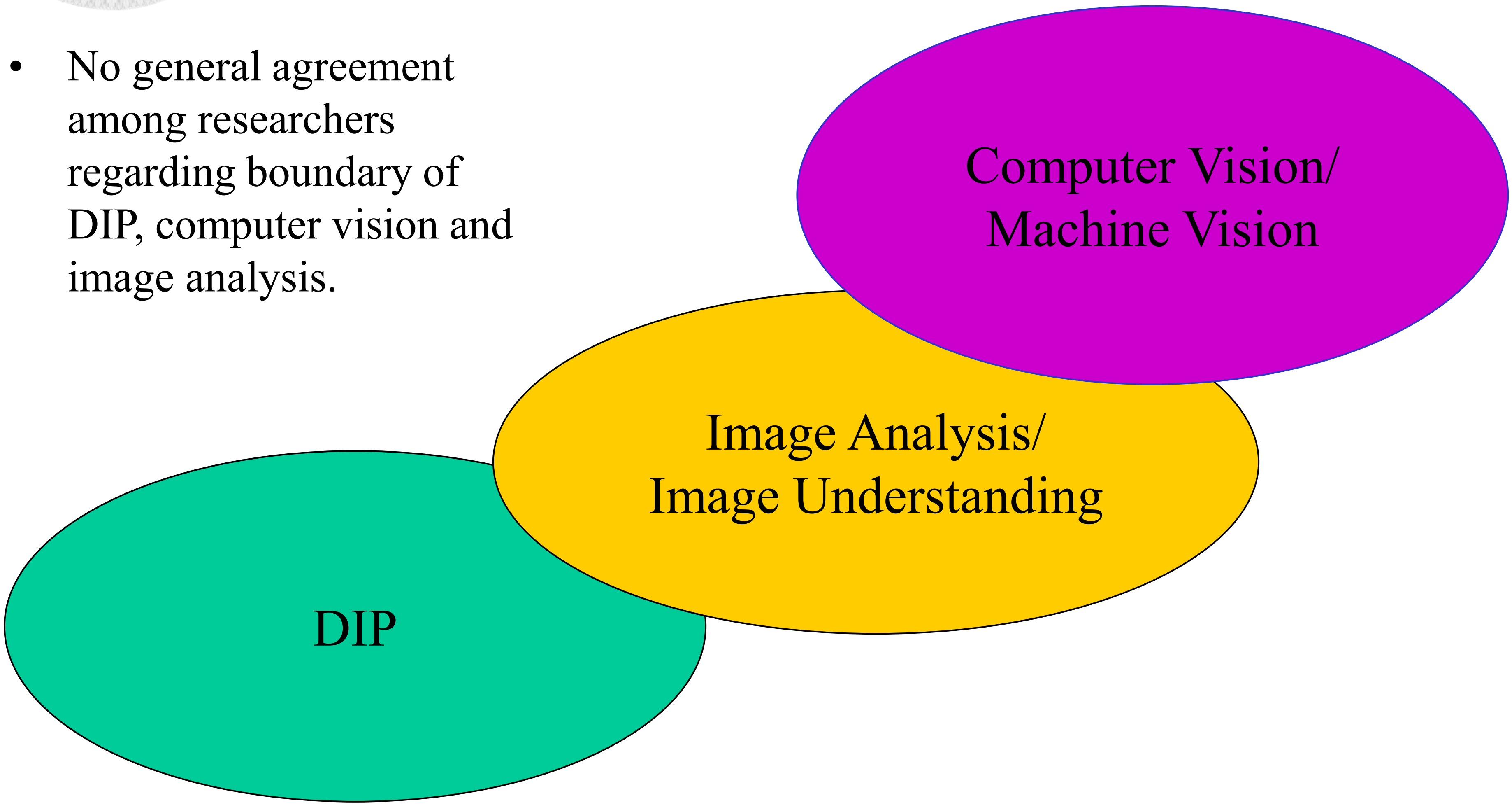


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

DIP, Computer Vision, Image Analysis Area of Coverage ?

- No general agreement among researchers regarding boundary of DIP, computer vision and image analysis.



A General Paradigm to Define Area Boundary

Low Level Process:

- **input, output are images**
- primitive operation,
  i.e., image preprocessing to reduce noise, contrast enhancement, image sharpening, etc.

High Level Process:

- Making sense of an ensemble of recognized objects, image analysis, etc.

Mid Level Process:

- **Inputs may be images, outputs are attributes extracted from those images**
- segmentation (partitioning an image into regions), feature extraction, classification, etc.

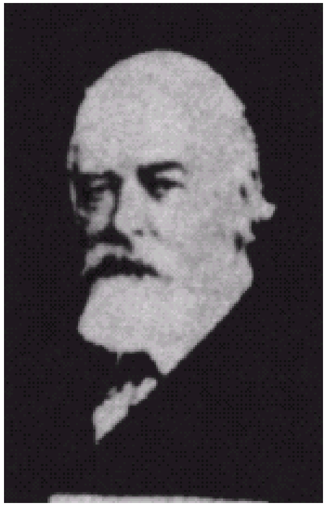
DIP areas

The Origin of Digital Image Processing

One of the first application of DIP in the newspaper industry – image sent from London to New York using submarine cable

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. Some errors are visible. (McFarlane.)



Early system using 5 level of gray

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

15 gray level in 1929

First Computer for DIP

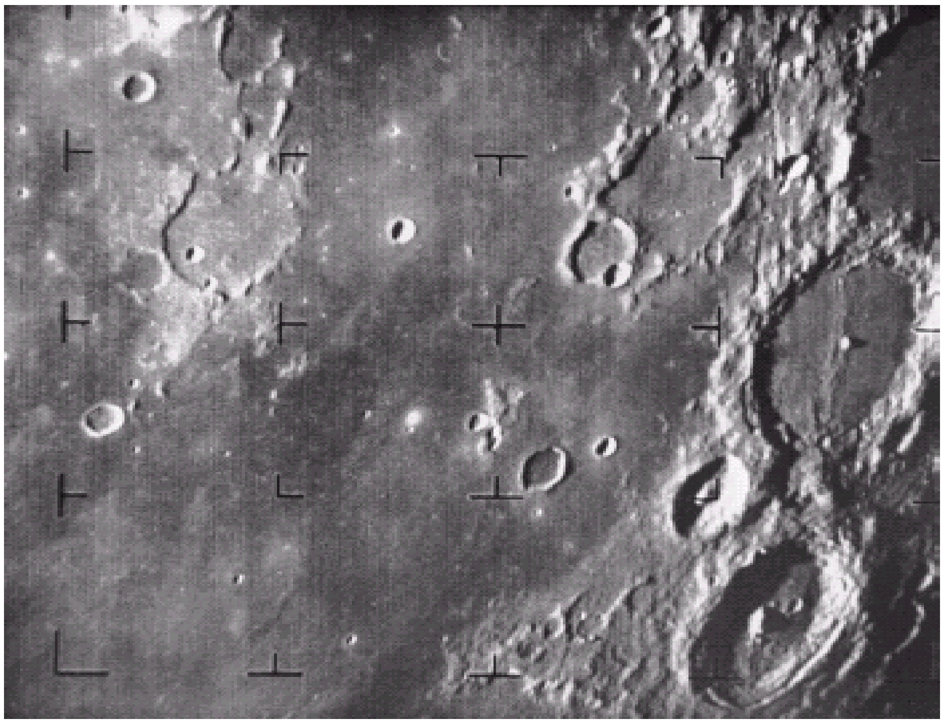


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

In 1964, Jet Propulsion Laboratory, (Pasadena, California) used computer to correct various types of image distortion.

DIP Area of Applications

Simplest way of categorizing is from the source of the image taken.

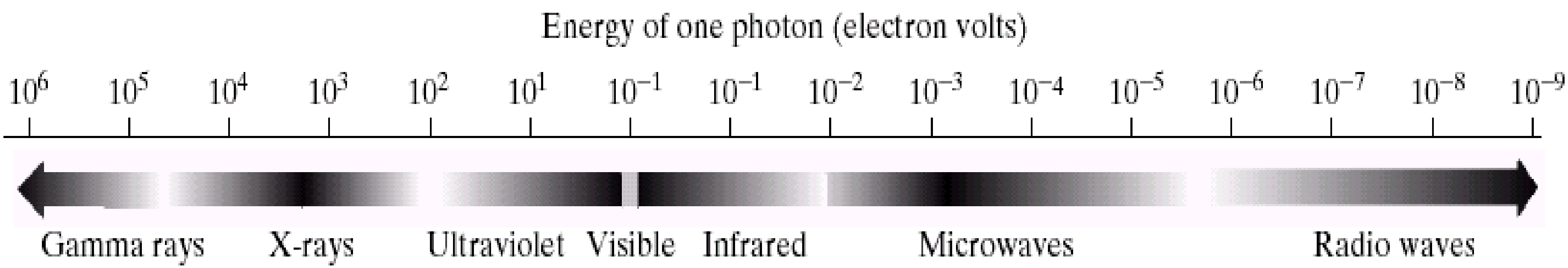


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Other sources: acoustic, ultrasonic, electronics (electron beams in SEM) & syntactic images (computer generated).

Images Based on Radiation from EM Spectrum

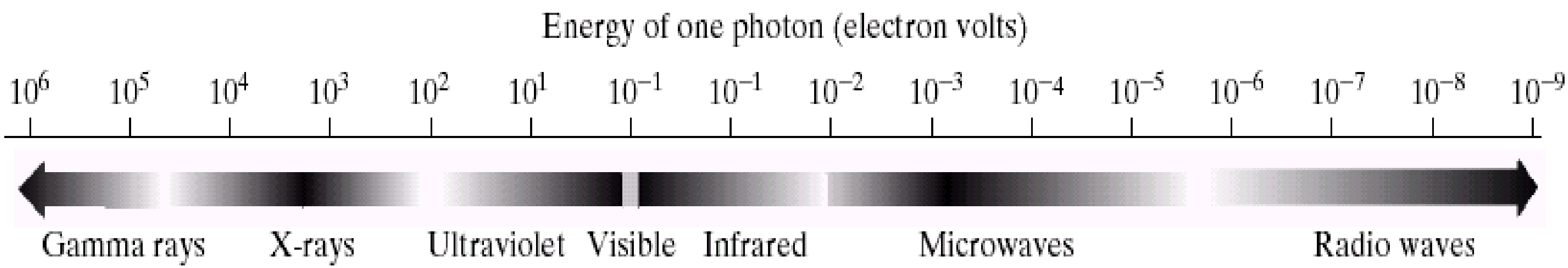


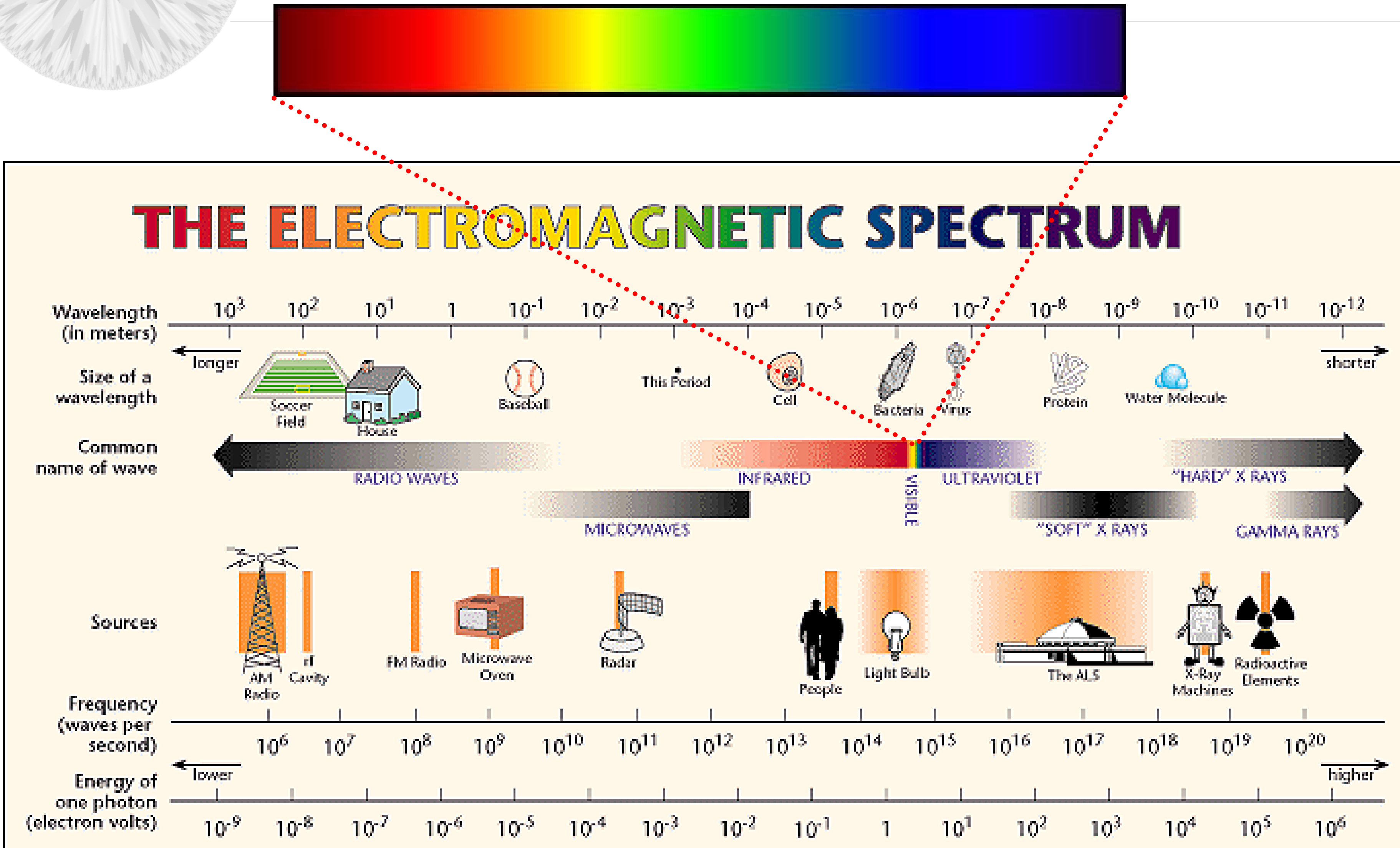
FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Highest energy → Lowest energy

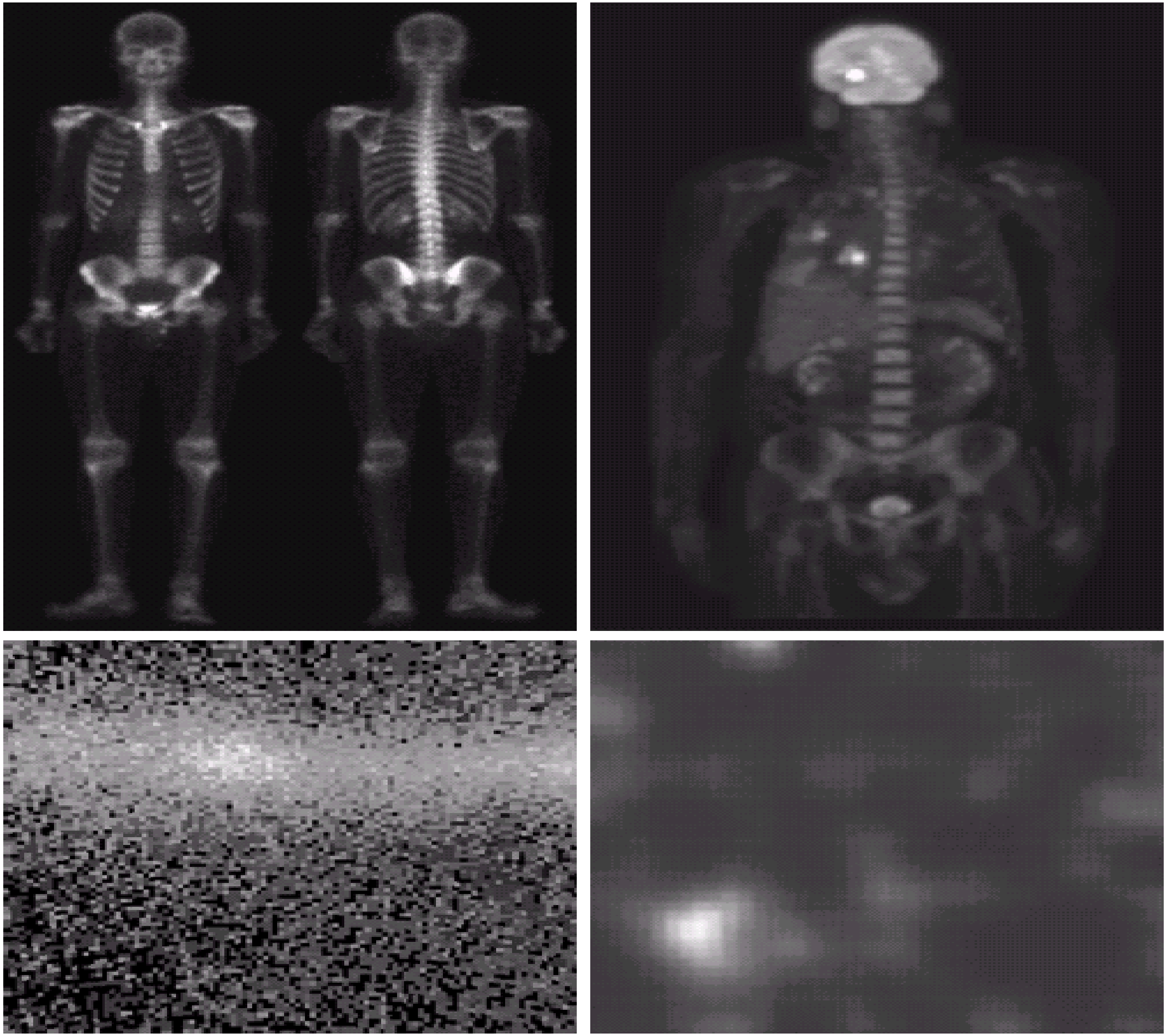
EM waves could be conceptualized as a stream of massless particles, each traveling in a wavelike pattern & moving at a speed of light.

Each massless particle contains a certain amount (bundle) of energy. Each bundle of energy is called a *photon.*

The Electromagnetic Spectrum



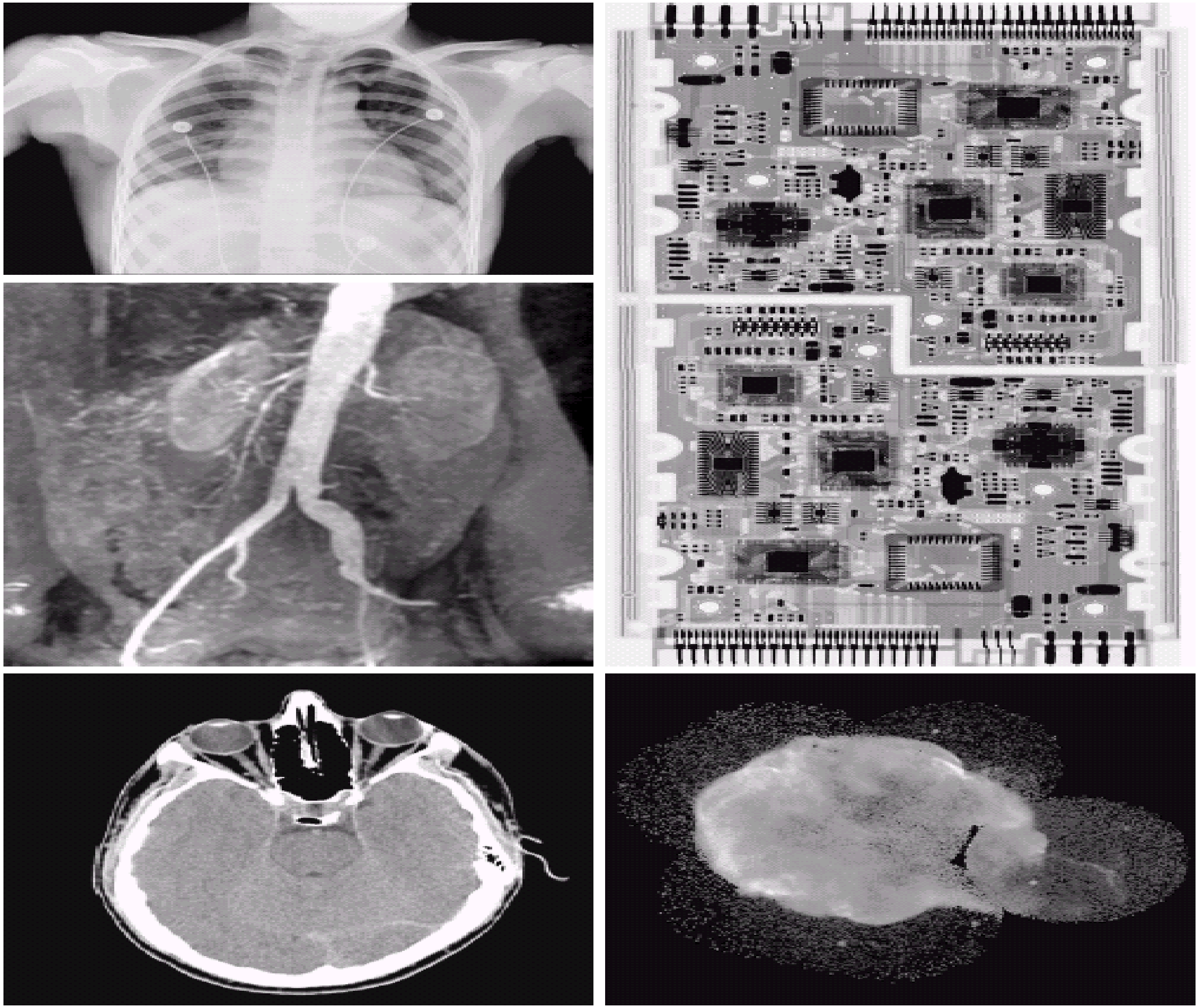
Gamma-Ray Imaging



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.)

X-ray Imaging



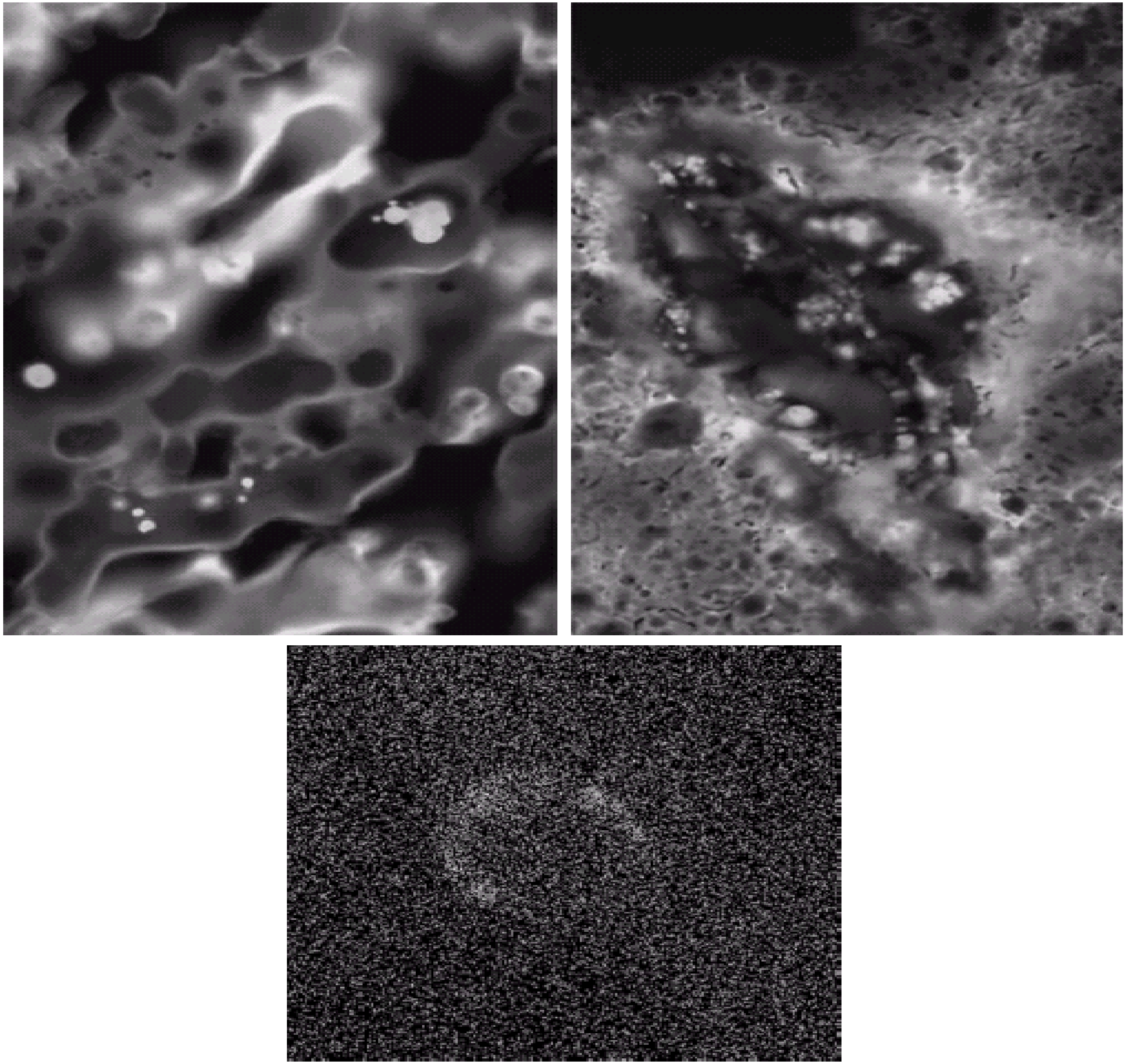
a	d
b	
c	e

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.)

Imaging in 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 Visible & Infrared Bands

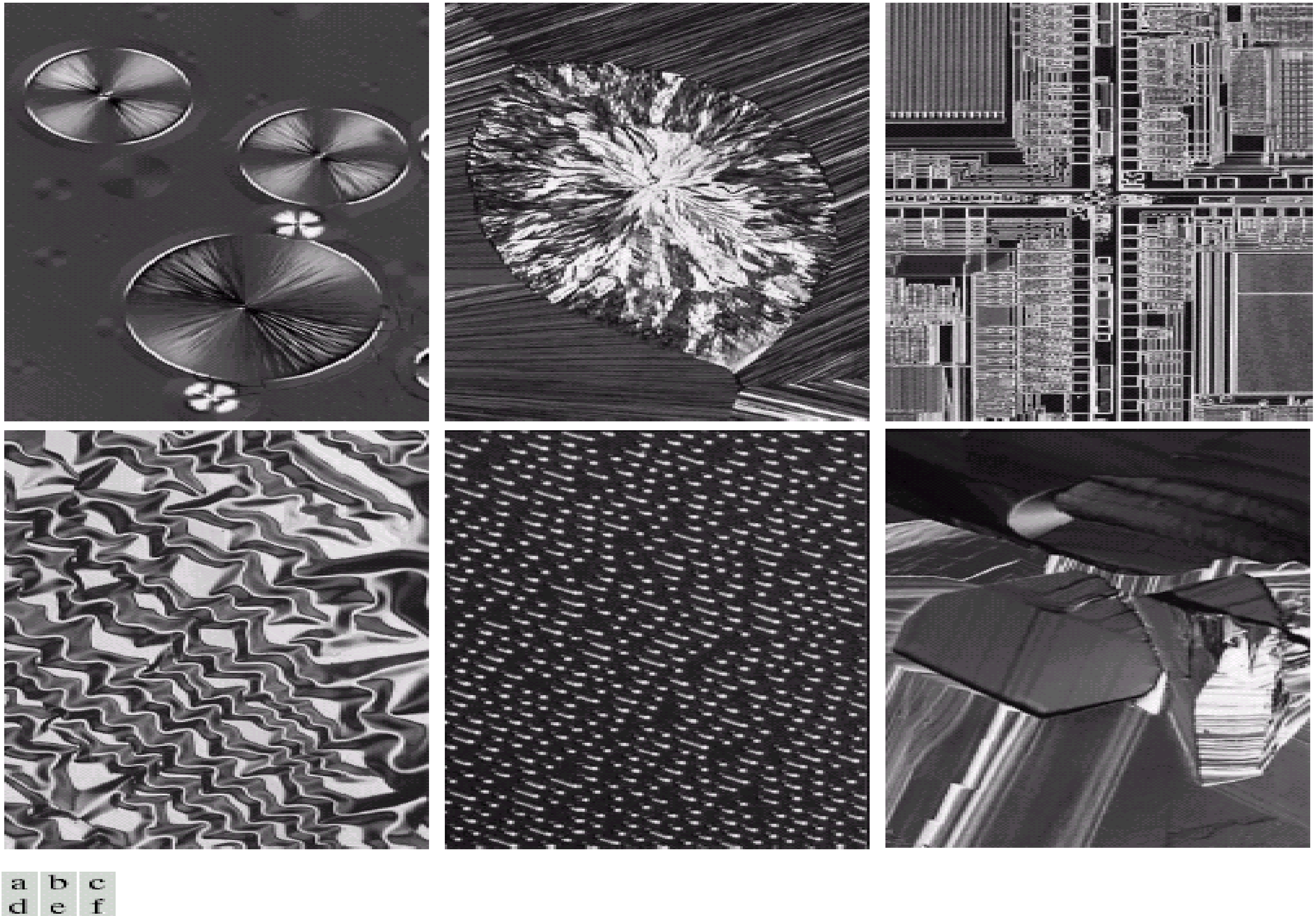


FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

Remote Sensing: Monitoring environmental conditions on the planet

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

Remote Sensing Imaging Example

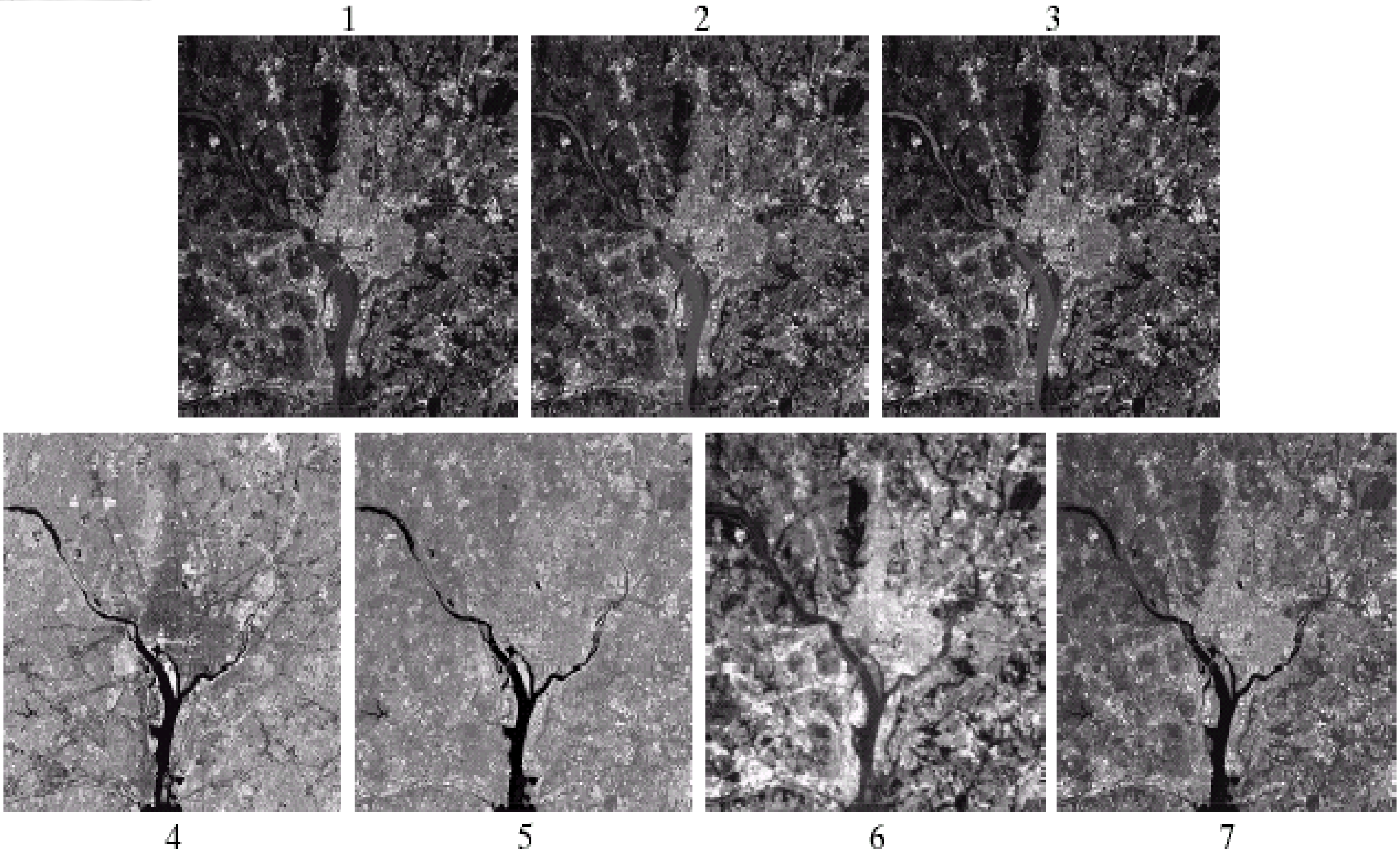


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Remote Sensing: Weather observation & prediction

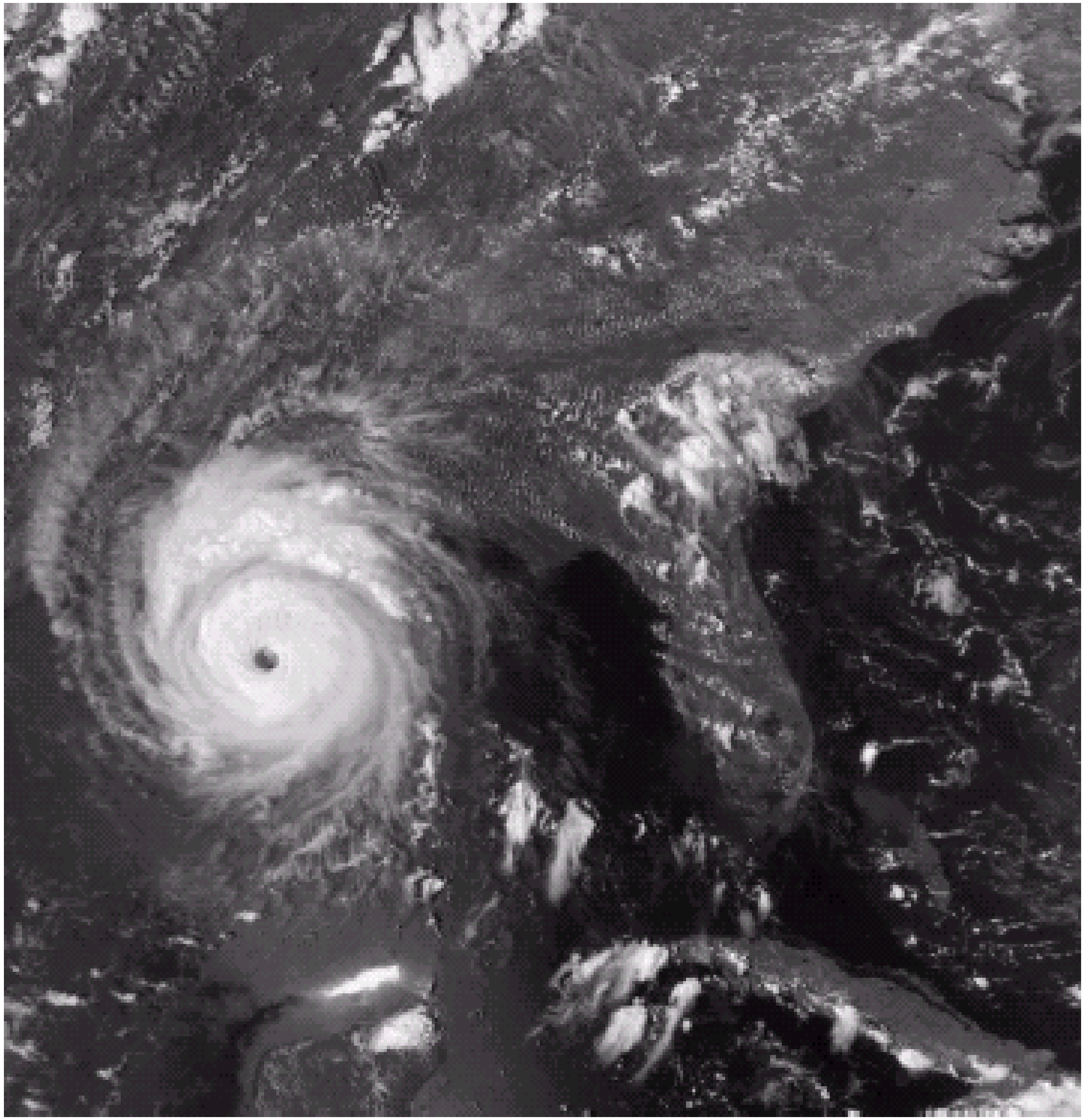
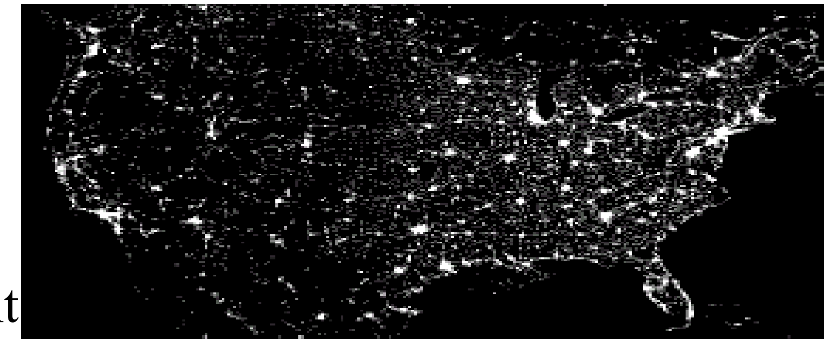


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

Remote Sensing: Nighttime Lights of the Worlds

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



-provides a global inventory of human settlement

Remaining populated part of the world

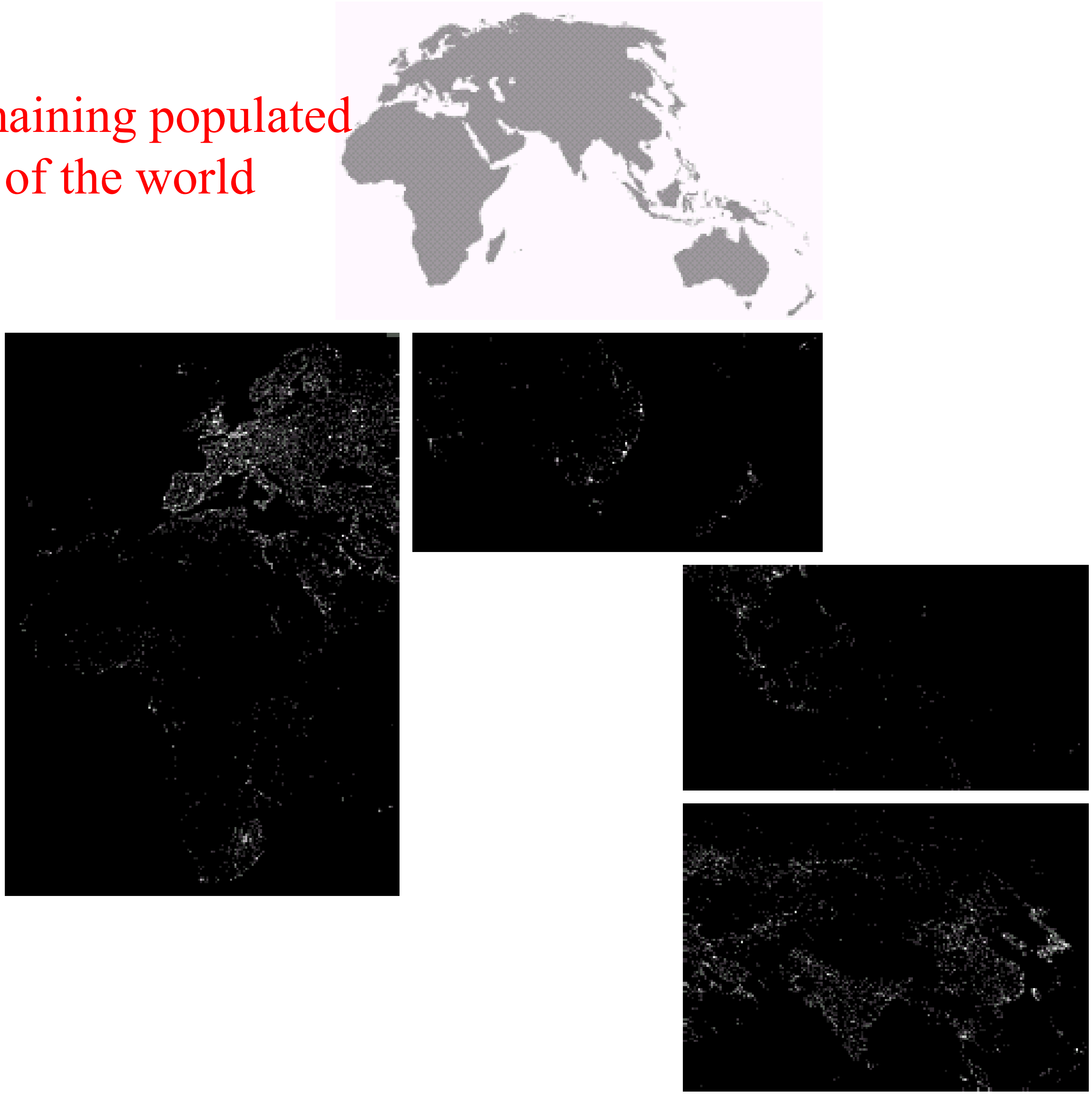
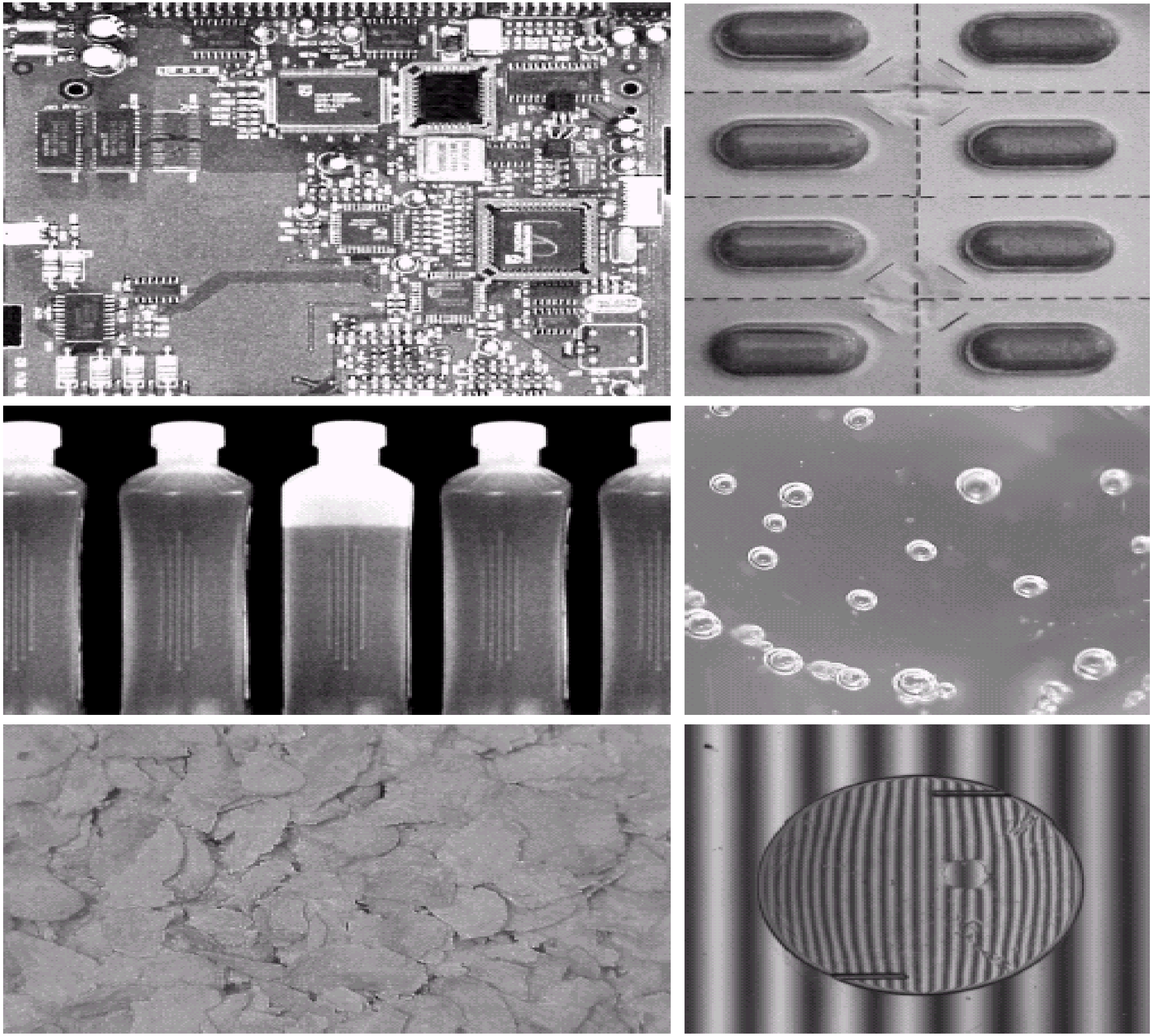


FIGURE 1.13 Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

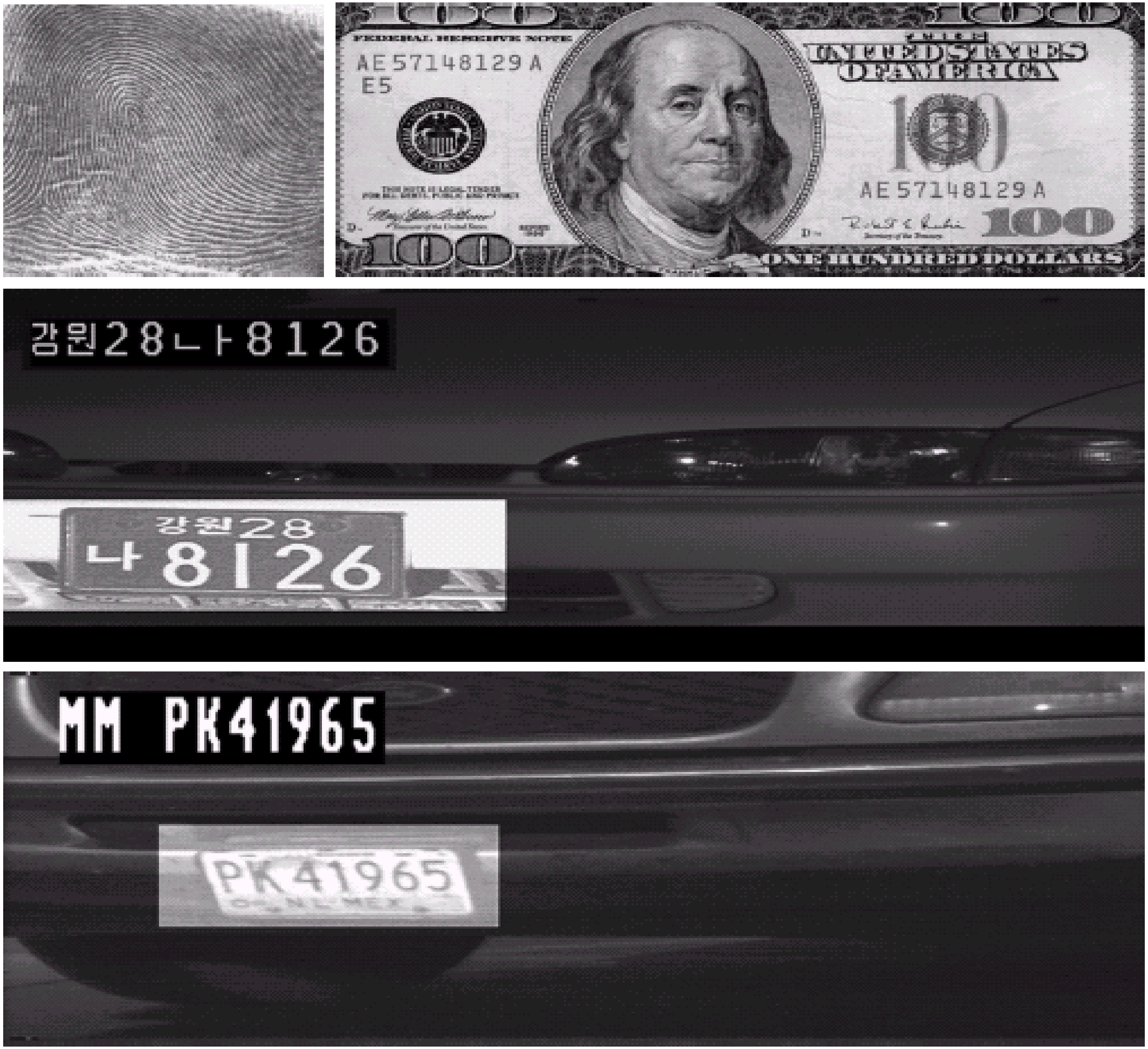
Industrial Applications: Automated visual inspection



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.)

Visual Spectrum: Law Enforcement

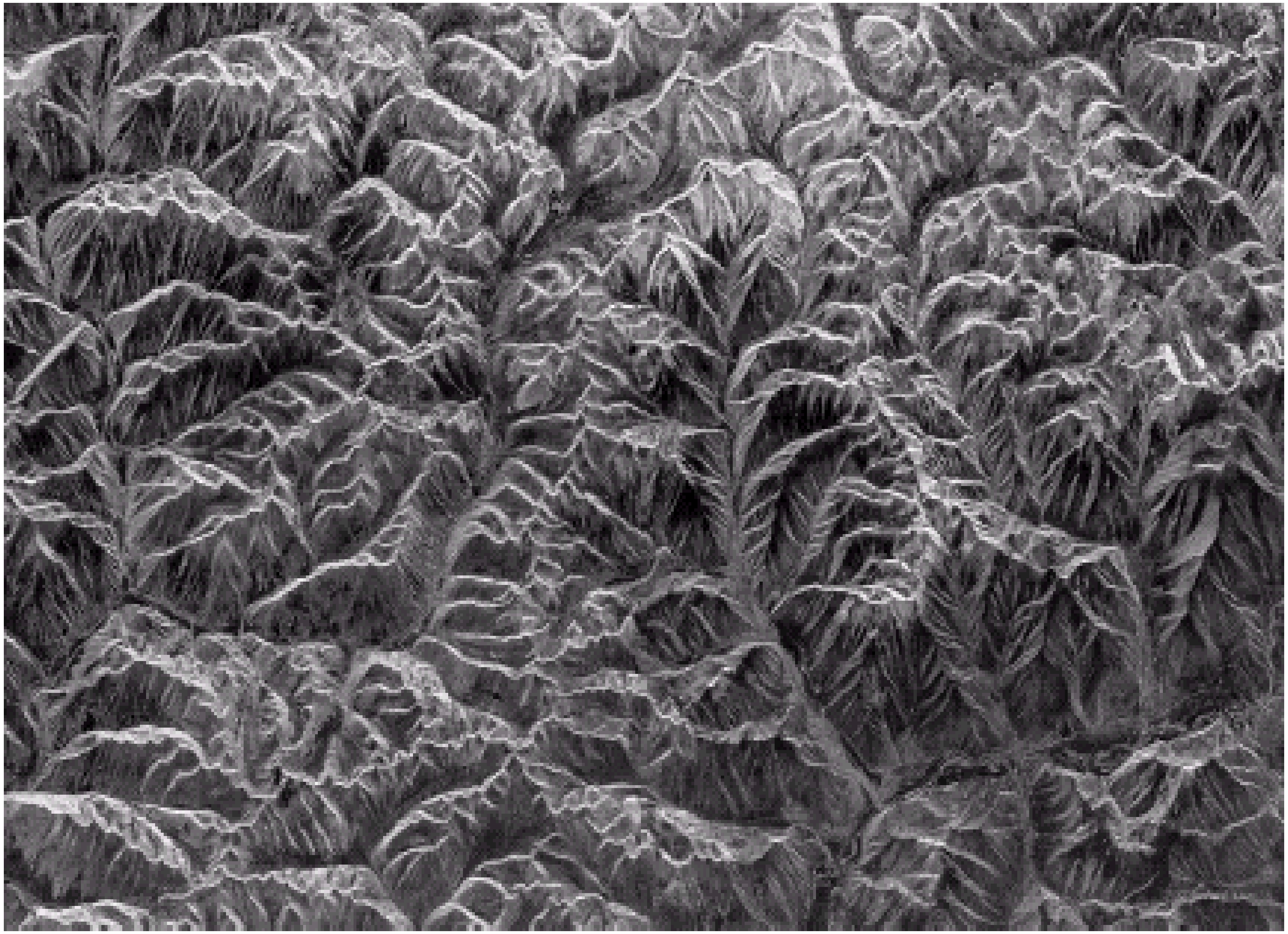


a b
c
d

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.)

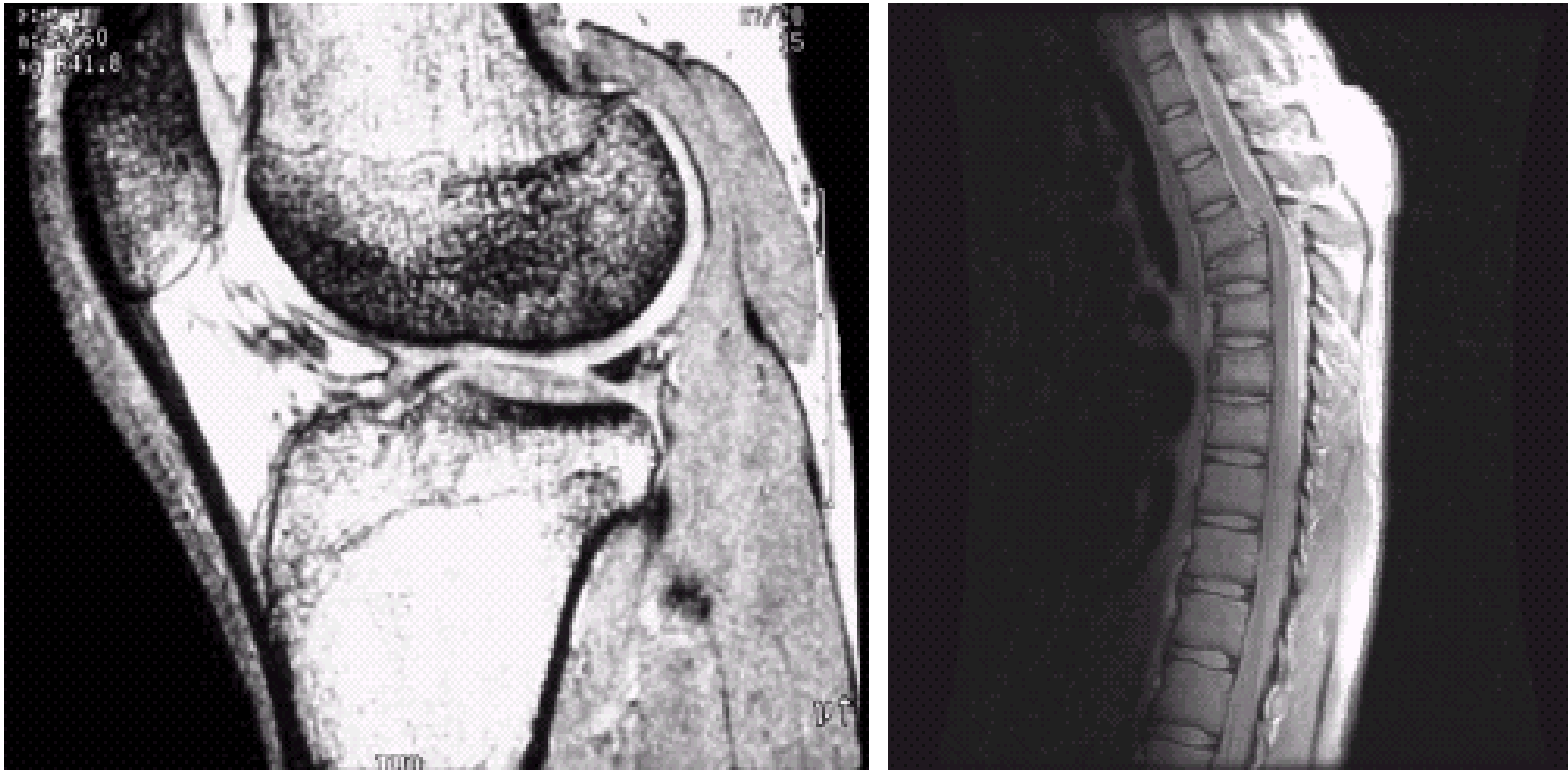
Imaging in Microwave Band

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



Imaging radar: the only way to explore inaccessible regions of the Earth's surface

Imaging in Radio Band: Magnetic Resonance Imaging (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.)

Image Taken in the Same Region but Different Band

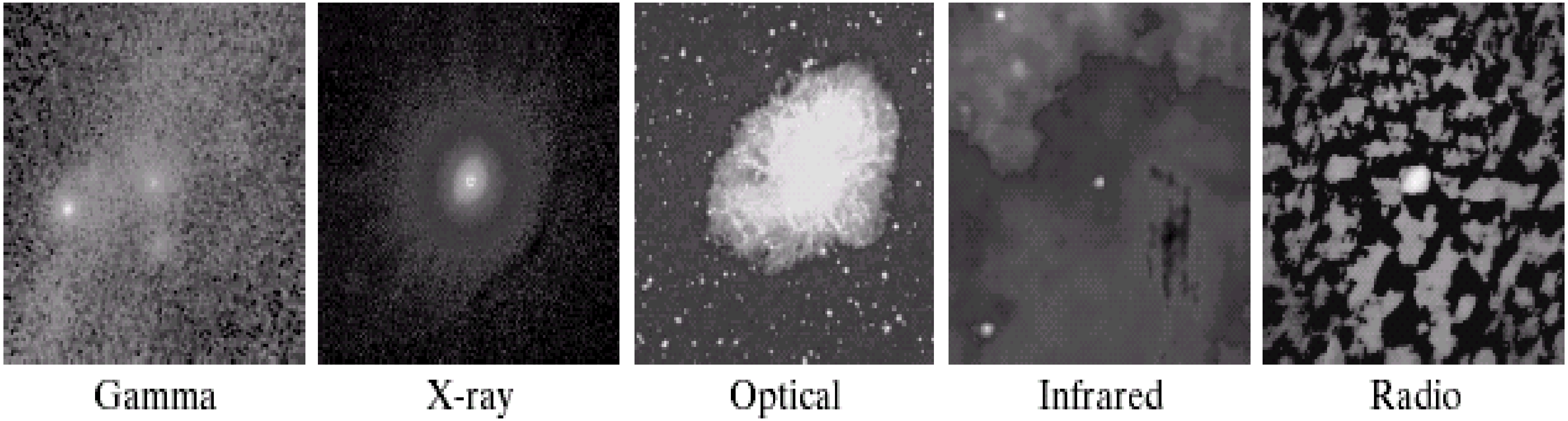


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Acoustic Imaging: Geological Applications

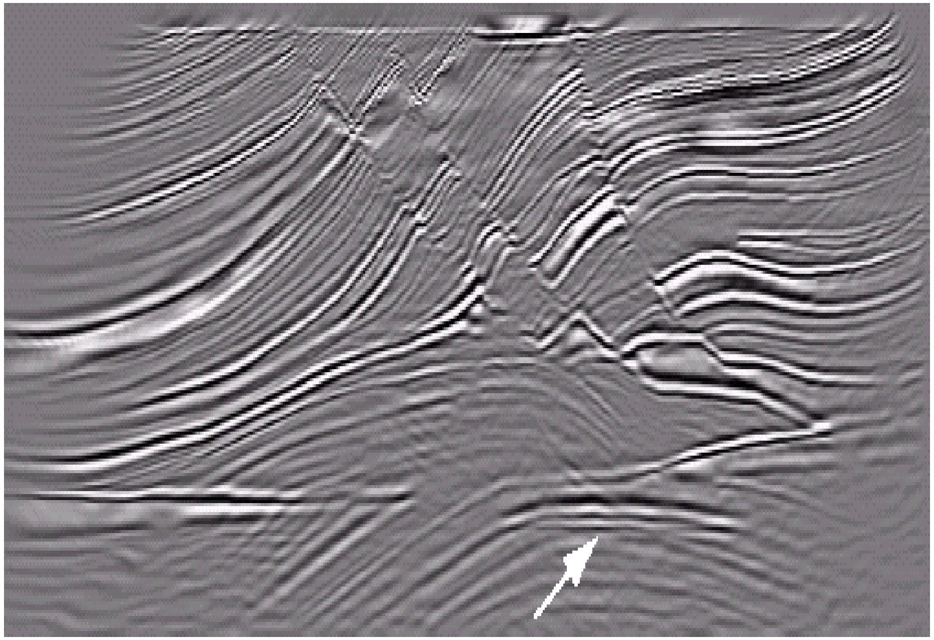
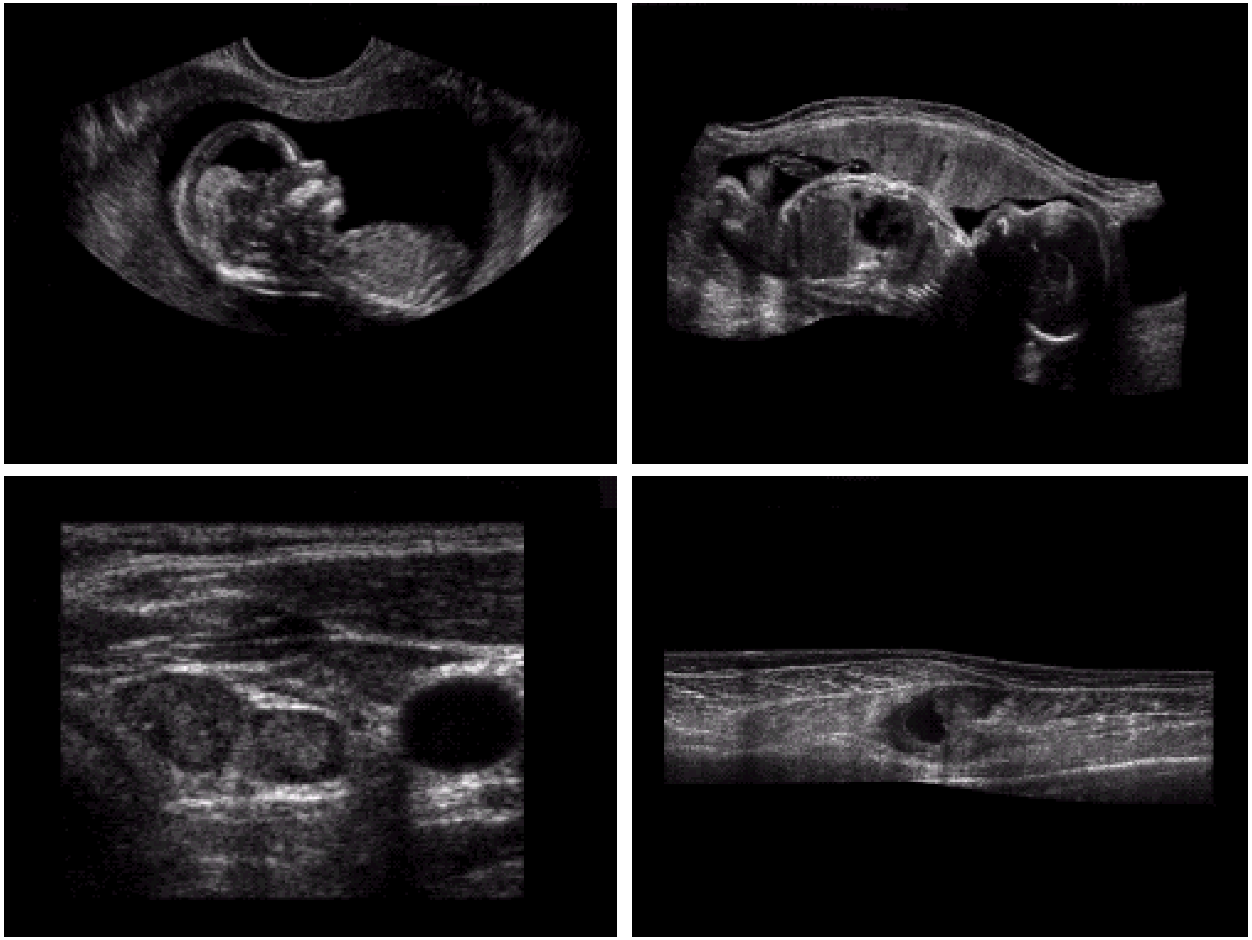


FIGURE 1.19 Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

Use of sound in the low end of the sound spectrum (hundred of Hz).

Mineral & oil exploration

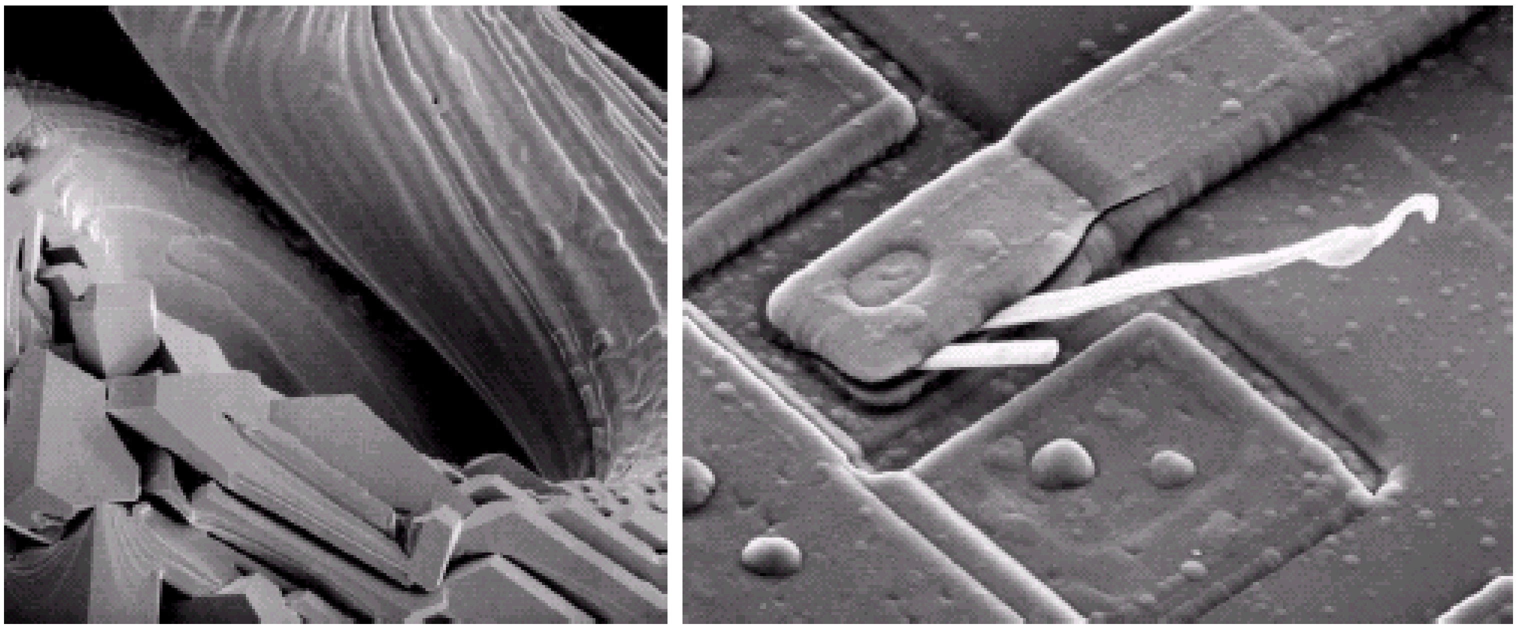
Ultrasound Imaging



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.)

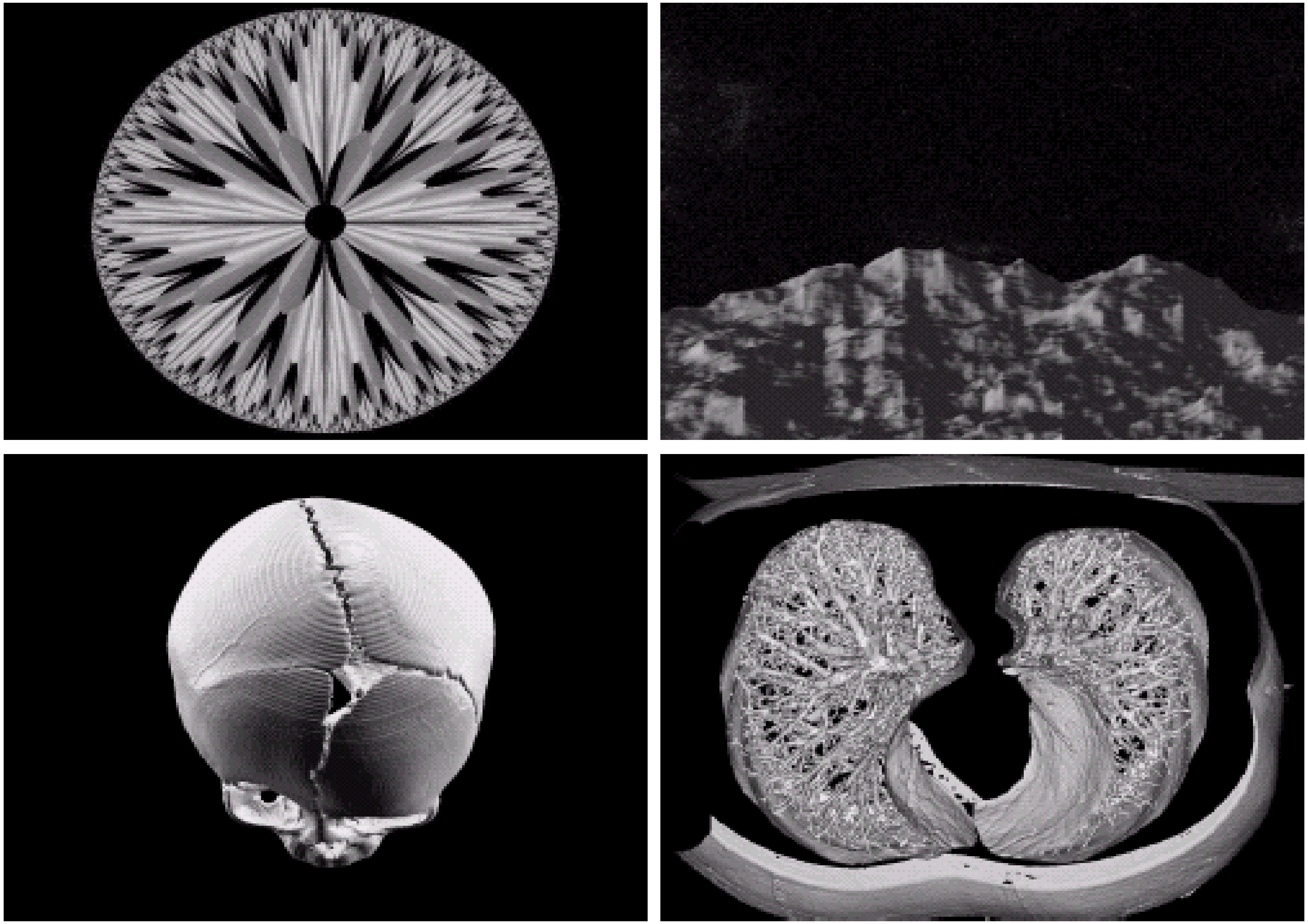
Industrial Applications



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.)

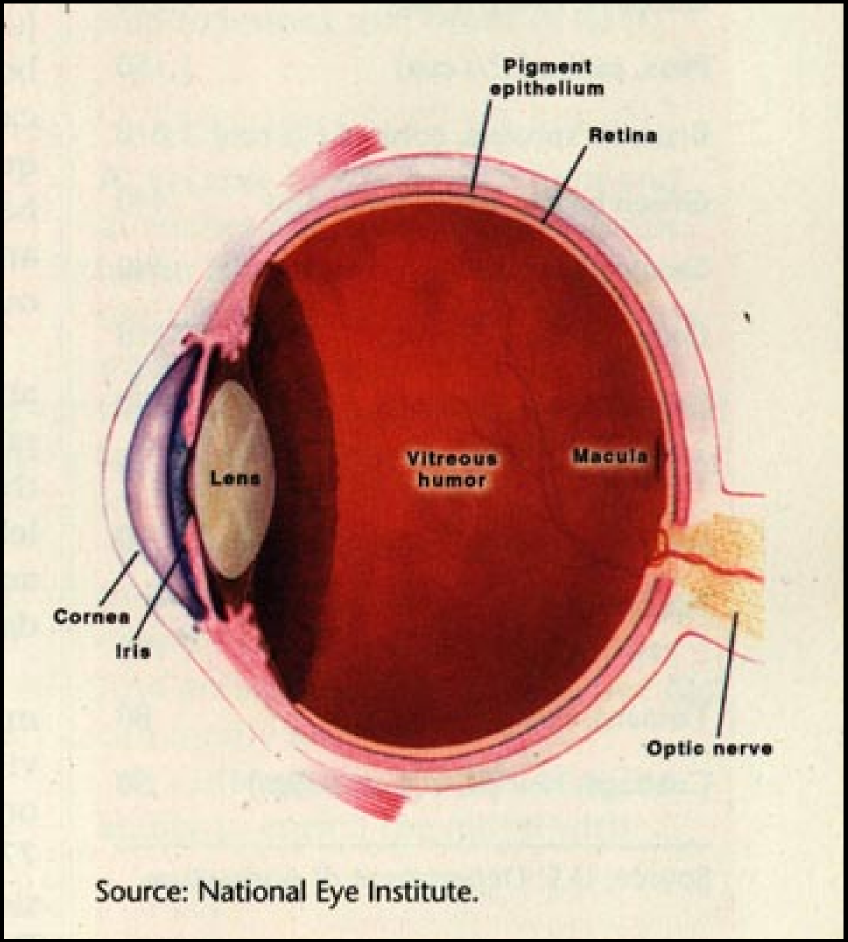
Syntactic Images: Modeling & Visualization



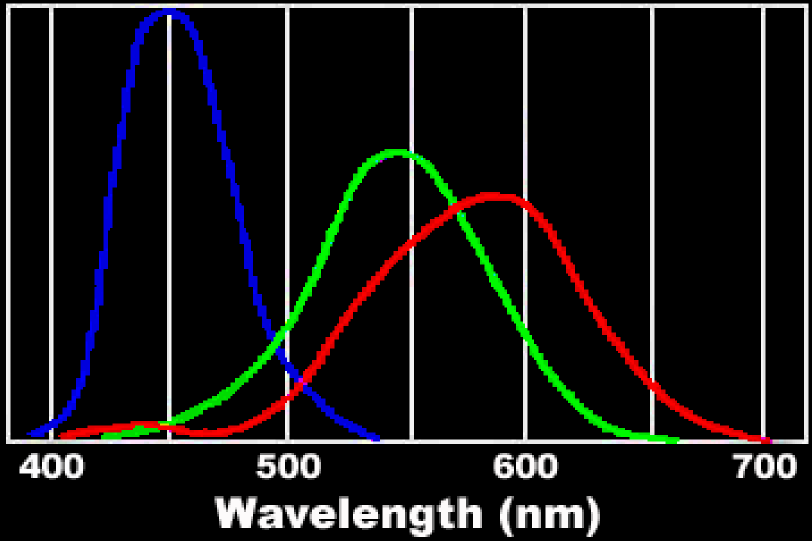
a b
c d

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.)

The Human Eye



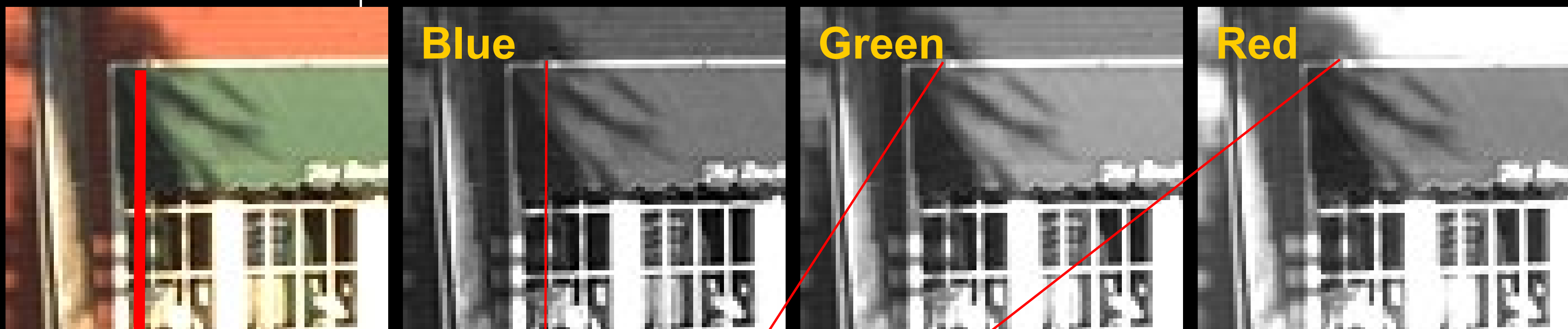
Source: National Eye Institute.



Film, Video, Digital Cameras

- Black and White (Reflectance data only)
- Color (Reflectance data in three bands - red, green, blue)

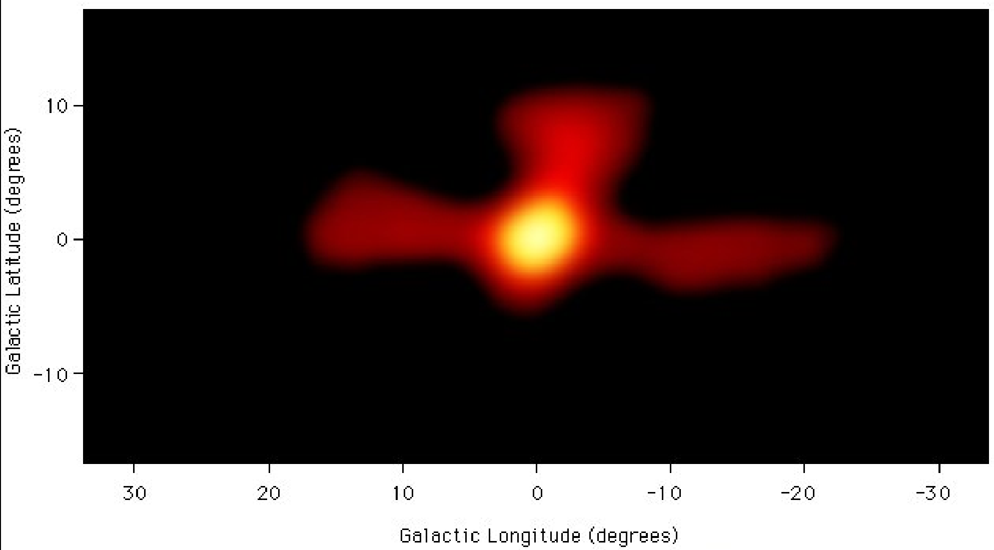
Color Images



‘Dimensions’ of an Image

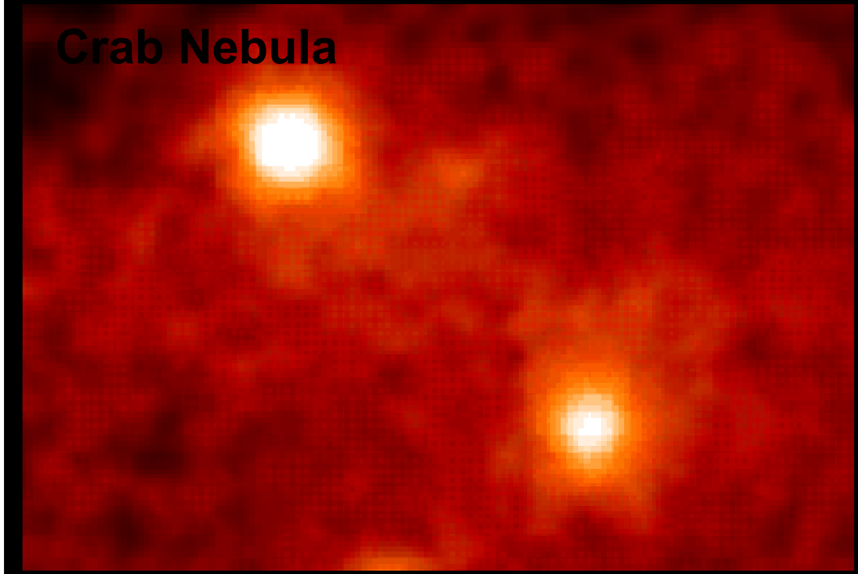
- Spatial (x,y)
- Depth (no. of components)
- Number of bits/channel
- Temporal (t)

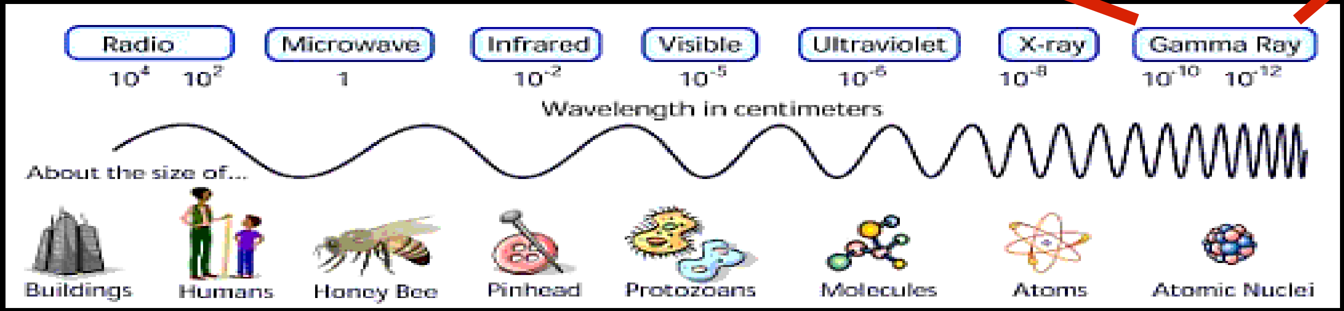
Across the EM Spectrum



Caption: Map of the distribution of positrons towards the center of the Milky Way Galaxy, including the newly discovered antimatter "cloud". The brightest feature corresponds to the nucleus of the Galaxy. The horizontal structure lies along the plane of the Galaxy. The antimatter "cloud" is located above the Galactic center.

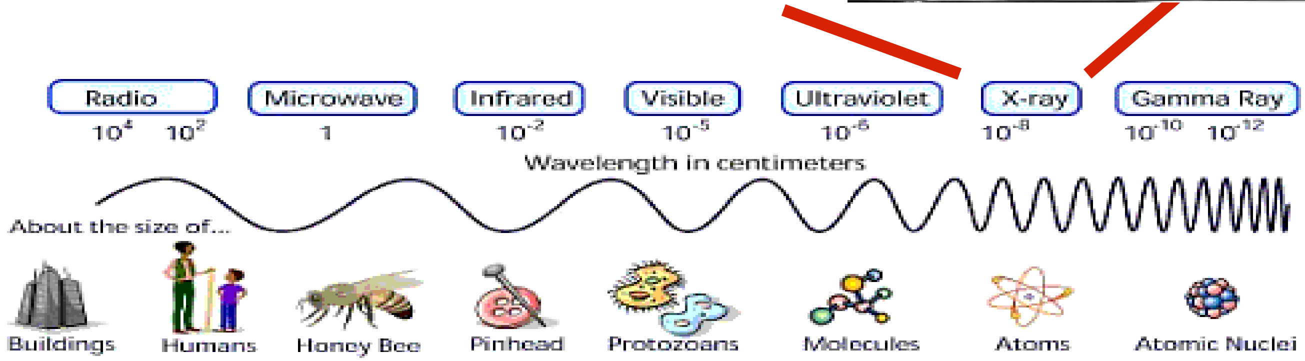
Courtesy of D. D. Dixon (University of California, Riverside) and W. R. Purcell (Northwestern University)





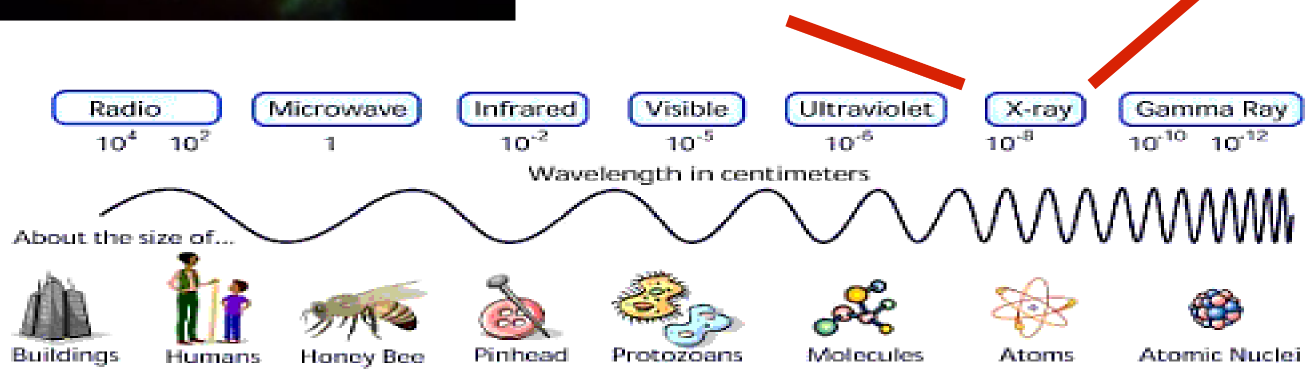
Across the EM Spectrum

- Medical X-Rays



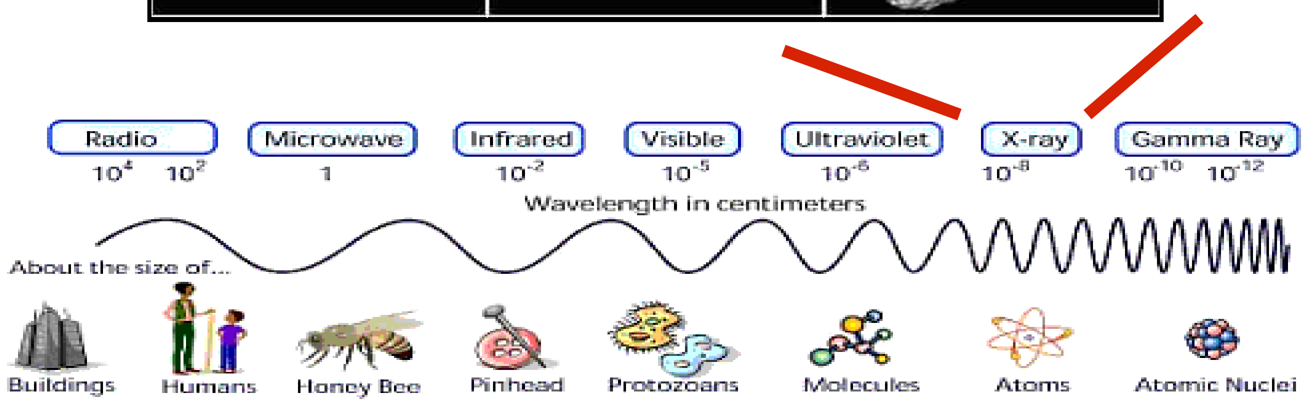
Across the EM Spectrum

- Chandra X-Ray Satellite



Across the EM Spectrum

- From X-Ray images to 3D Models: CT Scans

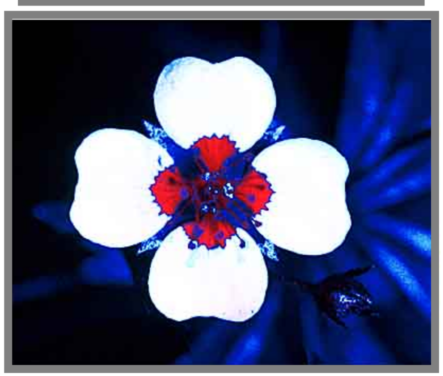


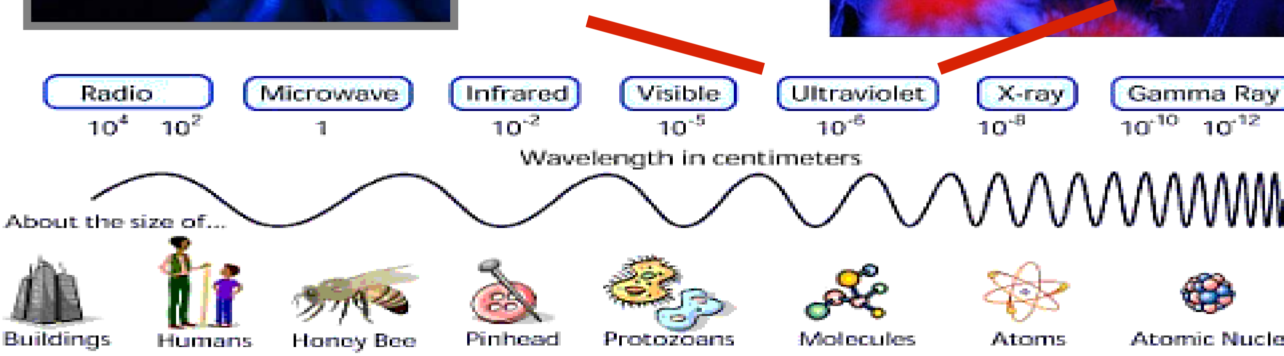
Across the EM Spectrum

- Flower Patterns in Ultraviolet

Dandelion - UV

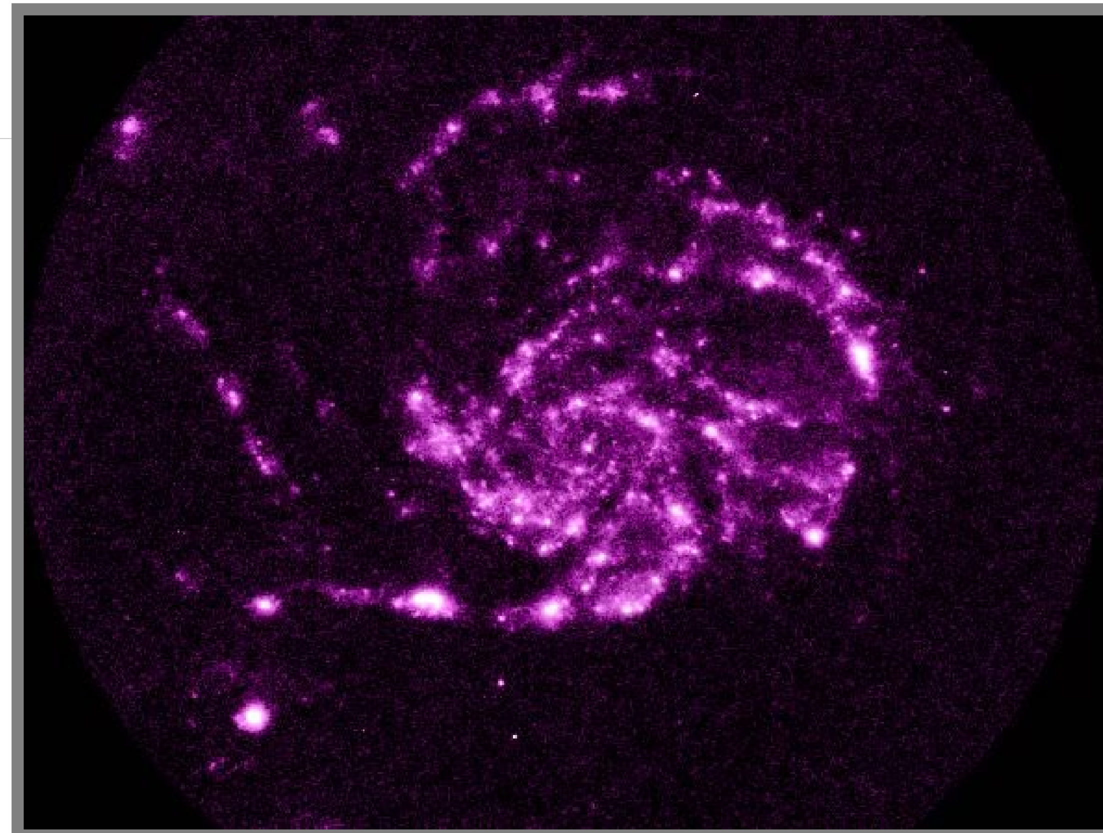
Potentilla

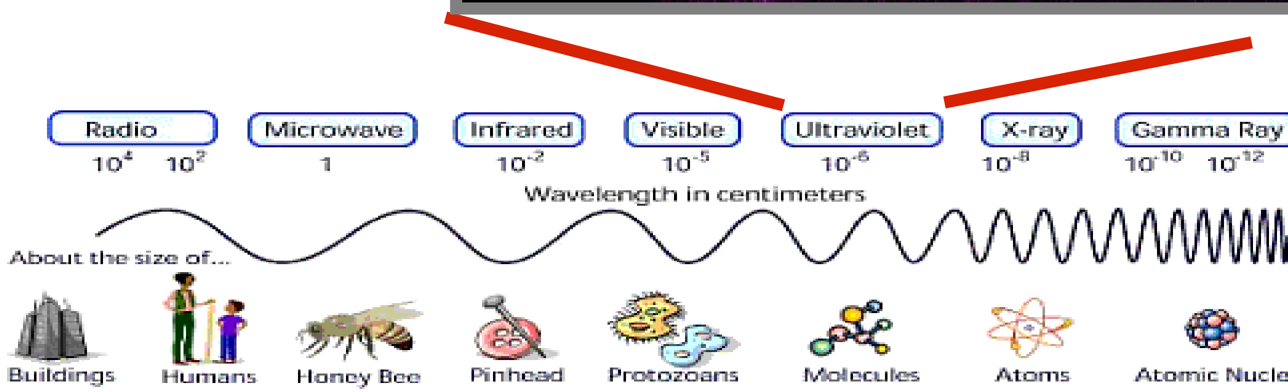




Across the EM Spectrum

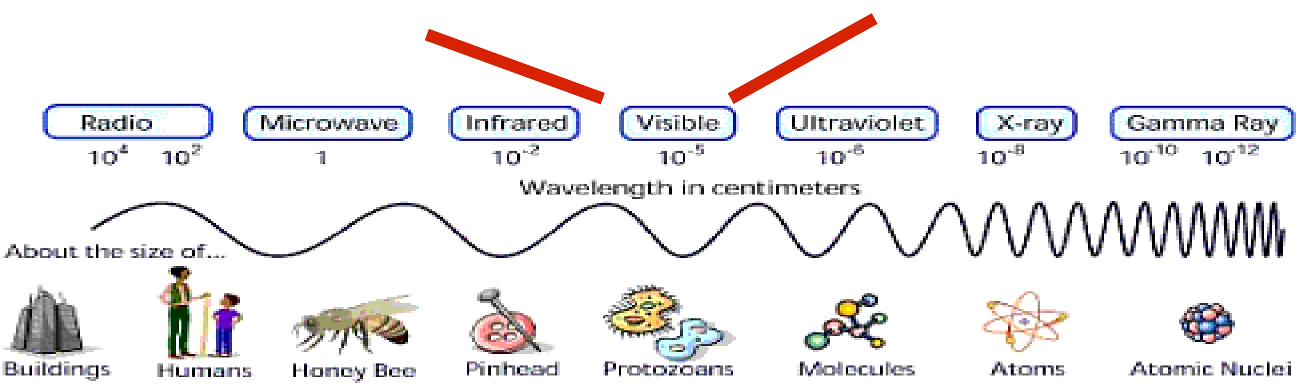
- Messier 101 in Ultraviolet





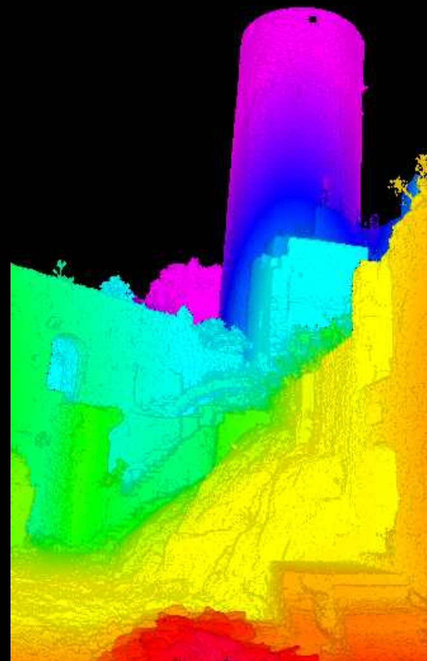
Across the EM Spectrum

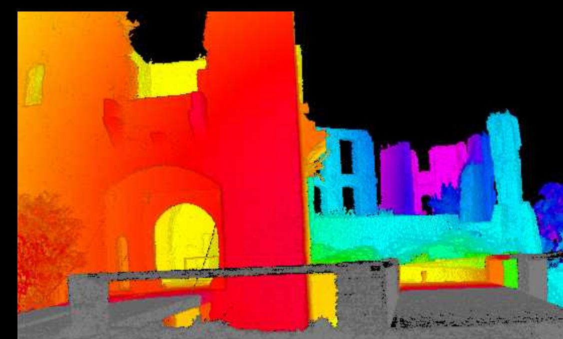
- Traditional images

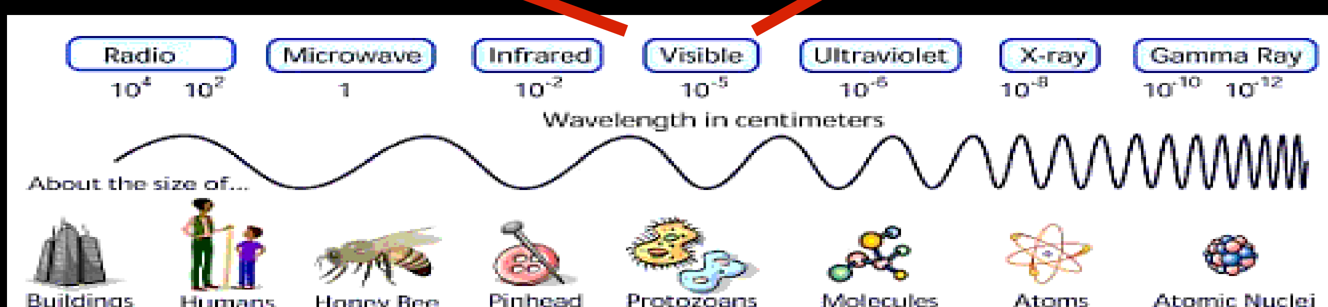


Across the EM Spectrum

- Non-traditional Use of Visible

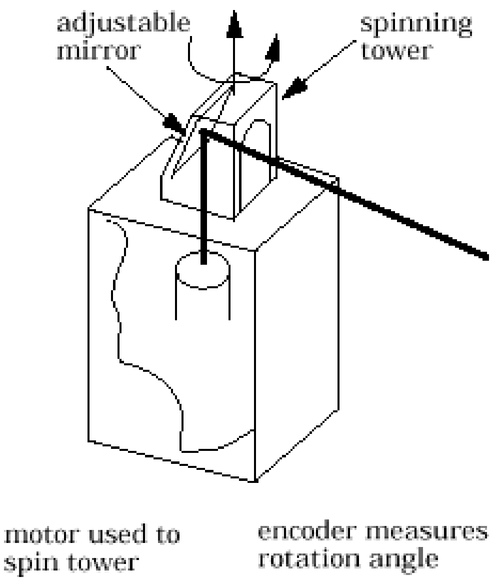


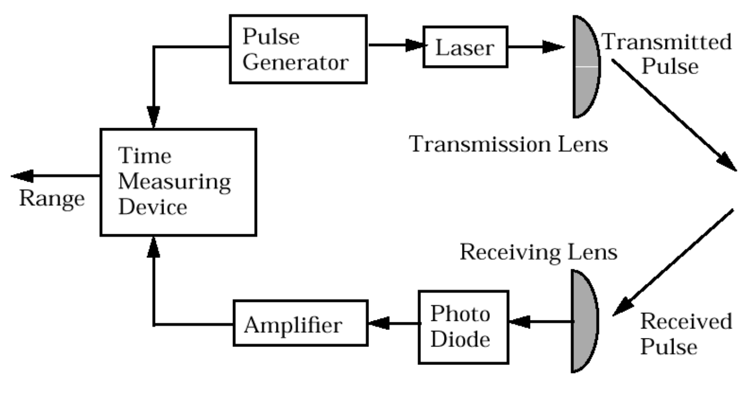


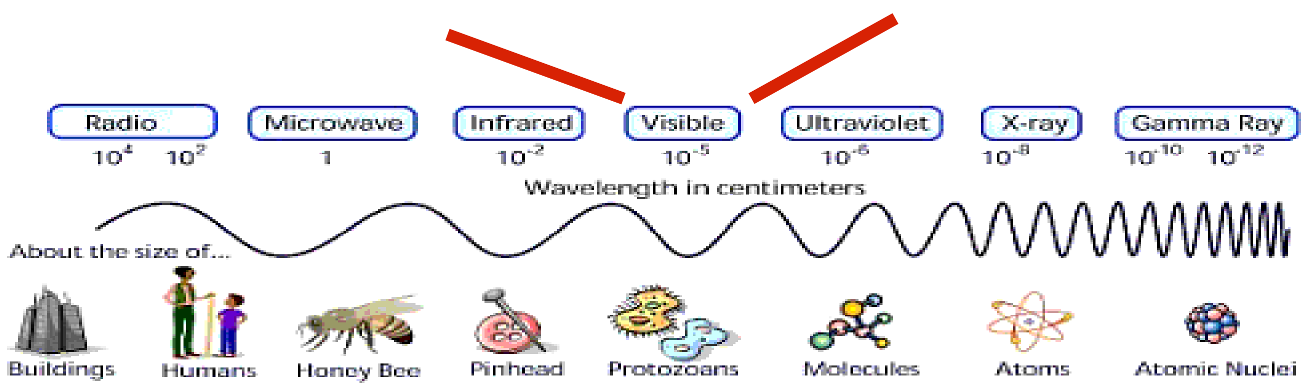


Across the EM Spectrum

- Scanning Laser Rangefinder

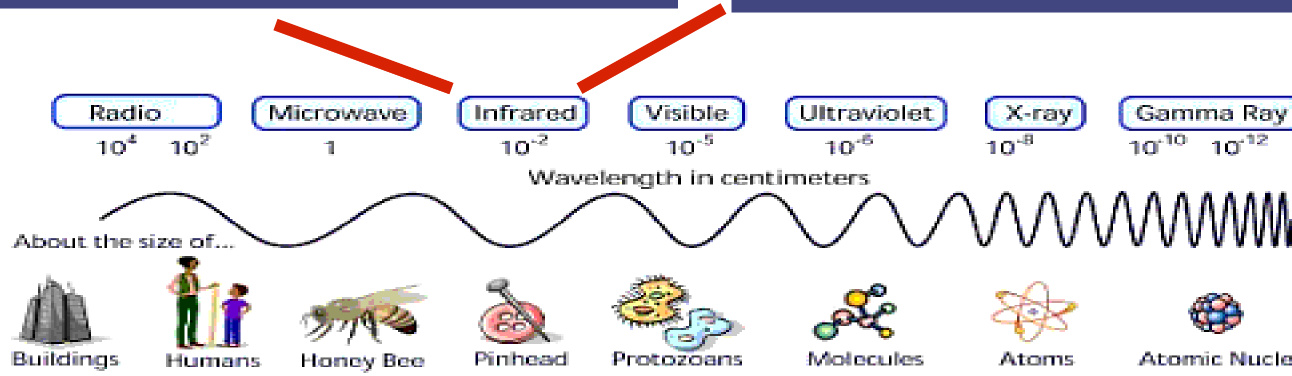






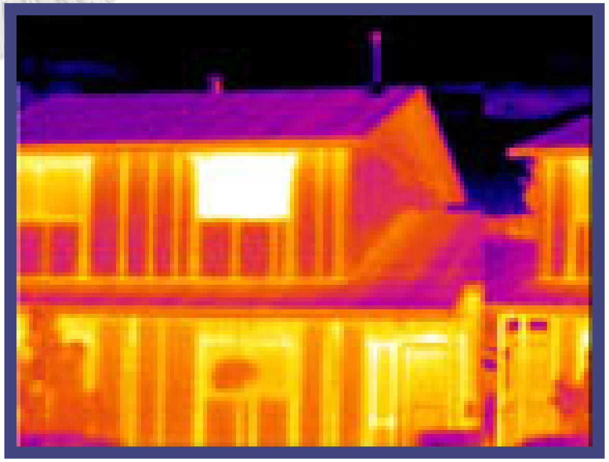
Across the EM Spectrum

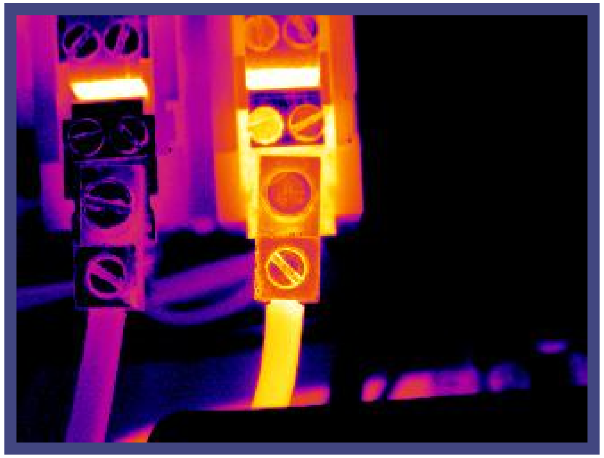
- IR: **Near**, Medium, Far (~heat)

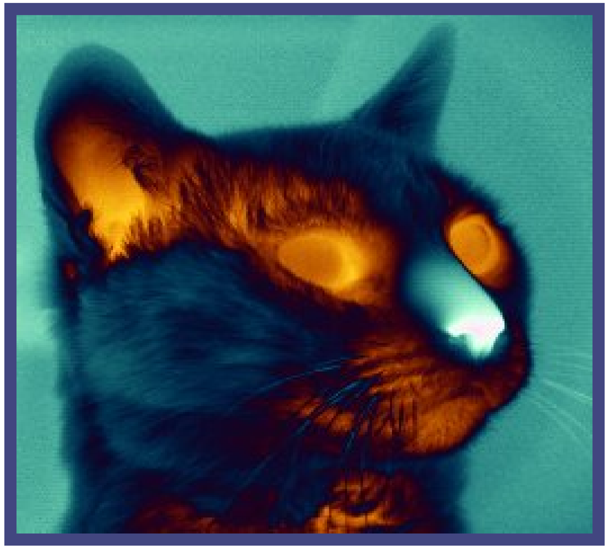


Across the EM Spectrum

- IR: **Near**, Medium, **Far (~heat)**





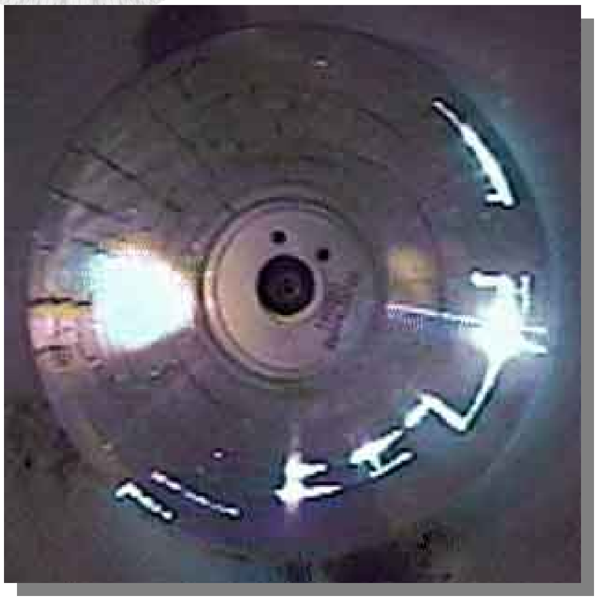


Across the EM Spectrum

- IR: Finding chlorophyl

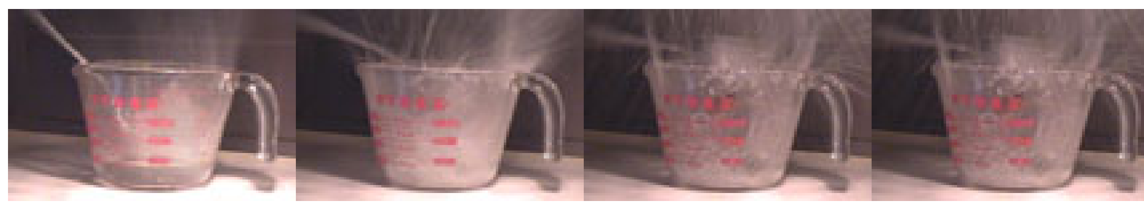
Across the EM Spectrum

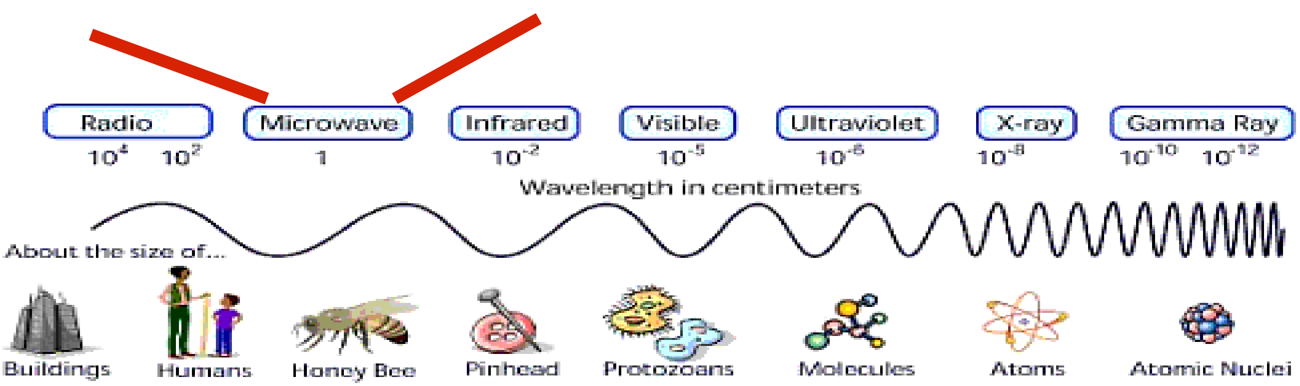
- (Un)Common uses of Microwaves



CD Movie

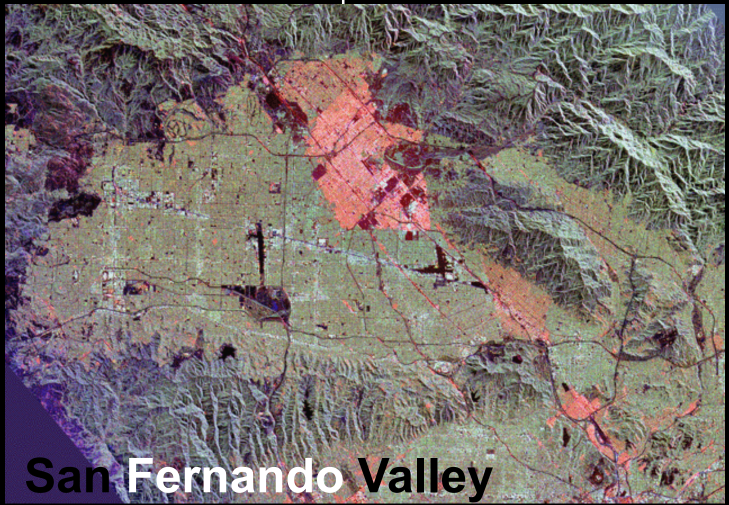
Exploding Water Movie

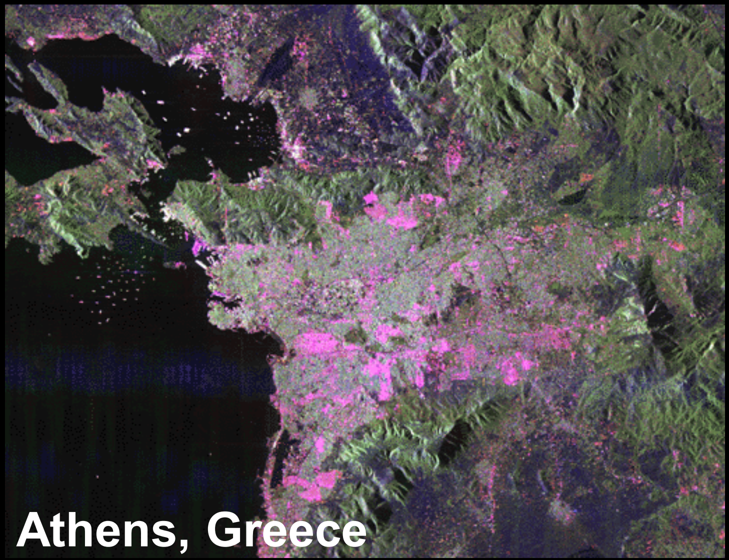


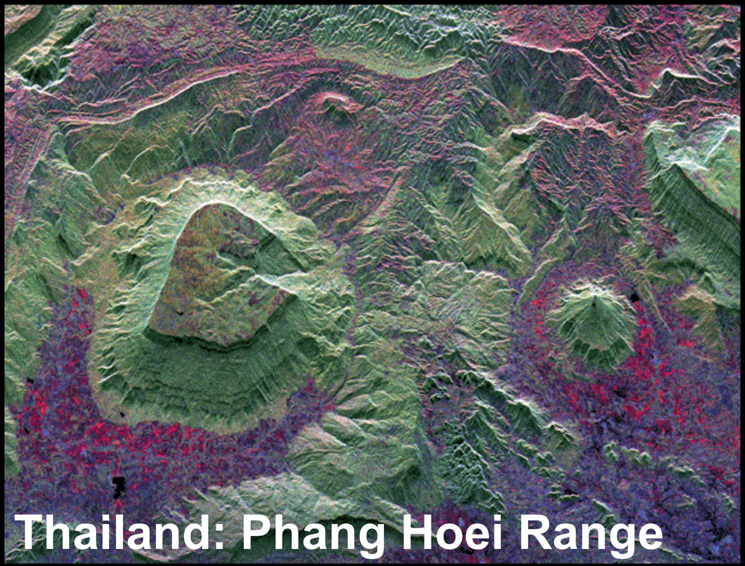


Across the EM Spectrum

- Microwave Imaging: Synthetic Aperature Radar (SAR)

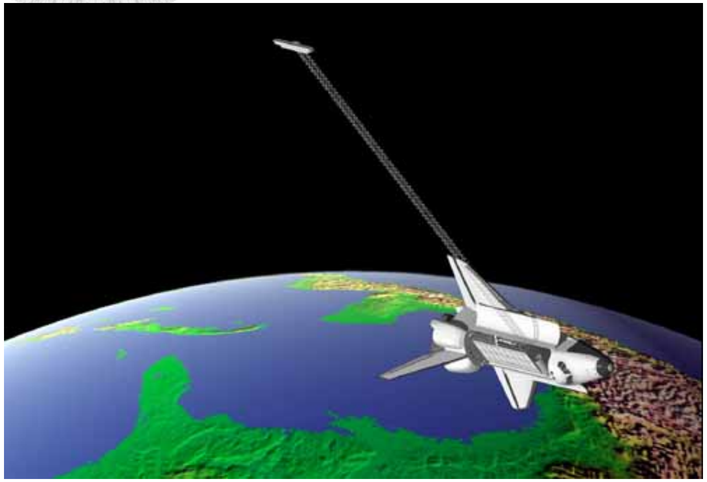


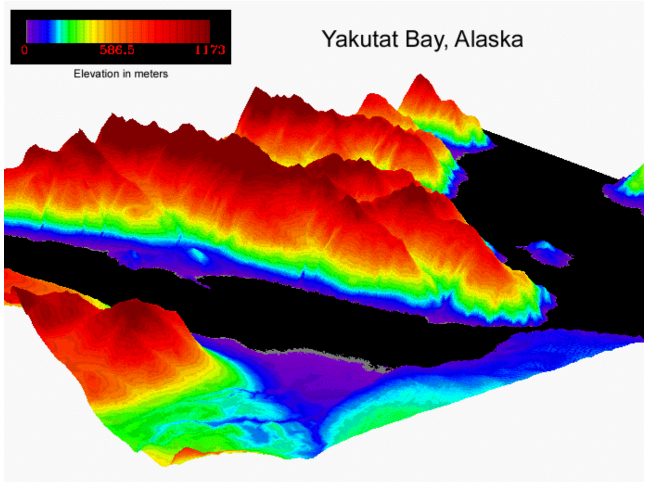


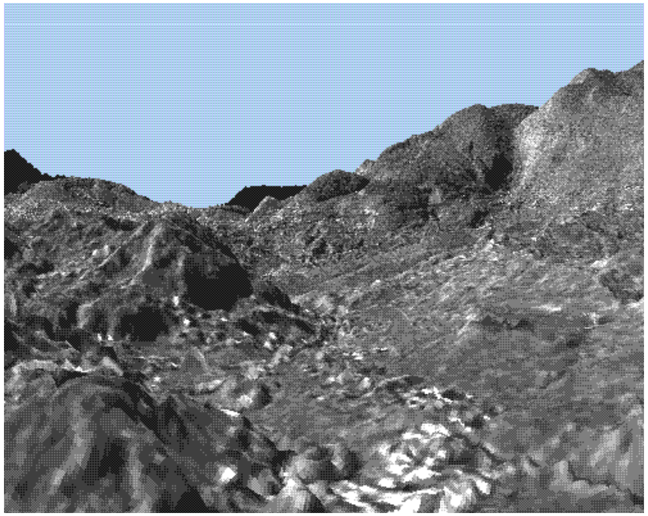


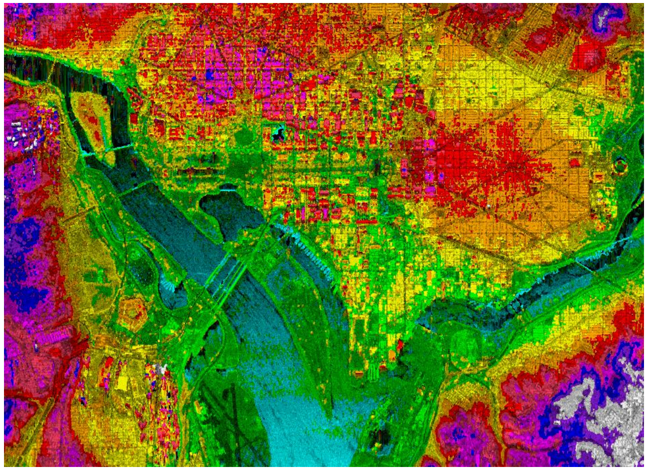
Across the EM Spectrum

- Radar in Depth: Interferometric Synthetic Aperature Radar - IFSAR



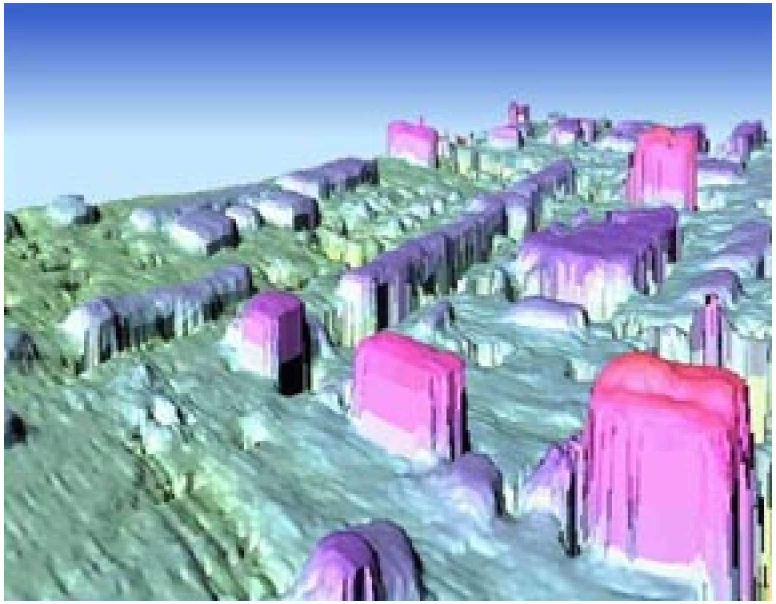


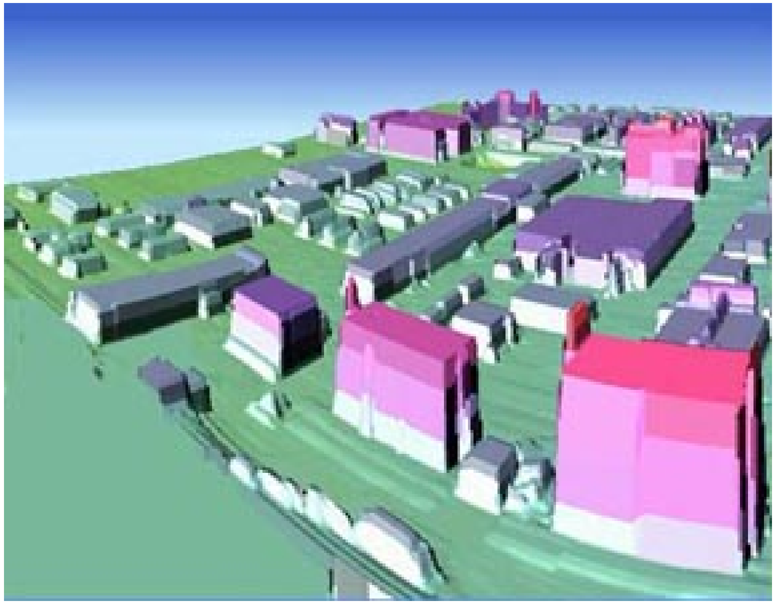




Across the EM Spectrum

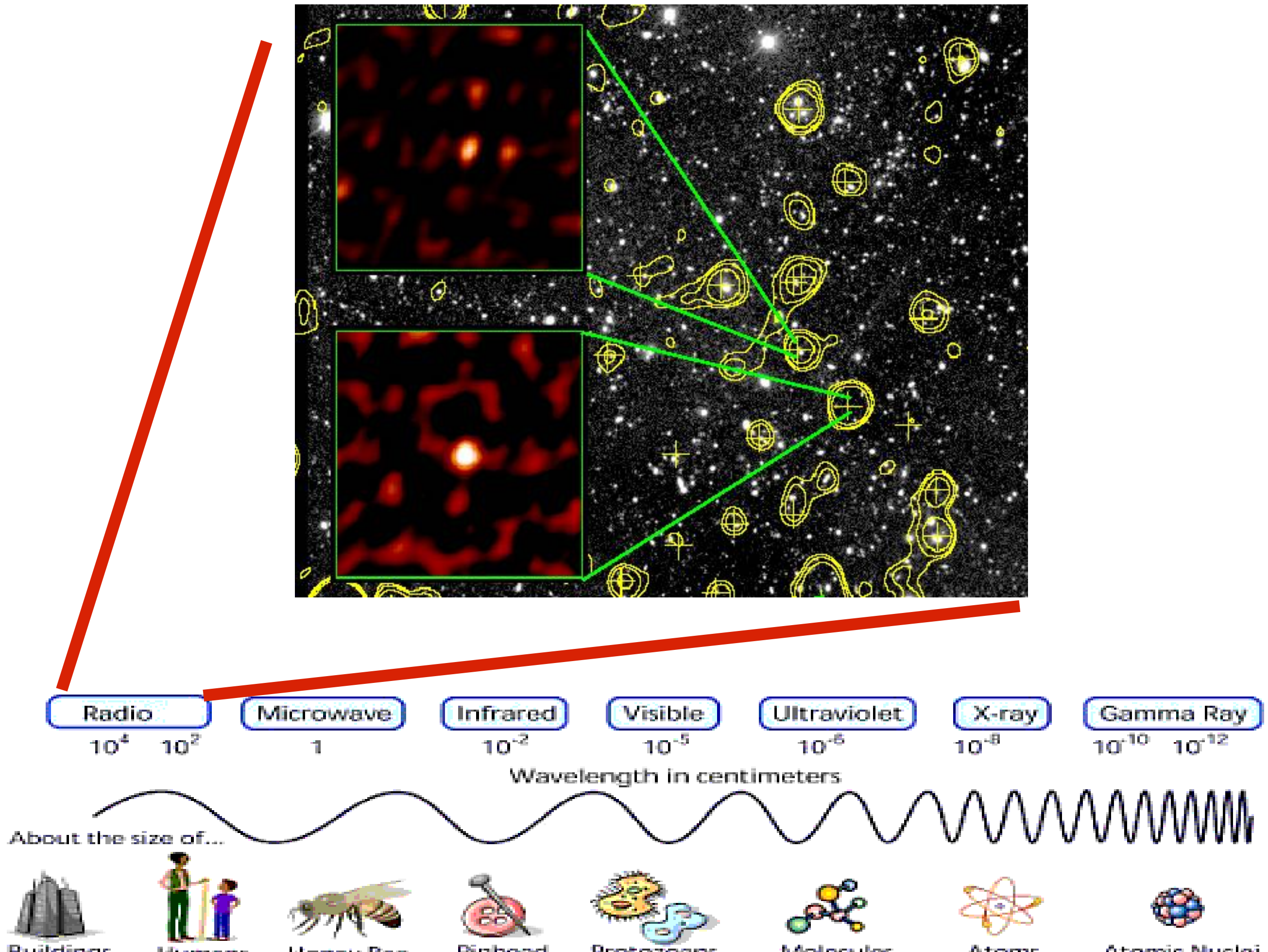
- Low Altitude IFSAR





Across the EM Spectrum

- Radio Waves



Fundamental Steps in DIP

FIGURE 1.23 Fundamental steps in digital image processing.

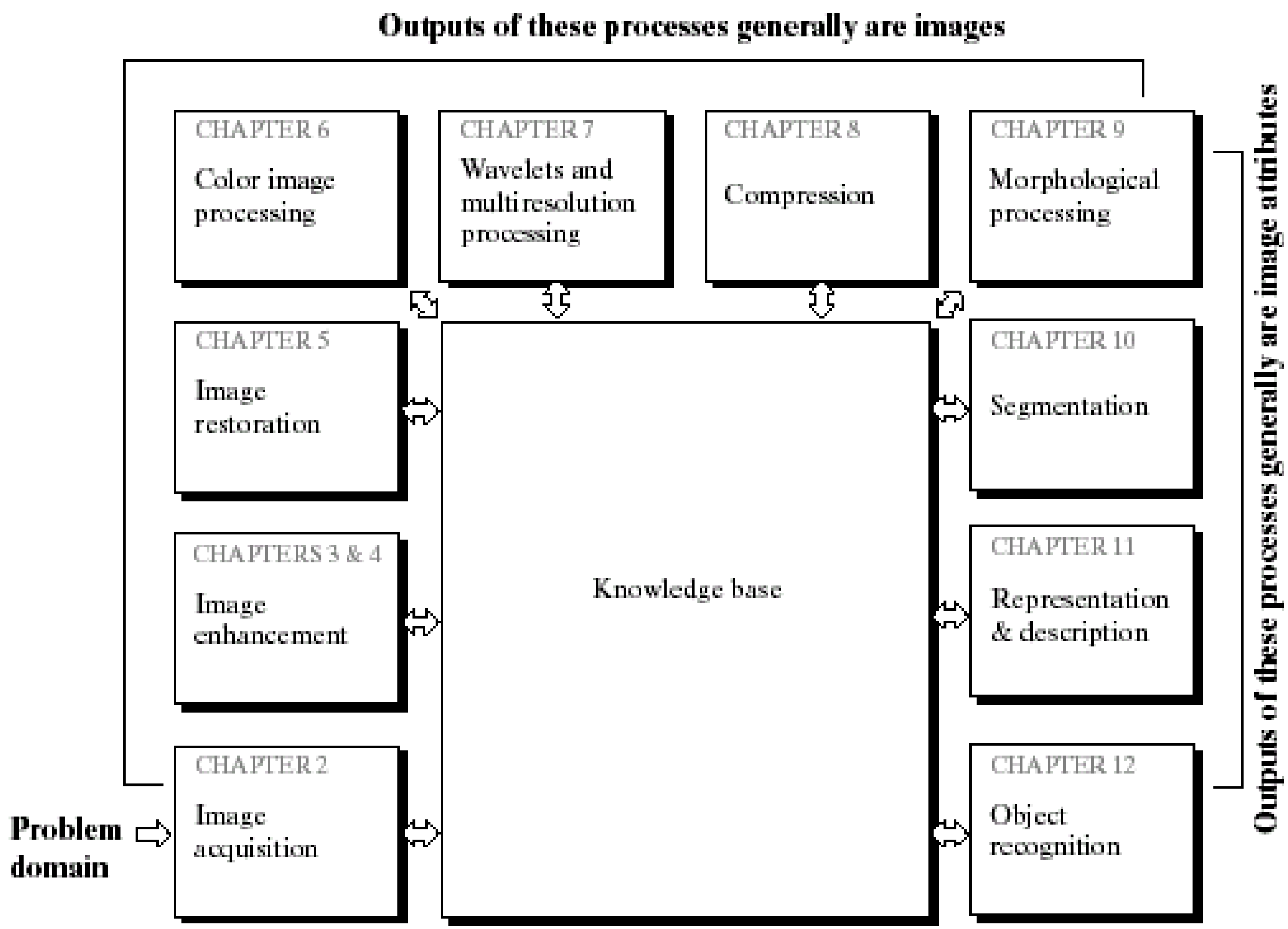


Image Acquisition

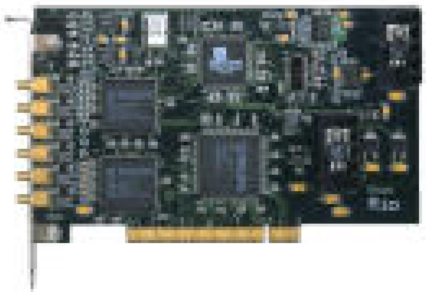
An image is captured by a sensor (camera) and digitized.

Camera

Consists of 2 parts:

- A lens that collects the appropriate type of radiation from the object of interest which later form an image of the real object
- A Charged Coupled Device (CCD) which converts the irradiance to an electrical signals.

Frame Grabber



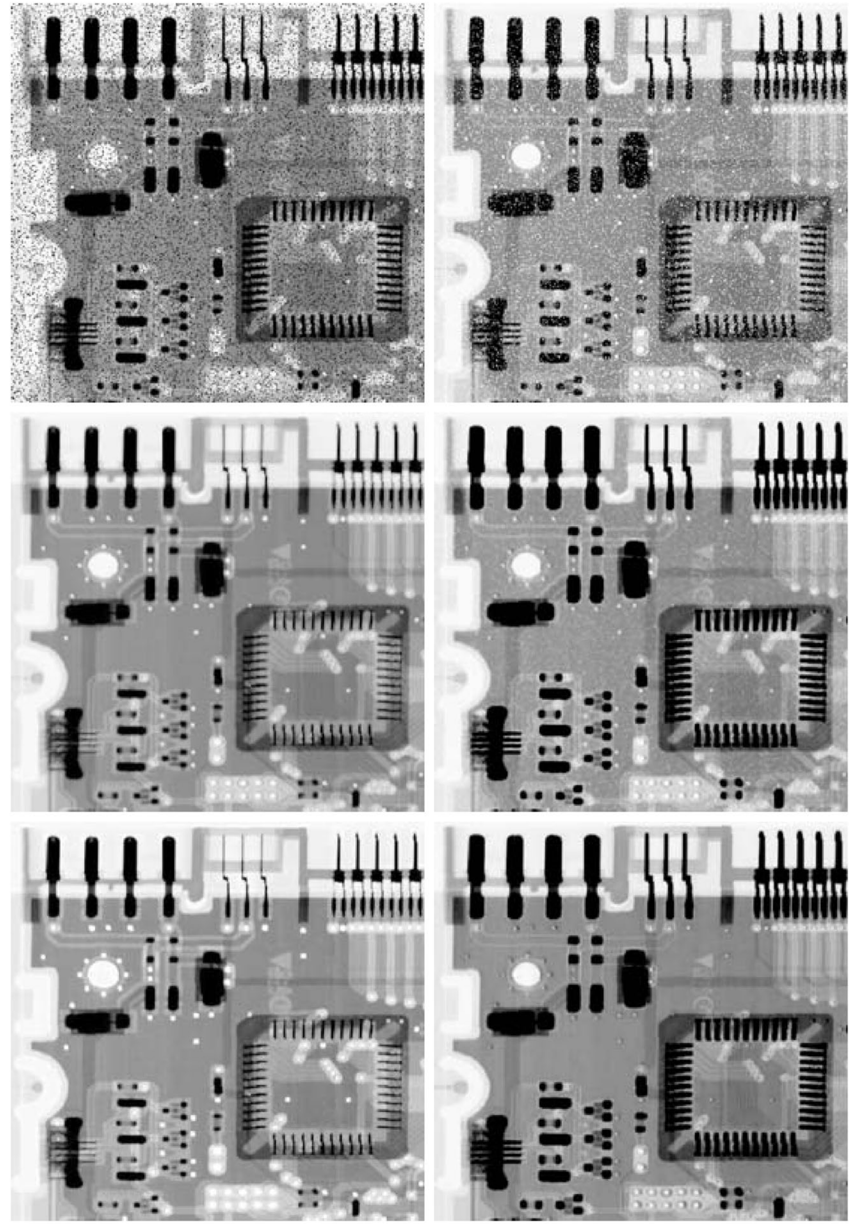
- To digitize the electrical signal from the CCD camera to enable storage or processing in the computer

Image Enhancement

- To bring out detail that is obscured or simply highlight certain features of interest in an image.
- Very subjective area of image processing.
- Based on human subjective preferences regarding what constitutes a "good" measure of enhancement result.

Image Restoration

- Improving the appearance of an image.
- Very objective – in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation.

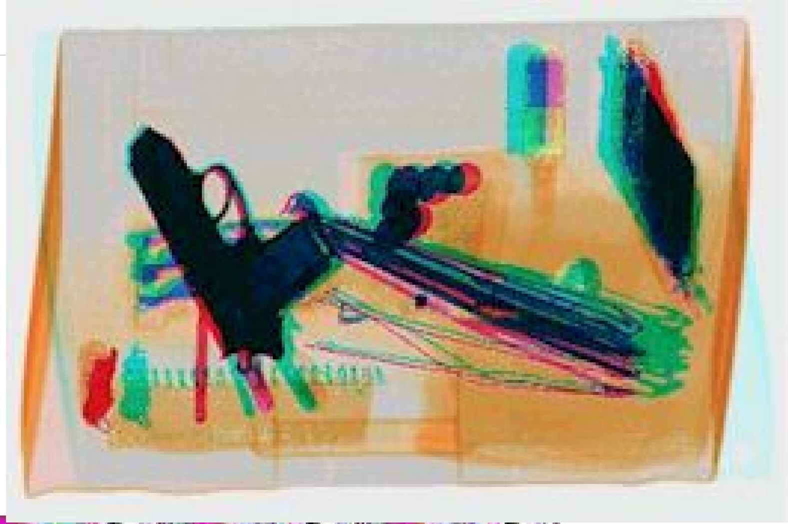


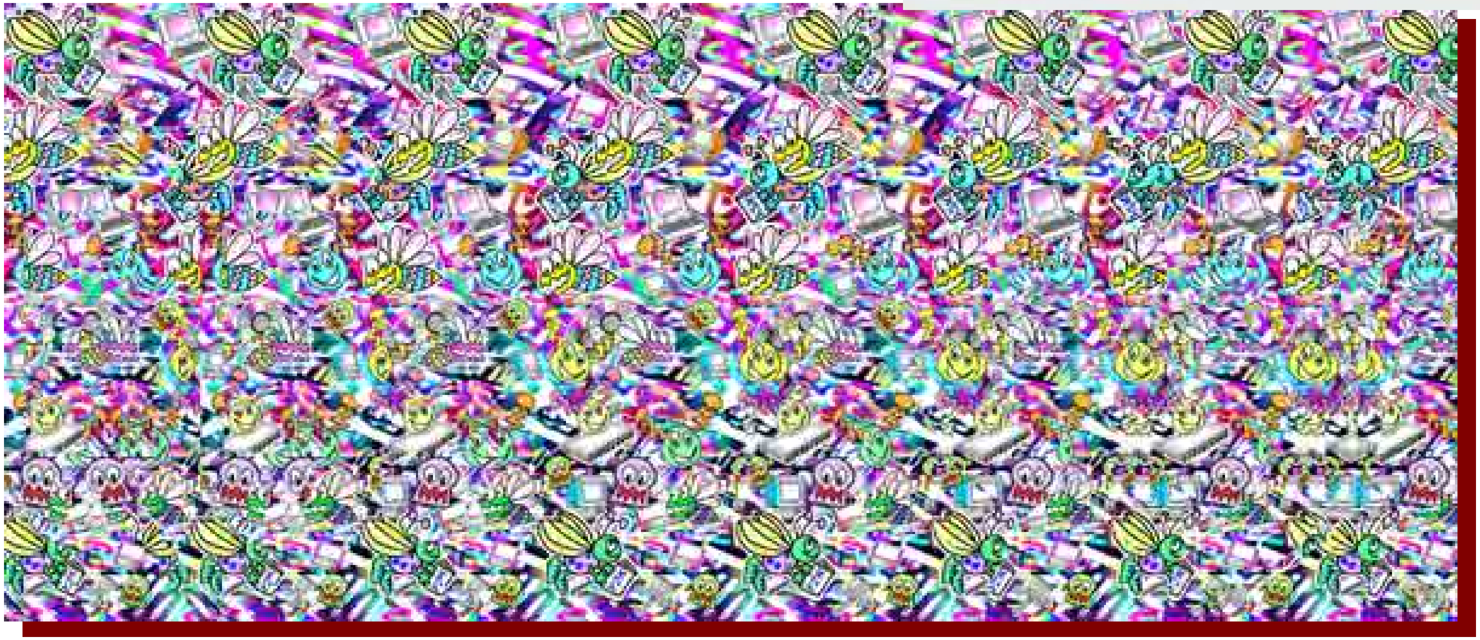
a	b
c	d
e	f

FIGURE 5.5 (a) Image corrupted by pepper noise with probability 0.1. (b) Image corrupted by salt noise with the same probability. (c) Result of filtering (a) with a 3×3 contraharmonic filter of order $Q = 1.5$. (d) Result of filtering (b) with $Q = -1.5$. (e) Result of filtering (a) with a 3×3 max filter. (f) Result of filtering (b) with a 3×3 min filter.

Color Image Processing

- Gaining importance in today's world, i.e internet.





Wavelets

- Are the foundation for representing images in various degrees of resolution.
- Used in image data compression & pyramidal representation in which images are subdivided successively into smaller regions.

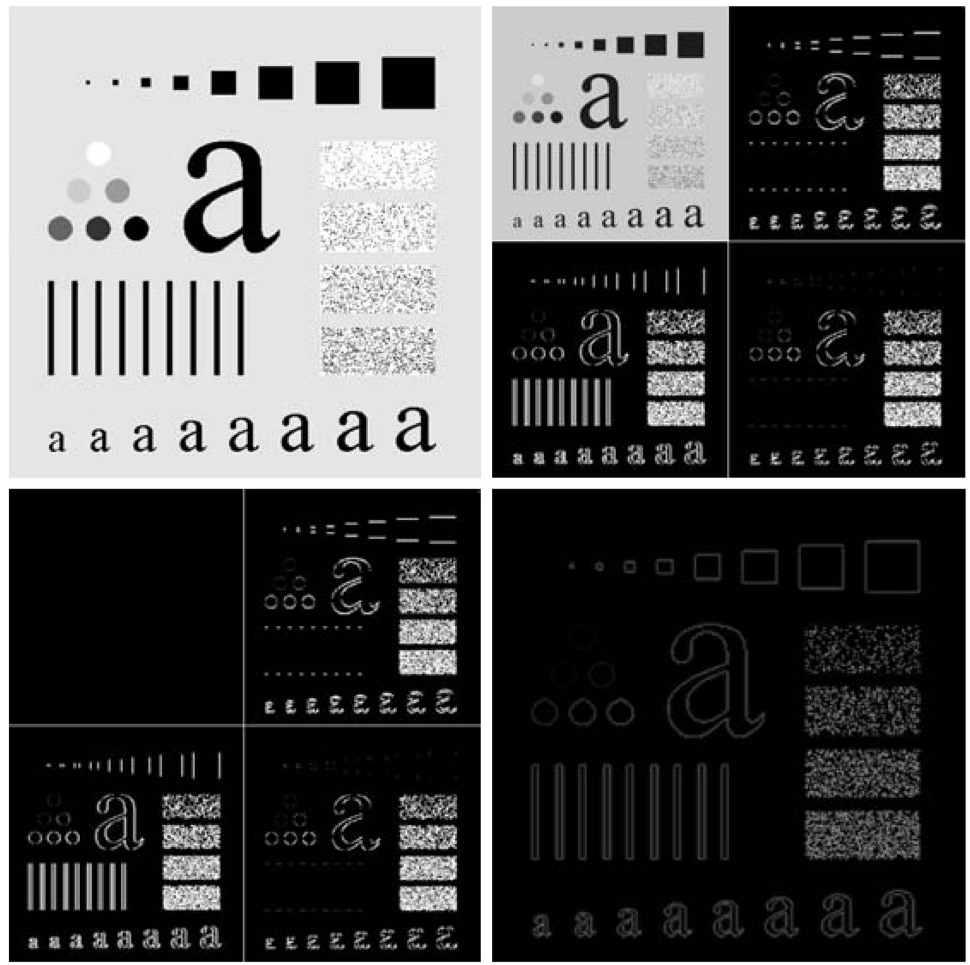


FIGURE 7.7 Wavelets in edge detection: (a) A simple test image; (b) its wavelet transform; (c) the transform modified by zeroing all approximation coefficients; and (d) the edge image resulting from computing the absolute value of the inverse transform.

Image Compressions

- Deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it.
- Although storage technology improves significantly, but not the transmission capacity.
- Use file extension such as JPEG (Joint Photographic Experts Group).

Smaller size

Morphological Processing

- Deals with tools for extracting image components that are useful in the representation and description of shape.

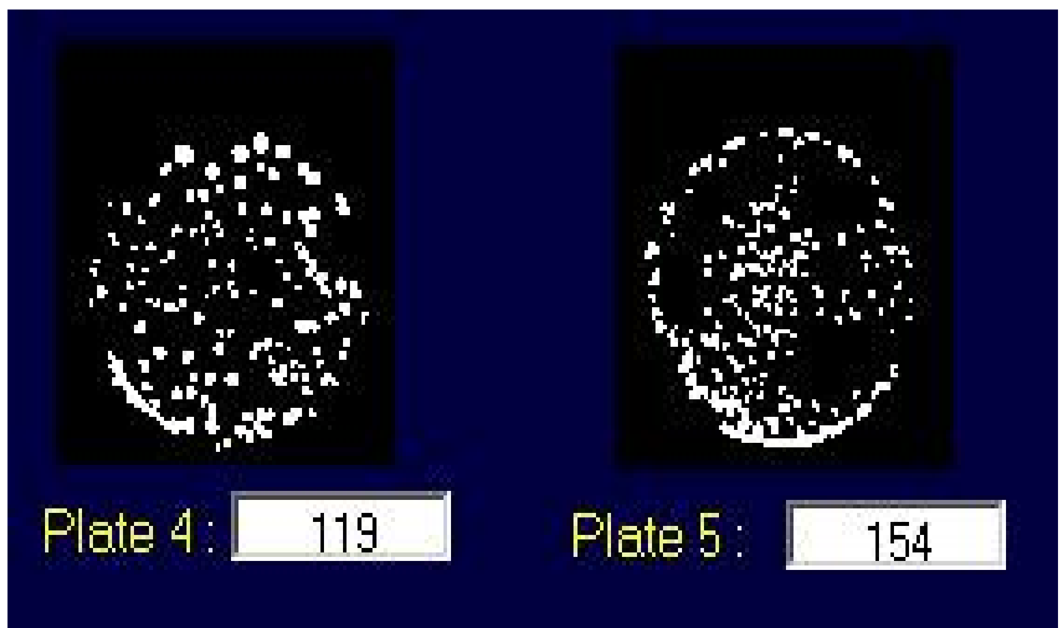
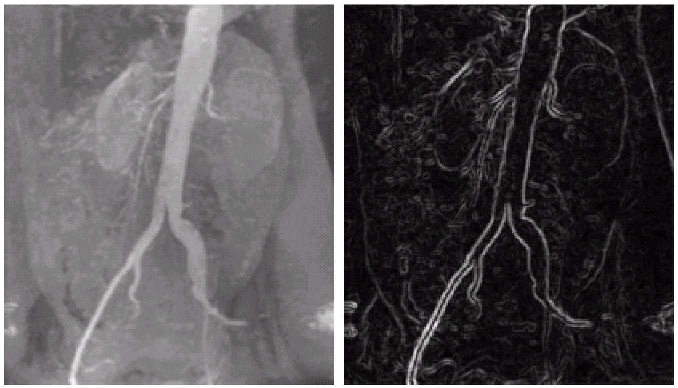
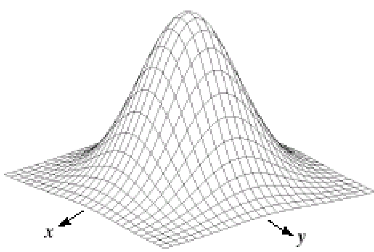


Image Segmentation



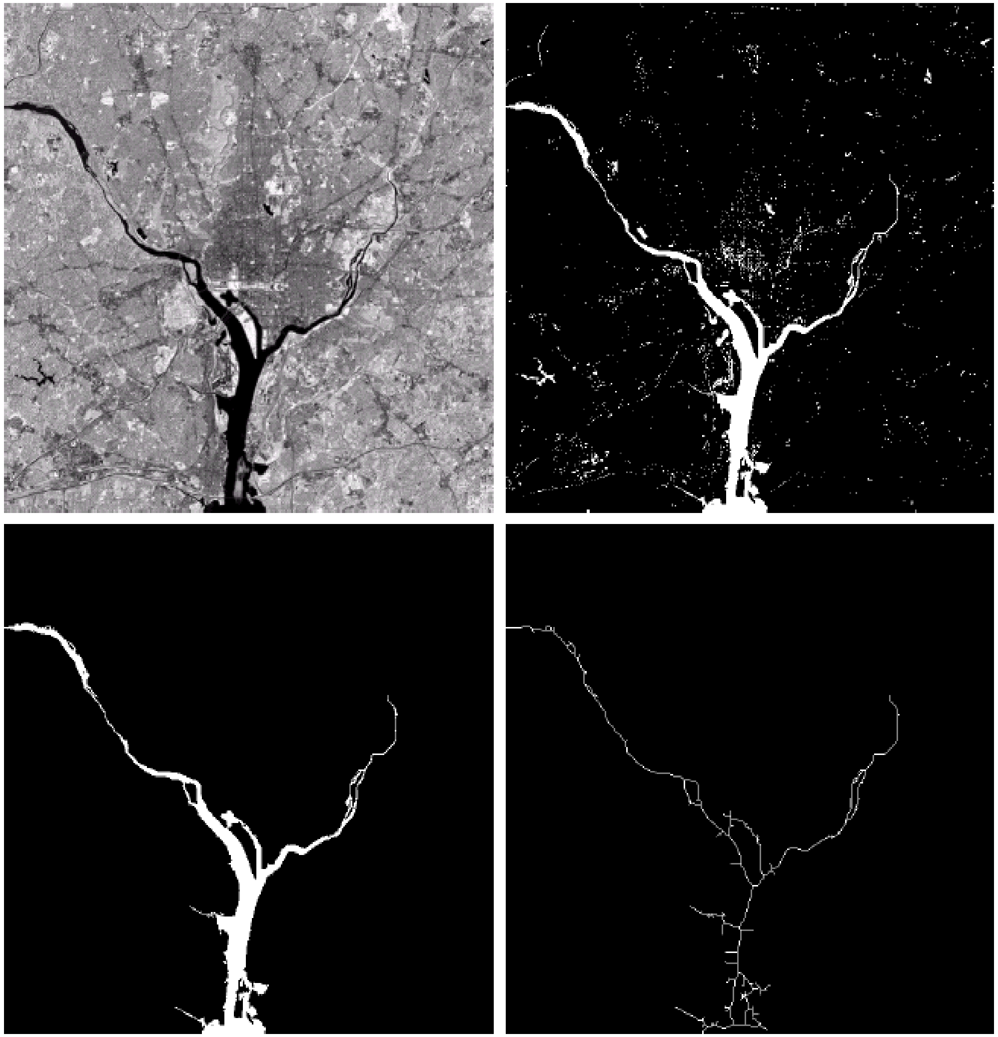


−1	−1	−1
−1	8	−1
−1	−1	−1

- To separate object from background
- Autonomous segmentation is one of difficult task in DIP.
- A rugged segmentation procedure brings the process a long way toward successful solution of an image problem.

Representation & Description

- Decide either a raw pixel data constituting boundary of a region or as a complete region (all the points in the region)
- Boundary representation – focus on external shape characteristics such as corners and inflections.
- Region representation – focus on internal properties such as texture or skeleton shape.



a b
c d

FIGURE 11.21 (a) Infrared image of the Washington, D.C. area. (b) Thresholded image. (c) The largest connected component of (b). Skeleton of (c).

Representation & Description

1 connected component & 1 hole

1 connected component & 2 holes

Recognition & Interpretation

- Recognition – process that assigns a label to an object based on the information provided by its descriptors

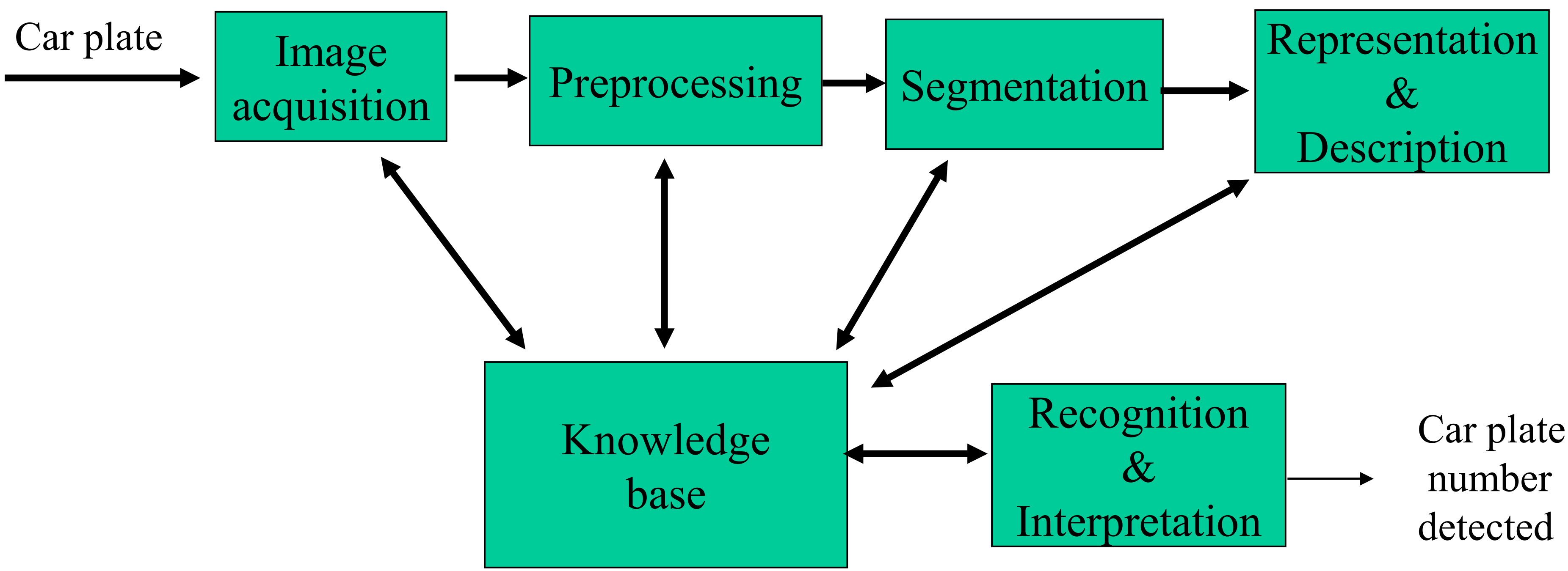
- Interpretation – assigning meaning to an ensemble of recognized objects

Knowledge base

- A problem domain – detailing regions of an image where the information of interest is known to be located
- Help to limit search

Mutual Integration of Processes

e.g. Car plate recognition



Components of an Image Processing System

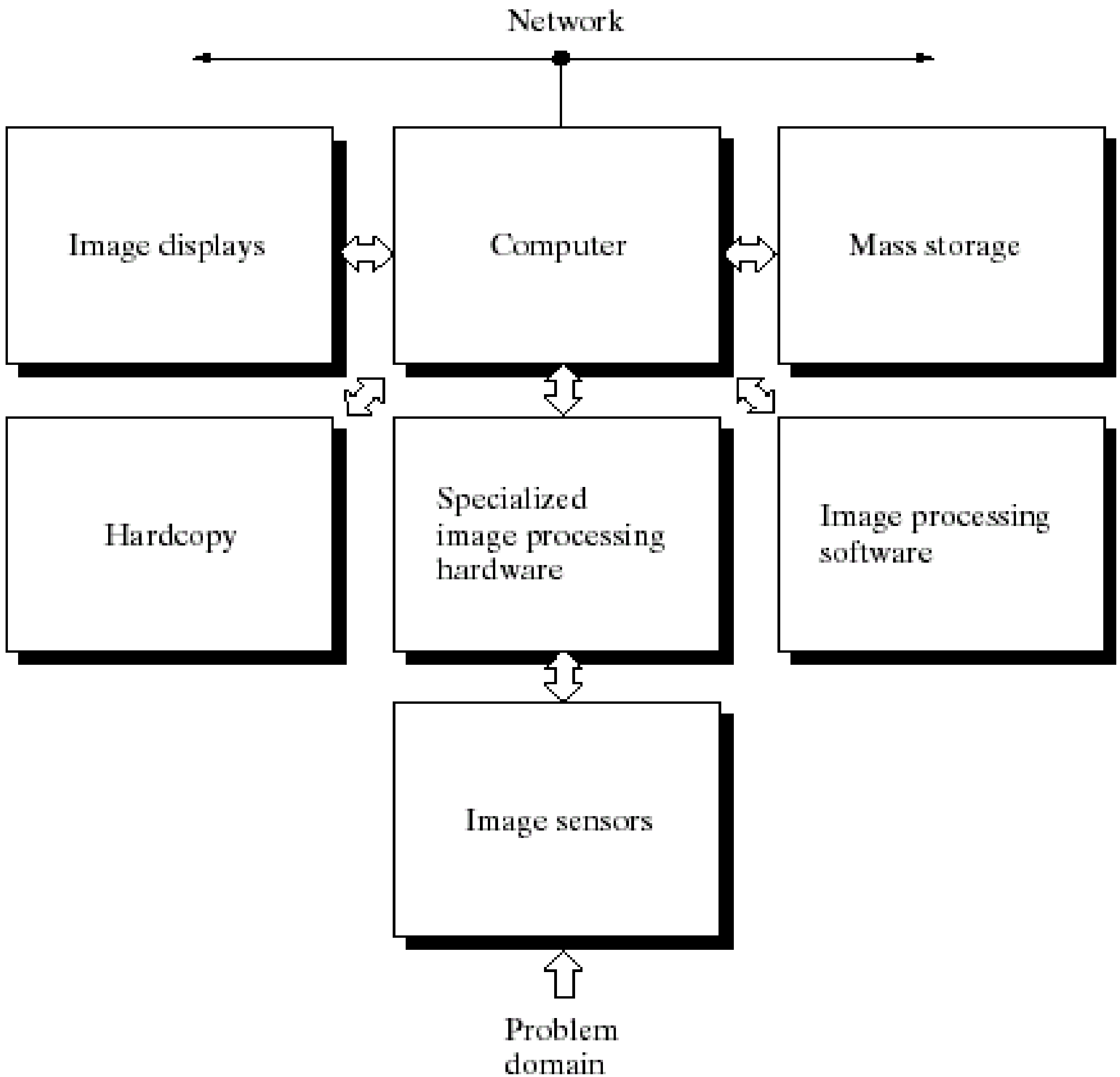


FIGURE 1.24 Components of a general-purpose image processing system.