# COMP.SGN.110 Introduction to Image and Video Processing
## (Start video recording)

- **Lecture times:** Tuesdays and Fridays, 16.15-17.45
- **Lecture period** (P2): 20.10 - 27.11.2020. (6 weeks, 12 lectures)
- **Name and Contact Information of Instructors:**



| | |
|---|---|
| – Prof. Moncef Gabbouj | Anton Muravev |
| – Offices: TF406 | TC413 |
| – Email: moncef.gabbouj@tuni.fi | anton.muravev@tuni.fi |



**Course Description:**

- Provides an overview of the principles and techniques of digital image processing and applications related to digital imaging system design and analysis. The course covers the following topics:
  - analysis and implementation of image and video processing algorithms
  - methods and filters for image enhancement and restorations,
  - Basics of color image processing, and
  - Basics of video processing.

# Zoom Instructions for Lecturer

- It is recommended to briefly review the common rules and the instructions for distance learning in the first meeting.
- **Follow the safety instructions** given on the video conferencing platform, eg invitation and meeting settings.
- Send the students participation instructions **in advance (eg in connection with a calendar invitation)**
- It is important that all participants use **a background image** or blur the background.
- It is the teacher’s responsibility to **react immediately** if a participant shares with others content that violates the guidelines.
- Tell everyone in advance if you plan to record a teaching session. Justify the need (eg other students can watch the session later).
- Keeping the camera turned on during recording is not mandatory.
- Record the participants on video only when it provides a clear **benefit** for teaching. In advance, think about an alternative participation method for students who do not want to be videoed.
- Tell in advance that students need to be **prepared** for the use of camera in the teaching situation.
- Using video via poor network connections may interfere with the teaching session and, at worst, even prevent it. You can agree that after the start, the video connection can be shut down, and each speaker / presenter turns it on while they are speaking.
- Video should not be used for the remote monitoring of students. Its use does not effectively eliminate the possibility of abuse. Instead, mandatory use exposes us to various data protection issues.

# Zoom Instructions for Students

- **Lectures** are recorded !!!!!
- Use **a profile picture**, which makes it easier to identify the speaker even without video.
- **Always** blur the background and avoid unnecessary visibility of your location
- **Connect** from a location that others will not enter during the lectures
- **Tell others living with you** that you are attending a remote lecture that may use live videos.
- Make sure that no inappropriate or confidential material is visible in the **background**. If possible, look for a quiet place for the teaching session where the background is neutral.
- **Mute** your microphone at all time, except when you are talking
- **Mute** external audio sources (music, TV, etc.) during the lectures.
- **Turn off your camera** if something irrelevant enters the camera's shooting range and during any breaks.
- If you do not want to comment orally during video recording, use the chat.

# Further Information

- Zoom video service
- Zoom meetings’ privacy and security

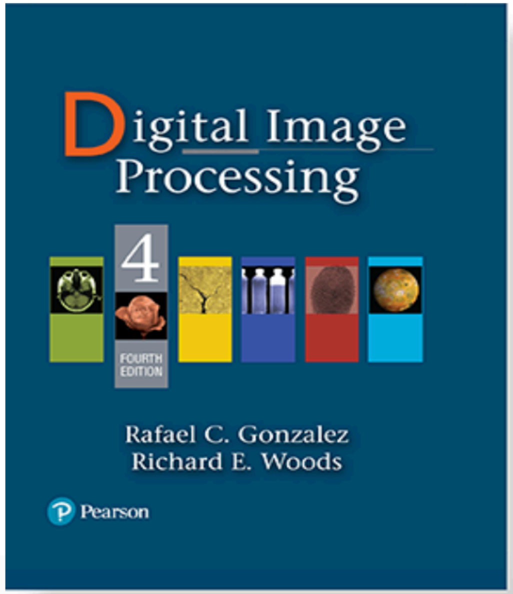
Questions/help:

IT Helpdesk
+358 294 520 500
it-helpdesk@tuni.fi
helpdesk.tuni.fi

# Textbook, Lecture Material and Pre-requisite

## Textbook:

Rafael Gonzalez, Richard Woods, Digital Image Processing, Fourth Edition, 2018, Pearson.




## Lecture material:

Lecture notes will be posted on Moodle

## Supplementary material:

- Yao Wang, Jörn Ostermann, Ya-Qin Zhang, video Processing and Communications, Prentice Hall, 2002.
- Oge Marques, Practical Image and Video Processing Using MATLAB, Wiley-IEEE Press, 2011

## Pre-requisite:

COMP.SGN.100-2020-2021-1 Introduction to Signal Processing or equivalent knowledge of the basics of digital signal processing and Signals and Systems are required

**Moodle:** https://moodle.tuni.fi/course/view.php?id=10927

# Learning Outcomes

After completing the course, the student is able to

- **understand** and **explain** the concept of a digital image and digital image processing,
- know the **fundamentals** of the **electromagnetic spectrum** and its relation to IP
- become **familiar** with the components of a digital image processing system
- know the **basics** of the **human visual system**, the concept of brightness adaptation and discrimination
- **understand** the basics of image sampling and quantization
- **understand** the meaning of spatial and frequency domain processing and the different techniques used therein
- **know** the meaning of image histogram and how it can be used to enhance the image
- **understand** basic digital spatial and frequency domain filters and how they are used in image enhancement
- become **familiar** with noise models in image processing
- **present** verbally or with mathematical formulas the linear and nonlinear restoration methods applied to digital gray-scale images
- **understand** the fundamentals of color, color spectrum and color models
- **present** verbally or with mathematical formulas the enhancement and restoration methods applied to digital color images
- **explain** the basic concepts of video processing
- **implement** the image processing methods and algorithms using Matlab.

# Contents of the Course

**Contents of the course and core contents analysis (SG*)**

| Core content | Complementary knowledge | Specialist knowledge |
|---|---|---|
| Definition and representation of digital image, basics of the human visual system, brightness adaptation and discrimination, image formation, two-dimensional sampling and quantization | History of digital image processing, application areas and basic relationships between pixels | |
| Image enhancement and restoration both in spatial and frequency domains, two-dimensional discrete Fourier transform and classes of spatial and frequency domain filters | Continuous two-dimensional Fourier transform, properties of the two-dimensional discrete Fourier transform, other transforms and mathematical representation of individual filters | Mathematical derivation of the properties of the two-dimensional discrete Fourier transform |
| The basics of color vision, color models and pseudocolor images | Color transformations between color models, color image smoothing and sharpening | |
| The basics of video processing, video file formats, resolutions and bit rates | Video enhancement | |
| Motion analysis and estimation, motion compensated filtering, deinterlacing and sampling rate conversion | | MPEG standards |
| Topics of the possible visiting lecture | Details of the possible visiting lecture | |

# Course Evaluation

- **Course grade** is determined by the exam grade (max 30 points) and exercises bonus (max 2 points)
- To pass the course, you must have **at least 8 out of 13 exercises accepted** and get at least 15 points in the exam. There are 12 regular exercises and 1 special ICIP Exercise.
- Exercises are carried out remotely and you need to **sign up for two sessions per week**.
- To complete an exercise, the **Teaching Assistant checks/approves your solution and marks your attendance** (do not leave the Meeting before your solution is approved by the TA).
- 1 bonus point is given for each additional 2 exercises approved beyond the min 8 exercises required (for a **max of 2 bonus points**).
- Exercise bonus (max 2 points) are valid only for the **current course implementation round** (2020-2021).

# Lecture and Exercise Timetable

| Topics | Lectures | Exercises |
|---|---|---|
| Lecture 1: Intro to Digital Image Proc.  73s | 20.10.2020 | ICIP 2020 Exercises |
| Lecture 2: Digital Image Fundamentals 74s | 23.10.2020 | ICIP 2020 Exercises |
| Lecture 3: IE in Spatial Domain 47s | 27.10.2020 | Week 44 Ex 1 IP Matlab Toolbox |
| Lecture 4: Intensity Transformation and  Spatial Filtering 38s | 30.10.2020 | Week 44 Ex 2 Matlab and IP basics |
| Lecture 5: Filtering in the Freq Domain 32s | 3.11.2020 | Week 45 Ex 3 IE1 |
| Lecture 6: Filtering in the Freq Domain 32s | 6.11.2020 | Week 45 Ex 4 IE 2 |
| Lecture 7: Image Restoration and Reconstruction 46 s | 10.11.2020 | Week 46 Ex 5 IE 3 |
| Lecture 8: Image Restoration and Reconstruction 48s | 13.11.2020 | Week 46 Ex 6 IE4 |
| Lecture 9: Color Image Processing 55s | 17.11.2020 | Week 47 Ex 7 IR 1 |
| Lecture 10: Color Image Processing 54s | 20.11.2020 | Week 47 Ex 8 IR2 |
| Lecture 11: Video Fundamentals 1, 47s | 24.11.2020 | Week 48 Ex 9 Color IP 1 |
| Lecture 12: Video Fundamentals 2 and Course Review, 45s | 27.11.2020 | Week 48 Ex 10  Color IP 2 |
| | | Week 49 Ex 11 Video SP1 |
| | | Week 49 Ex 12 Video SP2 |
| **Total:** | 12 Lectures | 12 Exercises |

# Exercise Groups and TAs

**Sign up for one exercise group in each session (max 16 students/group)**

Each group has two sessions per week (remember the academic quarter!)

**Group 1:** Mete Ahishali and Junaid Malik
Zoom link: TBA
Wed 10:00 - 12:00
Fri 14:00 - 16:00

**Group 2:** Firas Laakom and Rabab Boulouchgour
Zoom link: TBA
Mon 12:00 - 14:00
Thu 12:00 - 14:00

**Group 3:** Aysen Degerli and (Mohammad Al-Sa'd or Anton Muravev)
Zoom link: TBA
Mon 18:00 - 20:00
Thu 18:00 - 20:00

**Group 4:** Fahad Sohrab and Yat-Hong Lam Jacky
Zoom link: TBA
Wed 18:00 - 20:00
Fri 18:00 - 20:00

**Group 5:** Jussi Taipalmaa and Dat Tran Thanh
Zoom link: TBA
Wed 16:00 - 18:00
Fri 12:00 - 14:00

**Group 6:** Kateryna Chumachenko and Bilge Can Pullinen
Zoom link: TBA
Mon 14:00 - 16:00
Fri 10:00 - 12:00

# ICIP (Special) Exercise

IEEE International Conference on Image Processing
25-28 October 2020, United Arab Emirates
FULLY VIRTUAL

IEEE International Conference on Image Processing (ICIP 2020) will be held ONLINE 25-28 Oct 2020.

1. **Register** to IEEE ICIP 2020 (https://cmsworkshops.com/ICIP2020/Registration.asp)
2. **Attend at least two technical events** (tutorials, plenaries, special sessions, challenges, industry workshops) (Sunday 25 – Wednesday 28 Oct 2020)
3. **Submit a report** for the two sessions you attended (you may attend more sessions, but report on only two of them):
   a) Title of the session
   b) Speaker(s)
   c) Brief description of the topic
   d) What did you learn from the session?
   e) What was the most relevant/important question from the audience to the speaker?
4. Submit your report in Moodle by **30 Oct 2020**.

## IMAGES (Chest X-Ray for COVID-19 Patients

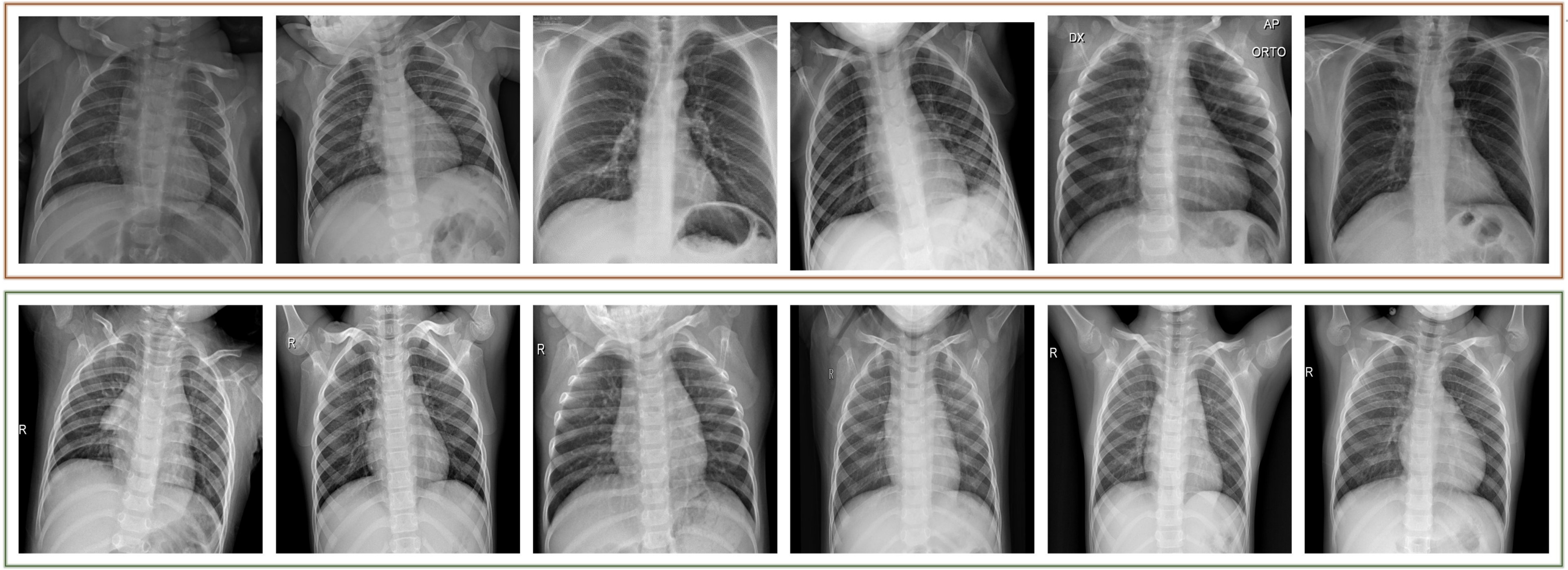
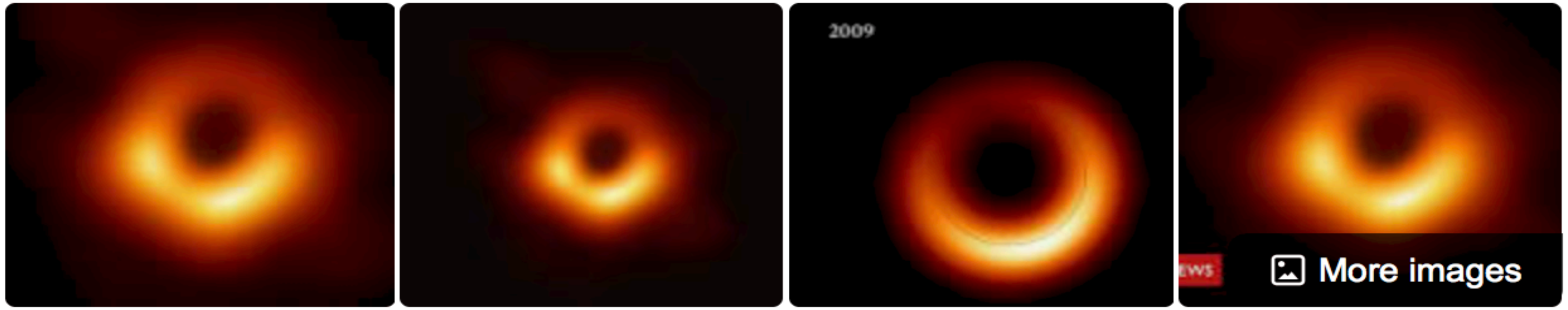



Fig. 1: (first row) Samples of COVID-19 pneumonia with very limited or no visible sign of COVID-19, and (second row) suspects where the person can spread the disease in the transport route (QaTa-COV19 dataset)

# IMAGES

M87 lies about 55 million light-years from Earth




## M87 black hole

**M87**, in full Messier 87, also called Virgo A or NGC4486, giant elliptical galaxy in the constellation Virgo whose nucleus contains a **black hole**, the first ever to be directly imaged. **M87** is the most powerful known source of radio energy among the thousands of galactic systems constituting the so-called Virgo Cluster. 5 days ago

IEEE ICIP 2020 Plenary Talk "Capturing the First Picture of a Black Hole & Beyond," by Prof. Katherine L. (Katie) Bouman, Tuesday 27 Oct 2020, 8 – 9 (Gulf Standard Time) (7-8 AM, Finland time) (link)

# IMAGES

Largest digital photo in the world?

- 195 Billion pixel of Shanghai (https://fstoppers.com/news/195-billion-pixel-interactive-image-shanghai-worlds-third-largest-photo-320409, http://www.bigpixel.cn/t/6334179385f26b370029382r)
- 365 Gigapixels

(https://petapixel.com/2015/05/24/365-gigapixel-panorama-of-mont-blanc-becomes-the-worlds-largest-photo/) Mont Blanc Largest Panoramic Photo

- 365 Giga Pixel,
- 46TB,
- 70K shots,
- 15 days shooting, and
- 2 months postprocessing

# IMAGES

- A camera that can photograph you from 45km away! (full article)
- Developed in China, the **LiDAR**-based system can cut through city smog to resolve human-sized features at vast distances
- Zheng-Ping Li (University of Science and Technology of China in Shanghai) uses single-photon detectors combined with a computational imaging to achieve super-high-resolution images by knitting together the sparsest of data points.
- The technique is based on **laser ranging and detection** (**LiDAR**) illuminating the subject with laser light and then creating an image from the reflected light.

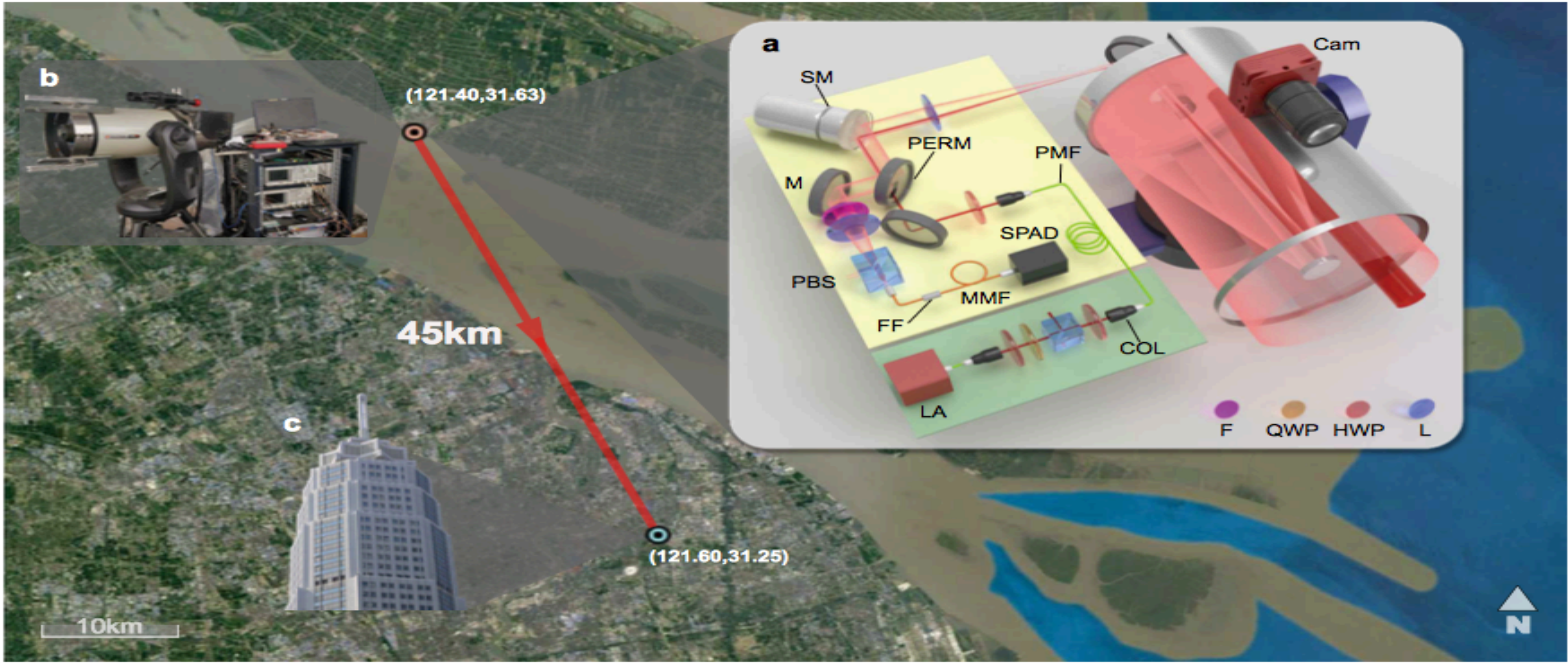
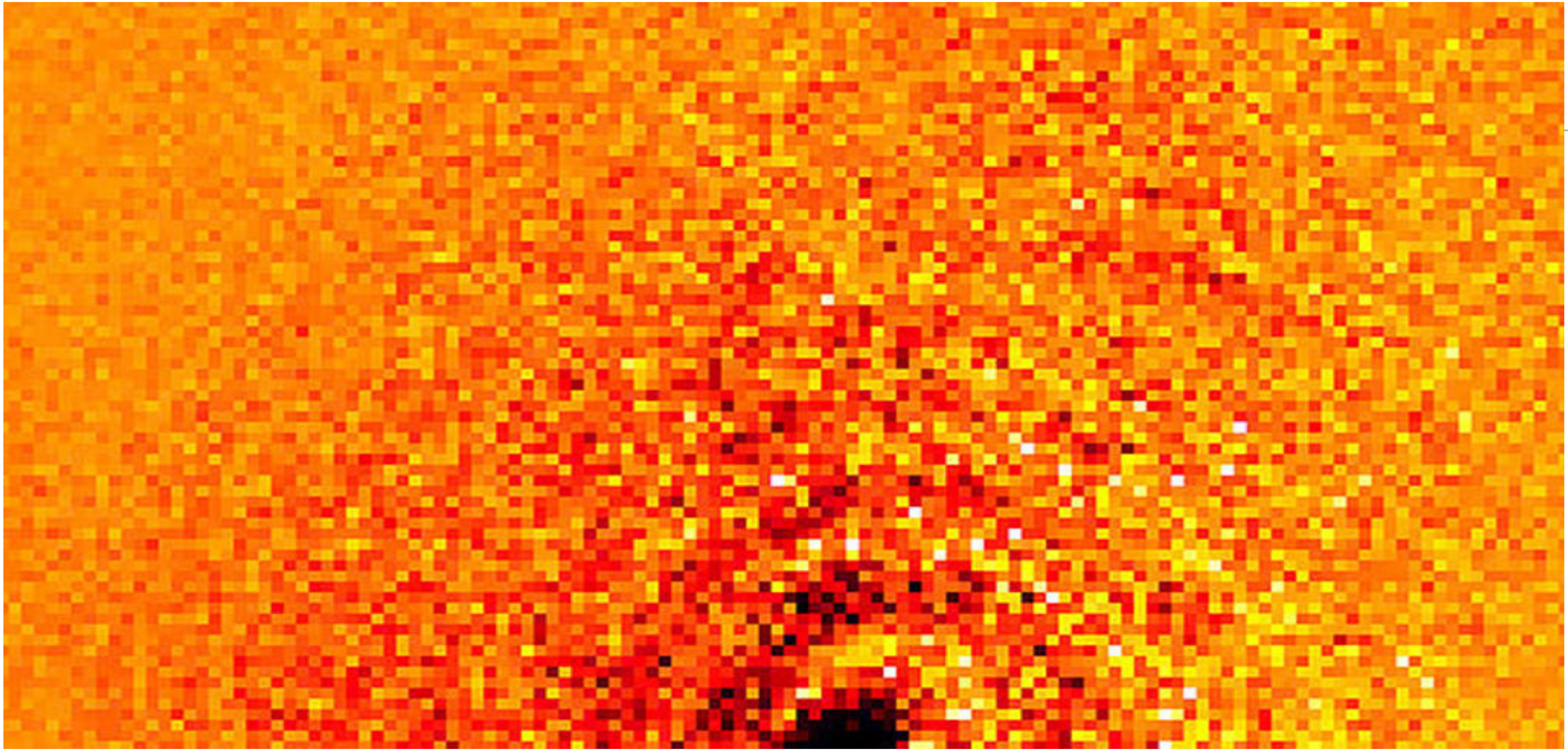



Figure 1: Illustration of long-range active single-photon LiDAR. Satellite image of the experiment layout in the urban area of Shanghai City, with the single-photon LiDAR positioned on **Chongming Island**. a, Schematic diagram of experimental setup. SM: scanning mirror; Cam: camera (visible band); M: mirror; PERM: 45◦ perforated mirror; PBS: polarization beam splitter; SPAD: single-photon avalanche diode detector; MMF: multimode fiber; PMF: polarization- maintaining fiber; LA: laser (1550 nm); F: filters (longpass and 9 nm bandpass); FF: fiber filter (1.3 nm bandpass); L: lens; HWP: half-wave plate; QWP: quarter-wave plate; EDFA: erbium-doped fiber amplifier. b, Photograph of experimental setup, including the optical system (left) and the electronic control system (right). The optical system consists of a telescope congregation and an optical component box for shielding. c, Close-up photograph of the target: the **Pudong Civil Aviation Building**, which is on the opposite shore of the river from Chongming Island. The building is 45 km away from the camera.



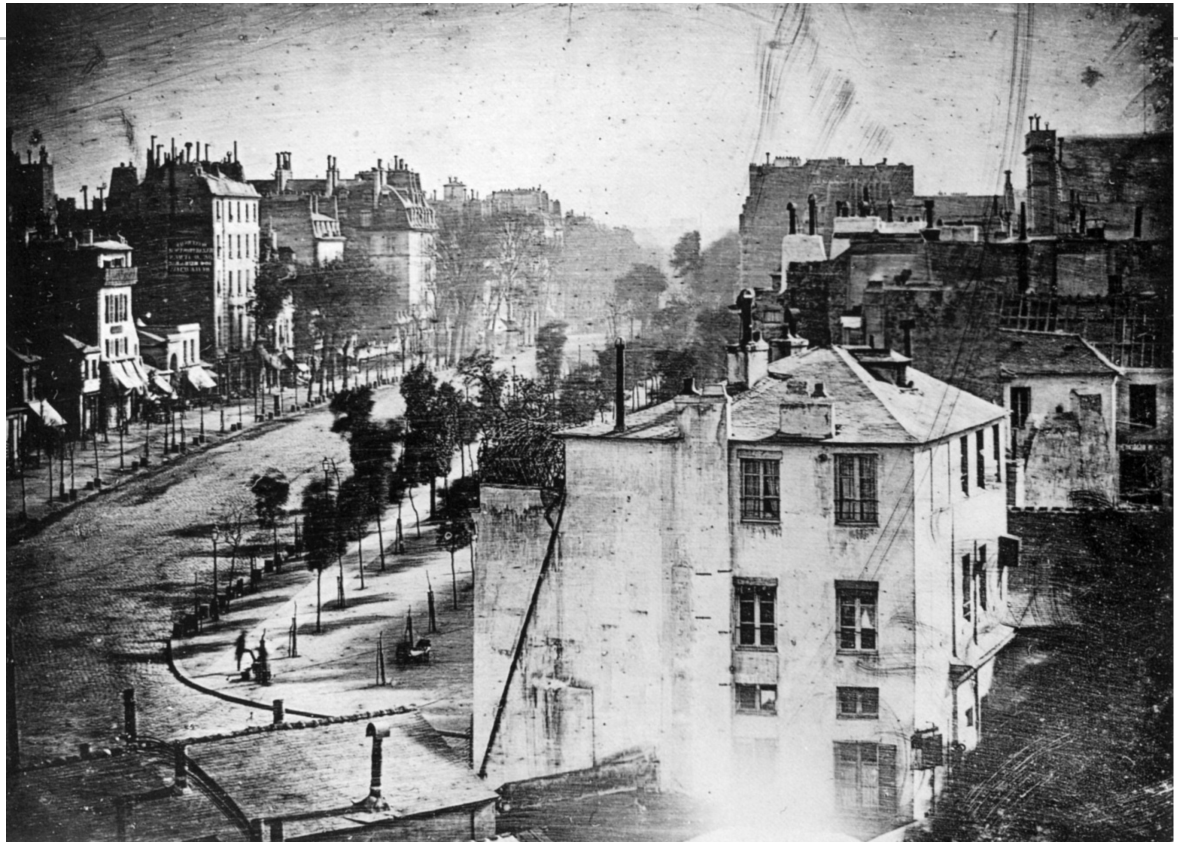
Griffith University research team has been able to photograph the shadow of a single atom for the first time, using a super high resolution microscope. (2012) (0.1 TO 0.5 NM ($1 \times 10^{-10}$ M TO $5 \times 10^{-10}$ M)

# The first photograph in the world*

Joseph Nicéphore Niépce, *View from the Window at Le Gras*, 1826.
Kodak Research Laboratory, Harrow, England.
Gelatin silver print reproduction of Joseph Nicéphore Niépce's
Gelatin silver print. 20.3 x 25.4 cm.

*** Disclaimer: The lecturer does not assume/support nor propagate any opinion regarding the images displayed in the lecture material.**

# The First Photograph of a Human
# "Boulevard Du Temple" [Paris, 1838]



- Boulevard du Temple, taken by Louis Daguerre in late 1838, was the first-ever photograph of a person. It is an image of a busy street, but because **exposure time was over ten minutes**, the city traffic was moving too much to appear. The exception is a man in the bottom left corner, who stood still getting his boots polished long enough to show up in the picture.

- Robert Cornelius, self-portrait, Oct. or Nov. 1839, approximate quarter plate daguerreotype which is a procedure invented in 1839 using silver on a copper plate.
- The back reads, “The first light picture ever taken”. This self-portrait is the first photographic portrait image of a human ever produced.


Before the autochrome process was perfect in France, this photograph was taken in 1872 by **Louis Arthur Ducos du Hauron** who invented the **subtractive (cyan, magenta, and yellow) color method** of taking photographs. **Louis** was a French pioneer in color photography and he worked in both subtractive and **additive (red, green, and blue) color**. This particular photograph is called “Landscape of Southern France”.

# First “Motion Picture”

- In 1887, using a series of trip wires, Eadweard Muybridge created the **first high speed photo series** which can be run together to give the effect of motion pictures.
- High speed photography is the science of **taking pictures of very fast** phenomena. In 1948, the Society of Motion Picture and Television Engineers (SMPTE) defined high-speed photography as any set of photographs captured by a camera capable of **128 frames per second** or greater, and of at least three consecutive frames.
- Also see: http://www.youtube.com/watch?feature=player_embedded&v=F1i40rnpOsA

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special typefaces. (McFarlane.) [References in the bibliography at the end of the book are listed in alphabetical order by authors' last names.]

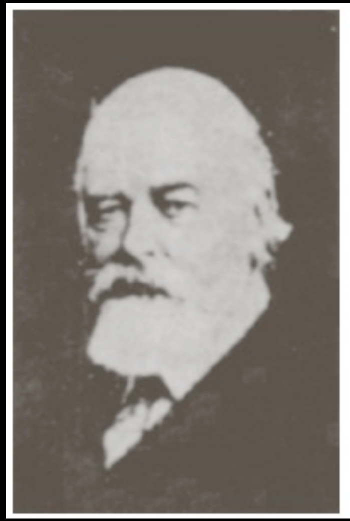


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

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

- The **first image scanner** ever developed was a drum scanner. It was built in 1957 at the US National Bureau of Standards by a team led by Russell Kirsch.
- The first image ever scanned on this machine was a **5 cm square photograph** of Kirsch's then-three-month-old son, Walden.
- The black and white image had a resolution of 176 pixels on a side. Technically, this is the very **first digital photograph** – all these years later, digital cameras are only just beginning to have the full capabilities of film cameras.

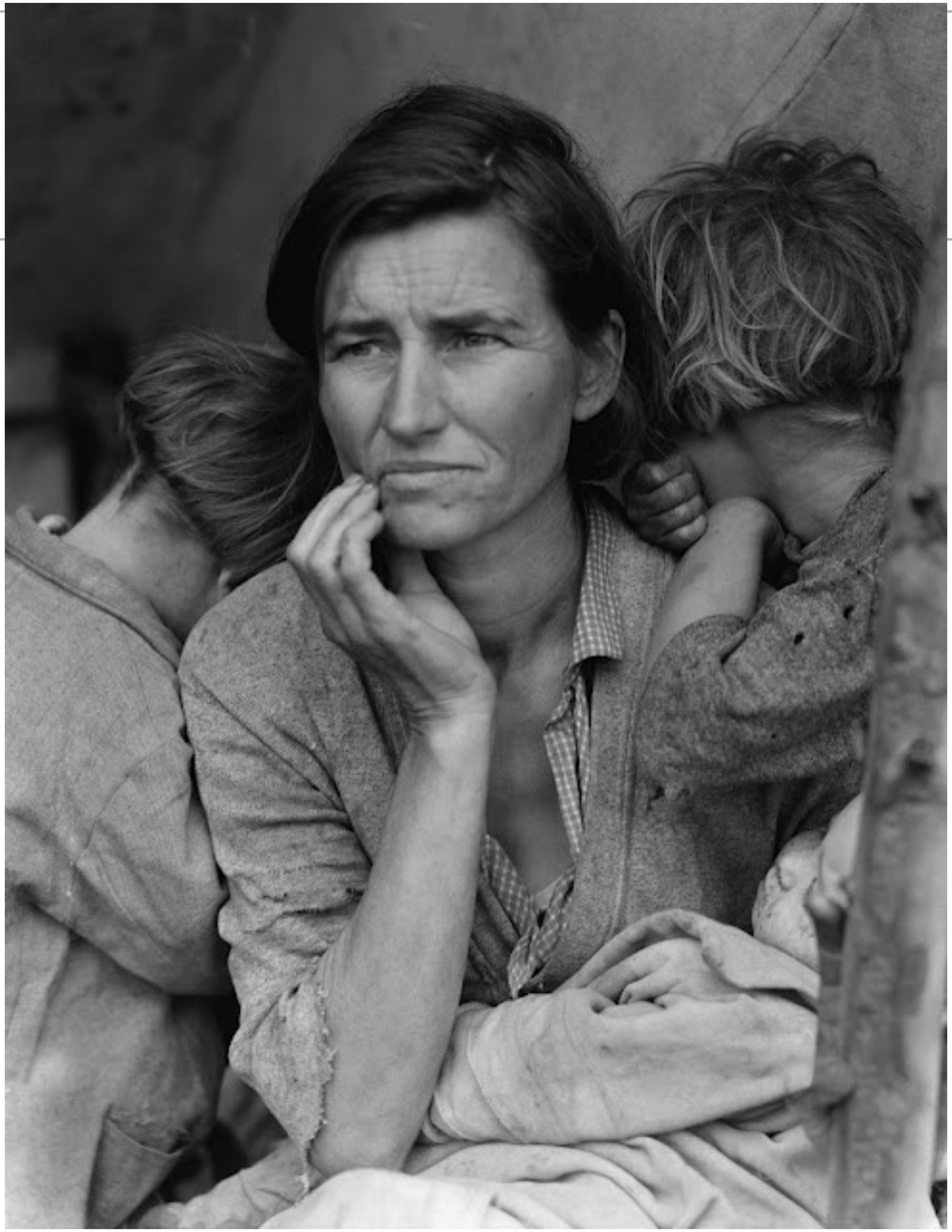
# 10 Images that made history*

- Lawrence Beitler took this iconic photograph on August 7, 1930, showing the lynching of Thomas Shipp and Abram Smith, two young black men accused of raping a white girl. A mob of 10,000 whites took sledgehammers to the county jailhouse doors to get these men; the girl's uncle saved the life of a third by proclaiming the man's innocence.
- Lynching photos were made into postcards designed to boost white supremacy, but the tortured bodies and grotesquely happy crowds ended up angering and revolting as many as they scared.
- The photo sold thousands of copies, which Beitler stayed up for 10 days and nights printing them. Ironically, this photo which had become iconic image of lynching was taken at Marion, Indiana, whereas most of the nearly 5,000 lynchings documented between Reconstruction and the late 1960s were perpetrated in the South. (Hangings, beatings and mutilations were called the sentence of "Judge Lynch.")
- This photo was so iconic that it has been the inspiration for many poems, books and songs down the years, "Strange Fruit" by the Jewish poet Abel Meeropol (later sung by Billie Holiday) being the best example.

*** Disclaimer: The lecturer does not assume/support nor propagate any opinion regarding the images displayed in the lecture material.**

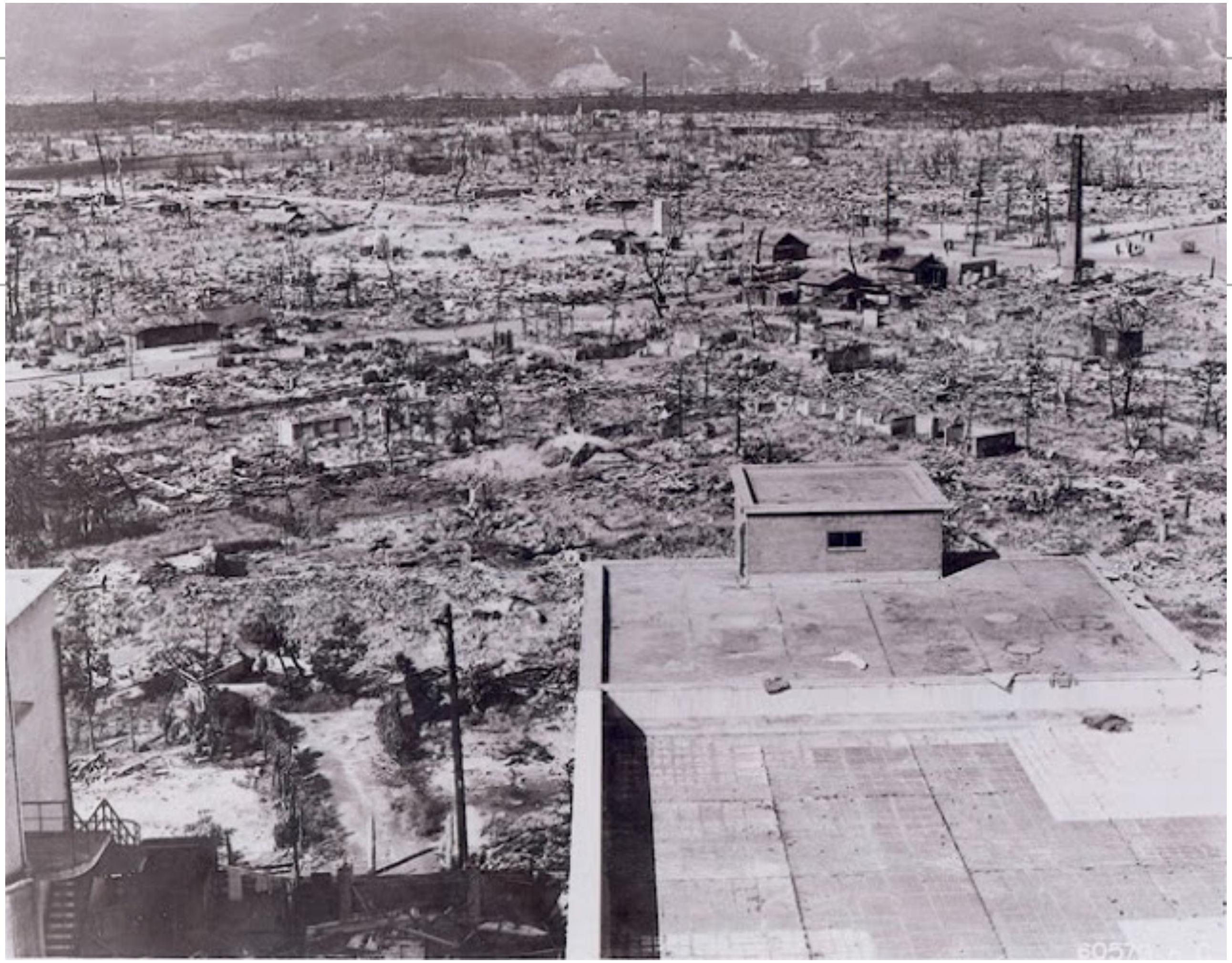
This picture's title is "**Migrant mother**" and was taken in 1936 in California by the photographer **Dorothea Lange**.

Migrant mother was probably, and still now, considered an **icon of the history of photography**: the subject of this picture is Florence Owens Thompson, a 32 years old woman, mother of seven children, immortalized near a pea field in California (the original title is, in fact, destitute pea picker), for many persons, Florence **Owens Thompson is the icon of the Great Depression**. Lange took this picture during the visit to a vegetable picking field in California in February 1936 and in the meanwhile she showed at best the resistance of a proud nation that was in the middle of a crisis that was never seen before.



- This photograph was taken of Adolf Hitler visiting Paris with his architect Albert Speer, on June 23, 1940. Hitler’s army had captured Paris and Hitler went to check out his new city.

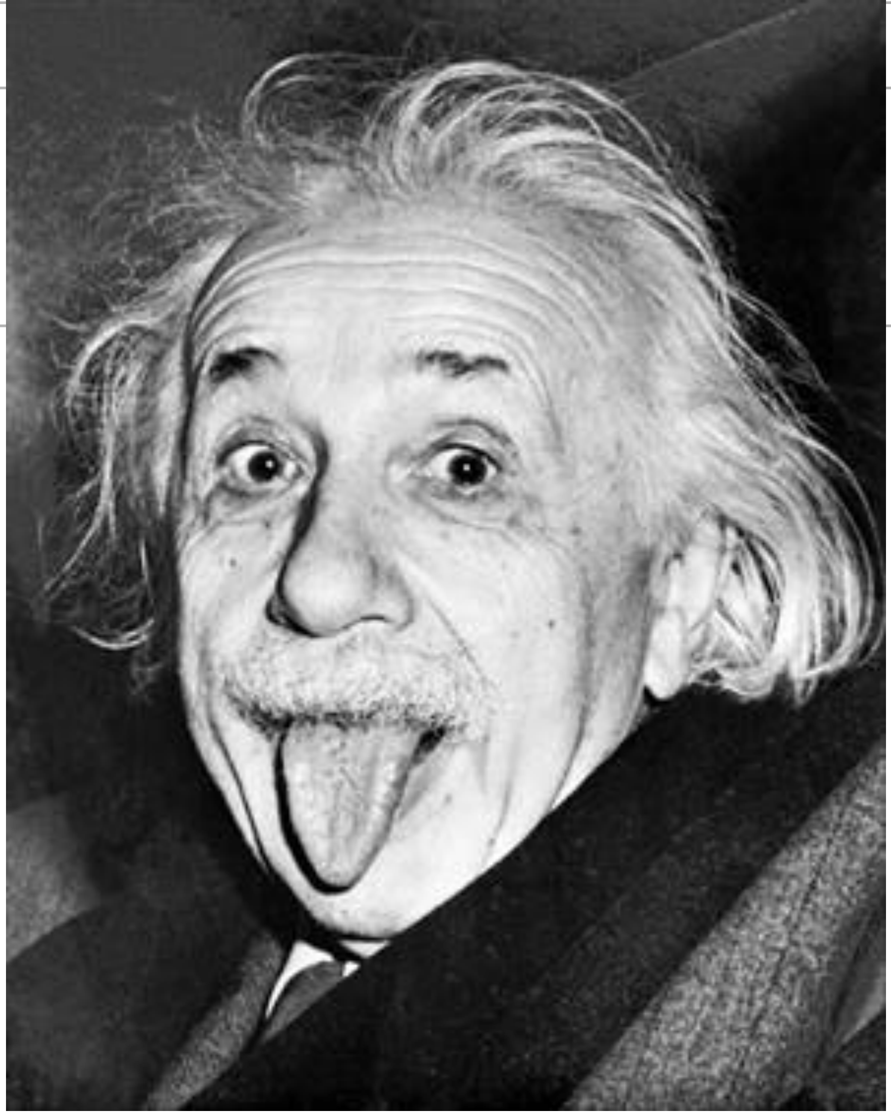
Raising a flag over the Reichstag is a historic photograph taken on May 2, 1945, by Yevgeny Khaldei. It depicts a number of Soviet Troops raising the flag of the Soviet Union atop the German Reichstag building during the Battle of Berlin in World War II. The photograph was extremely popular, being reprinted in thousands of publications. It came to be regarded around the world as one of the most significant and recognizable images of the war.



The morning of the 6th of august 1945, the U.S. air force threw the atomic bomb "little boy" on the Japanese city of Hiroshima, followed three days later by the the throwing of the bomb "fat man" on Nagasaki. The estimate of the direct victims is between 100.000 and 200.000 persons, most of whom were civilians. For the seriousness of its direct and indirect damages caused by the explosive devices, and for the fact that it was the first and only use of this kind of weapons during a war, **the two atomic attacks are considered among the most significant war episodes in the history of the entire humankind**.

- **Victory over Japan Day** (**V-J Day**, also known as **Victory in the Pacific Day**, or **V-P Day**) is a name chosen for the day on which the Surrender of Japan occurred, effectively ending World War II, and subsequent anniversaries of that event. This famous LIFE magazine photograph taken by Alfred Eisenstaedt on August 14, 1945 from V-J Day. The soldier and the nurse are unknown but people have come forward to claim the fame. Apparently the nurse slapped the soldier immediately after. The event was the celebration of the end of the war and it was taken in Times Square by Alfred Eisenstaedt.

- While Einstein certainly changed history with his contributions to nuclear physics and quantum mechanics, this photo changed the way history looked at Einstein. By humanizing a man known chiefly for his brilliance, this image is the reason Einstein's name has become synonymous not only with "genius," but also with "wacky genius."
- So why the history-making tongue? It seems Professor Einstein, hoping to enjoy his 72nd birthday (1951) in peace, was stuck in Princeton campus enduring incessant hounding by the press. Upon being prodded to smile for the camera for what seemed like the millionth time, he gave photographer Arthur Sasse a good look at his uvula instead. This being no ordinary tongue, the resulting photo became an instant classic, thus ensuring that the distinguished Nobel Prize-winner would be remembered as much for his personality as for his brain.



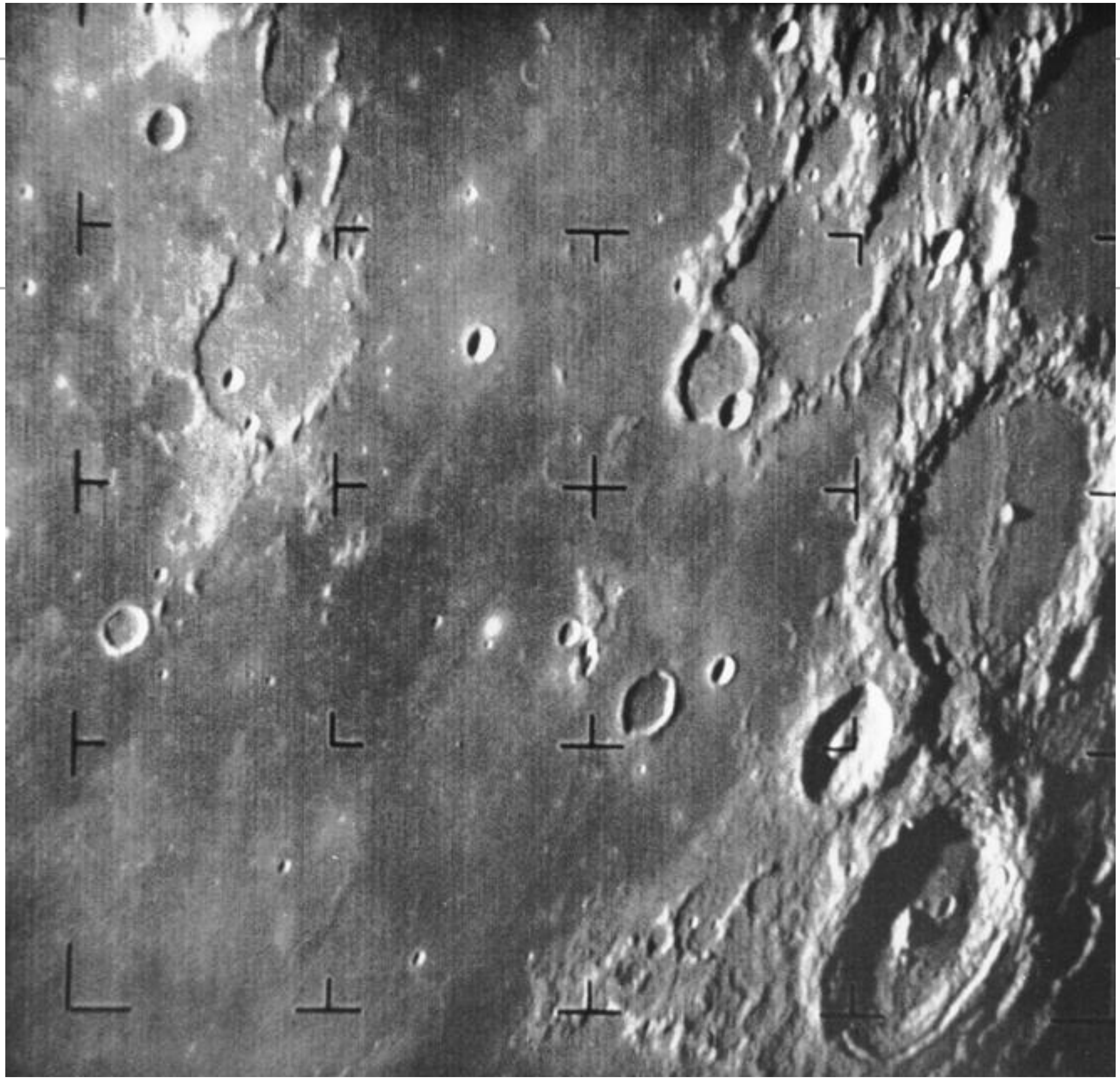


Fig. 1.4: The first picture of the moon by a US spacecraft.
Ranger 7 took this image on July 31, 1964, at 9:09 a.m. EDT, about 17 minutes before impacting the lunar surface (Courtesy of NASA)

- On July 20, 1969, Neil Armstrong put his left foot on the rocky Moon. It was the first human footprint on the Moon. This photograph was taken by Buzz Aldrin. It was part of an experiment to test the properties of the lunar soil.
- The first footprint on the Moon will be there for a million years.

- Sharbat Gula (born ca. 1972) is an Afghan woman who was the subject of a famous photograph by journalist Steve McCurry.
- Gula was living as a refugee in Pakistan during the time of the Soviet occupation of Afghanistan when she was photographed. The image brought her recognition when it was featured on the cover of the June 1985 issue of National Geographic Magazine at a time when she was approximately 12 years old.
- Gula was known throughout the world simply as "the Afghan Girl" until she was formally identified in early 2002. The photograph has been likened to Leonardo da Vinci's painting of the Mona Lisa and is sometimes popularly referred to as "the First World's Third World Mona Lisa."

# Can we do this with image processing?

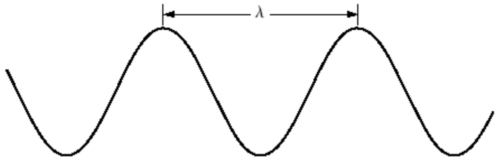
# Can this be done?

# Chapter 1: Introduction
## Back to the Basics of Physics --Radiation-based images

Images based on radiation from Electro-Magnetic (EM) spectrum are most familiar, e.g. visible spectrum and X-ray images.

EM waves can be thought of as propagating sinusoidal waves of varying wavelengths or as a stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light.

**FIGURE 2.11** Graphical representation of one wavelength.




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

If spectral bands are grouped according to energy per photon, we obtain the **spectrum** below.

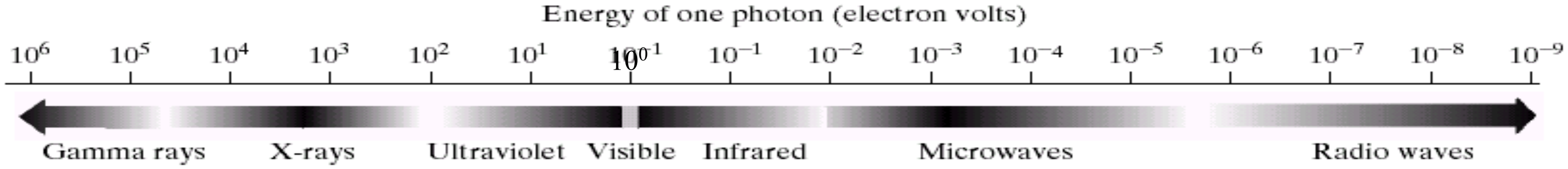



**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.

# Chapter 1: Introduction
## Radiation-based images

In general, images are generated by:

- **Transmitter**, which is a source of electromagnetic signals (beams/pulses), e.g. light, X-rays, sound.
- **Medium** (air, vacuum tube)
- **Subject** (object, human body) that either reflects or absorbs a portion of the EM signal
- **Receiver** that measures the remaining EM signal.

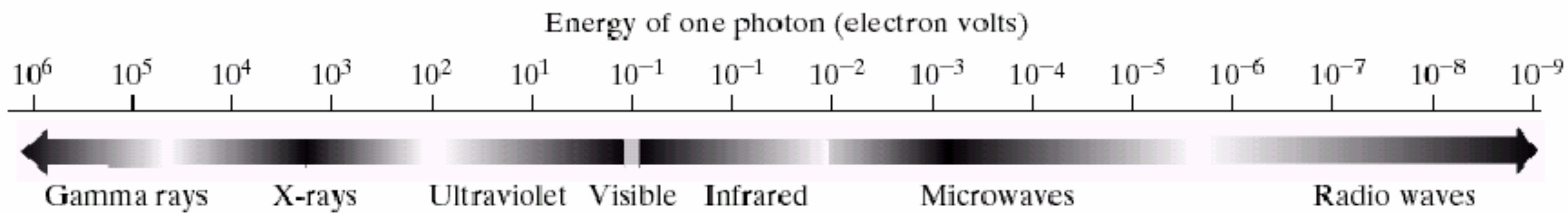
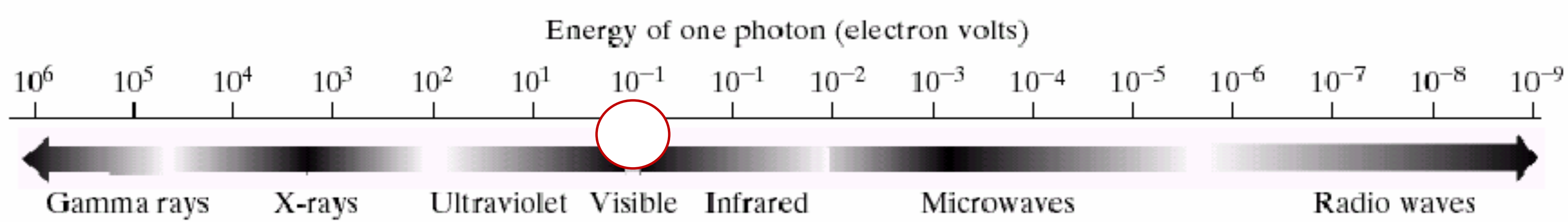


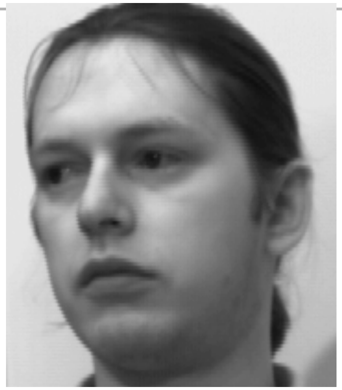
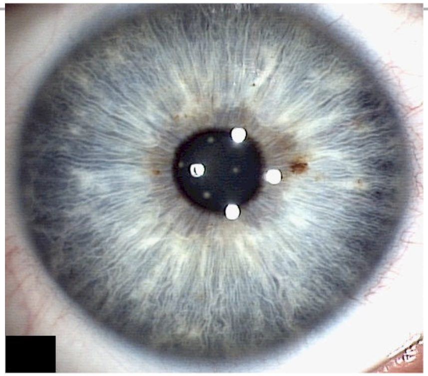

**Fig. 1.5**: The electromagnetic spectrum arranged according to energy per photon.

# Visible (I): Photography



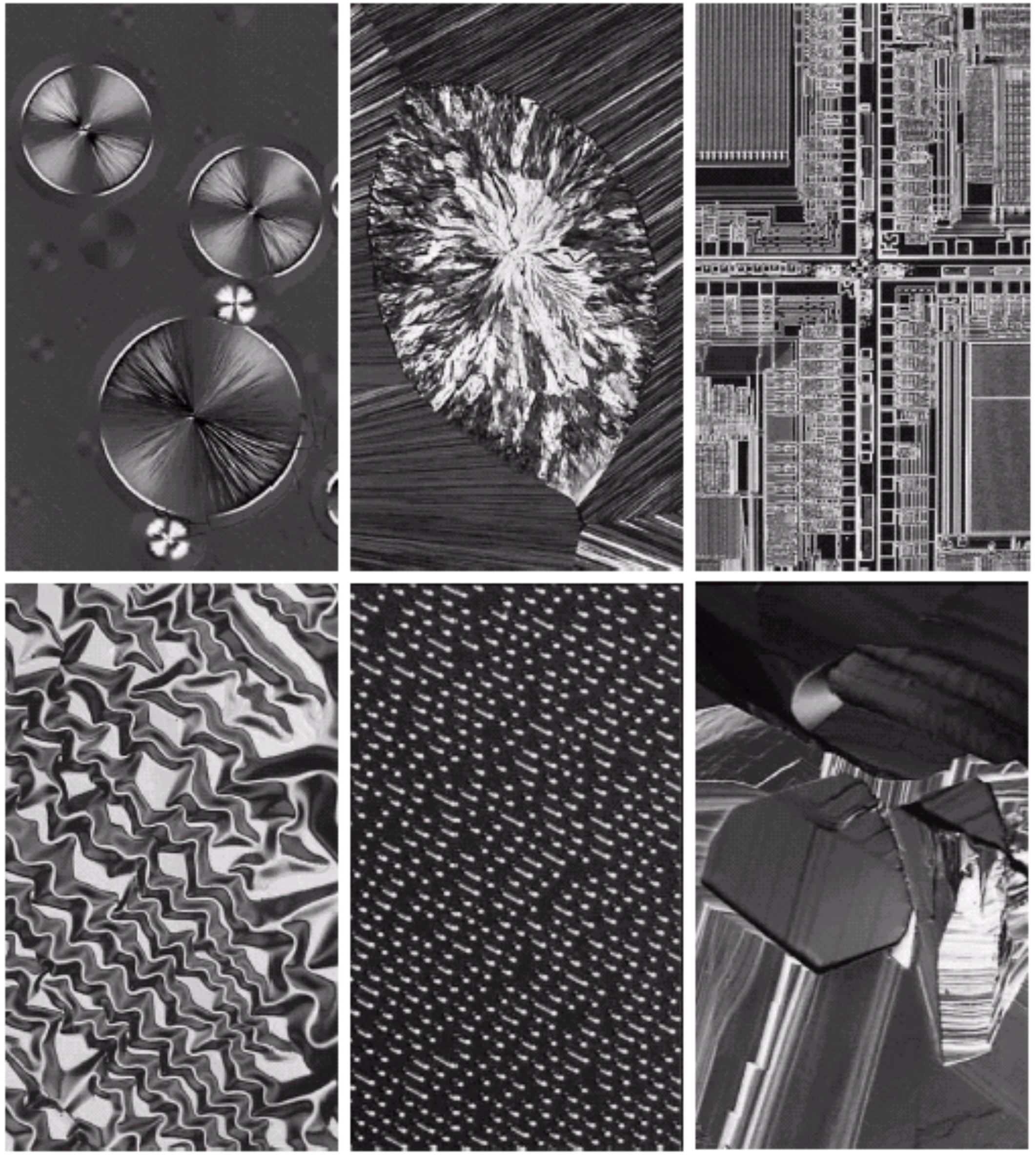

# Visible (II): Motion Pictures

# Visible (III): Biometrics and Forensics

You=ID


Examples of light microscopy images

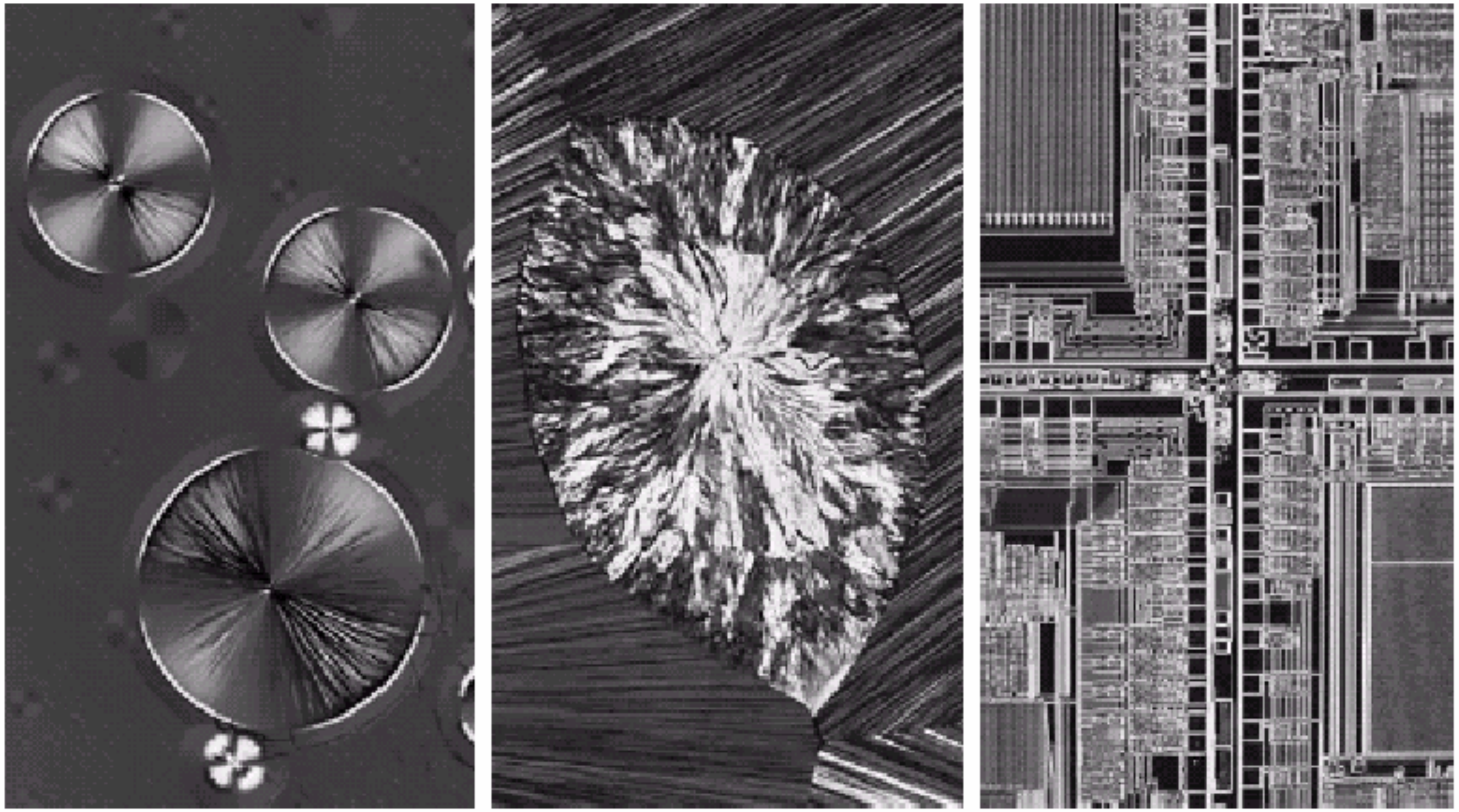


a b c
d e f

**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.)

Applications range from enhancement to measurements.

# Imaging in Visible and Infrared bands



Taxol (anticancer agent (250x)    Cholesterol (40×)    Microprocessor (60×)

Fig. 1.9: Examples of light microscopy images

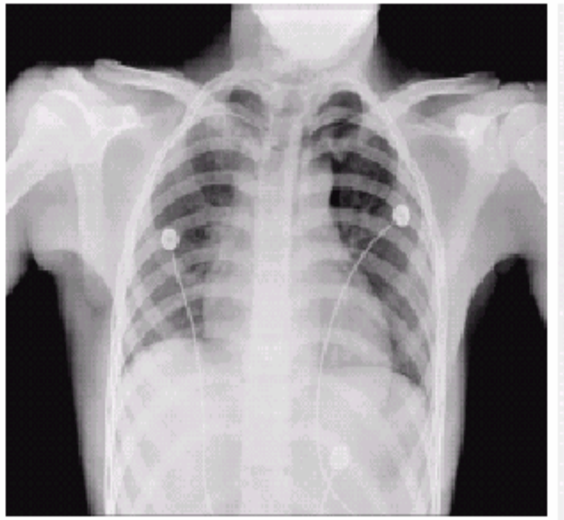
# Visible (V): Remote Sensing

Earth at night (Only Asia/Europe shown)

Infrared imaging

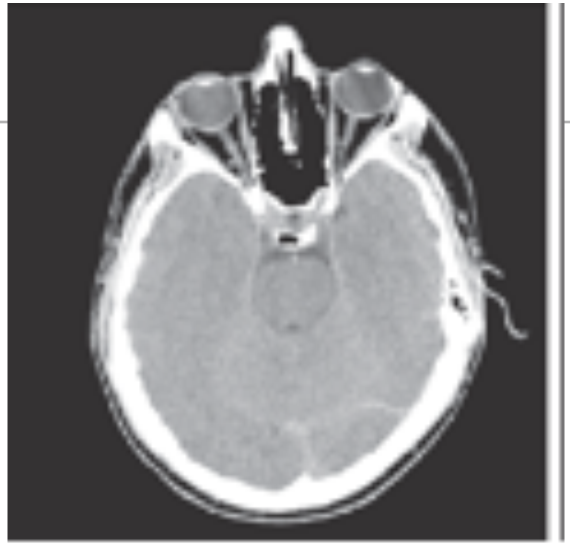
# Beyond Visible (IV): Medical Diagnostics

## Operate in X-ray frequency



Chest X-ray

Aortic angiogram



Head CT scan

**The Birth of Computer Tomography**

Godfrey Housefield and Allan Cormack shared 1979 Nobel Prize in Medicine for the invention of Computer Tomography.

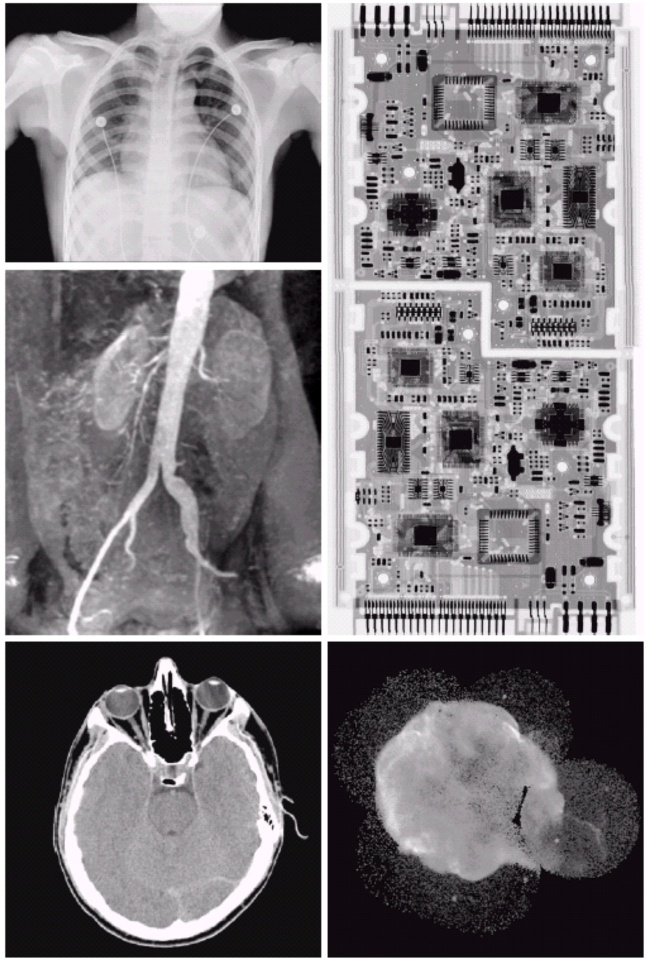
**CT scan**, also known as computed tomography scan, makes use of computer-processed combinations of many X-ray measurements taken from different angles to produce cross-sectional (tomographic) images (virtual "slices") of specific areas of a scanned object, allowing the user to see inside the object without cutting.

# Chapter 1: Introduction
## Examples of X-ray imaging

Chest X-ray

Image of blood vessels (angiogram)

Computerised axial tomography (CT) of the head



X-ray of circuit board

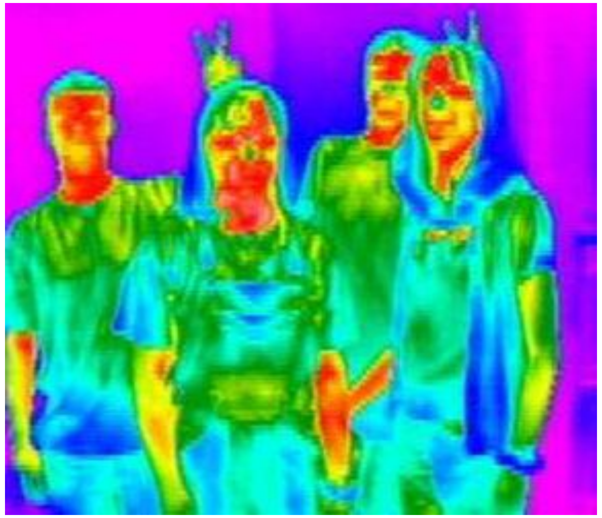
Cygnus loop in the X-ray band

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.)

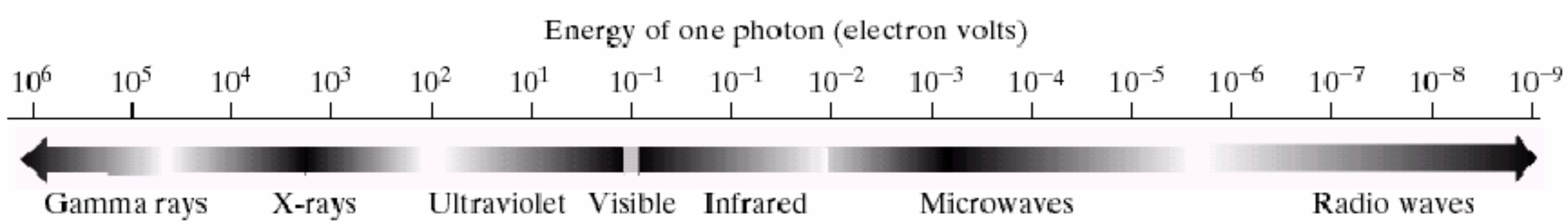
# Beyond Visible (I): Thermal Images

Operate in infrared frequency

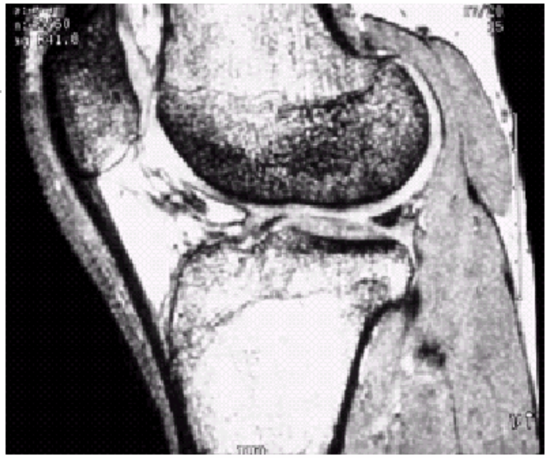


Human body disperses heat (red pixels)

Autoliv's night vision system on the BMW 7 series

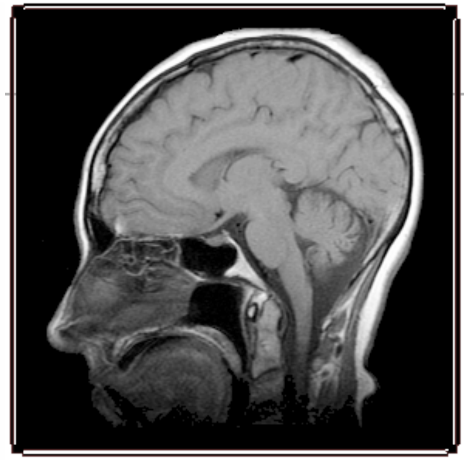


# Beyond Visible (II): MRI and Astronomy



knee

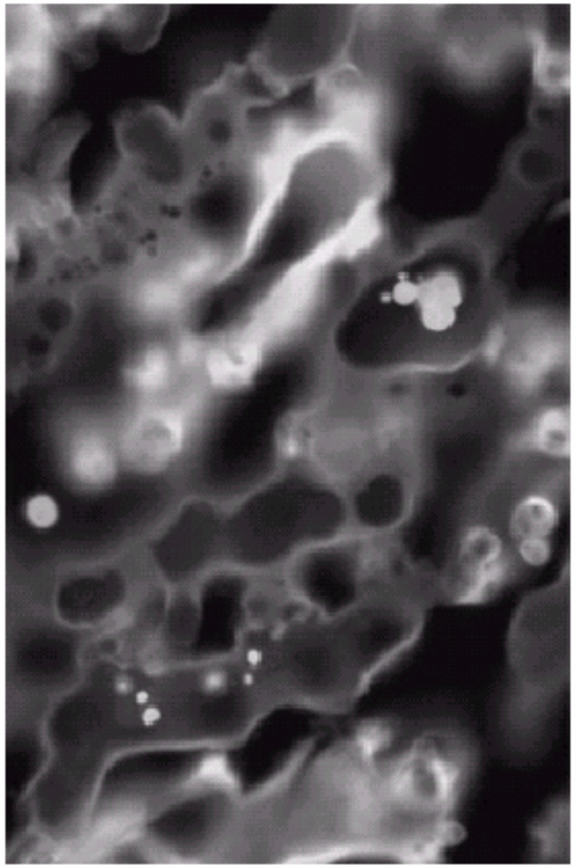
spine



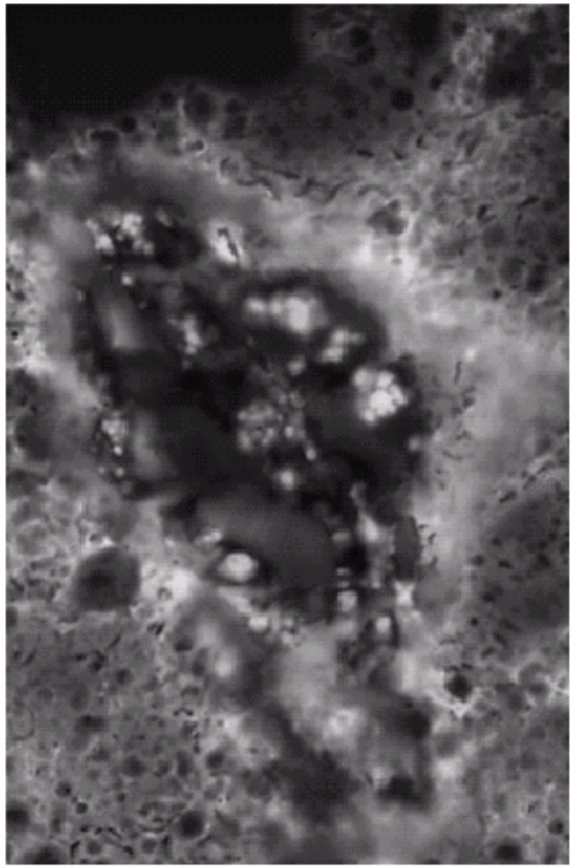
head

# Beyond Visible (III): Fluorescence Microscopy

Operate in ultraviolet frequency



normal corn

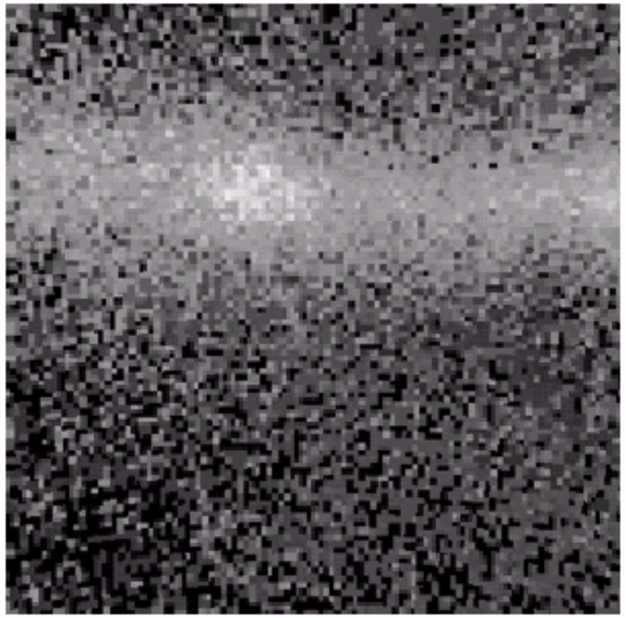


smut corn

# Beyond Visible (V): PET and Astronomy

Operate in Gamma-ray frequency

Positron Emission Tomography



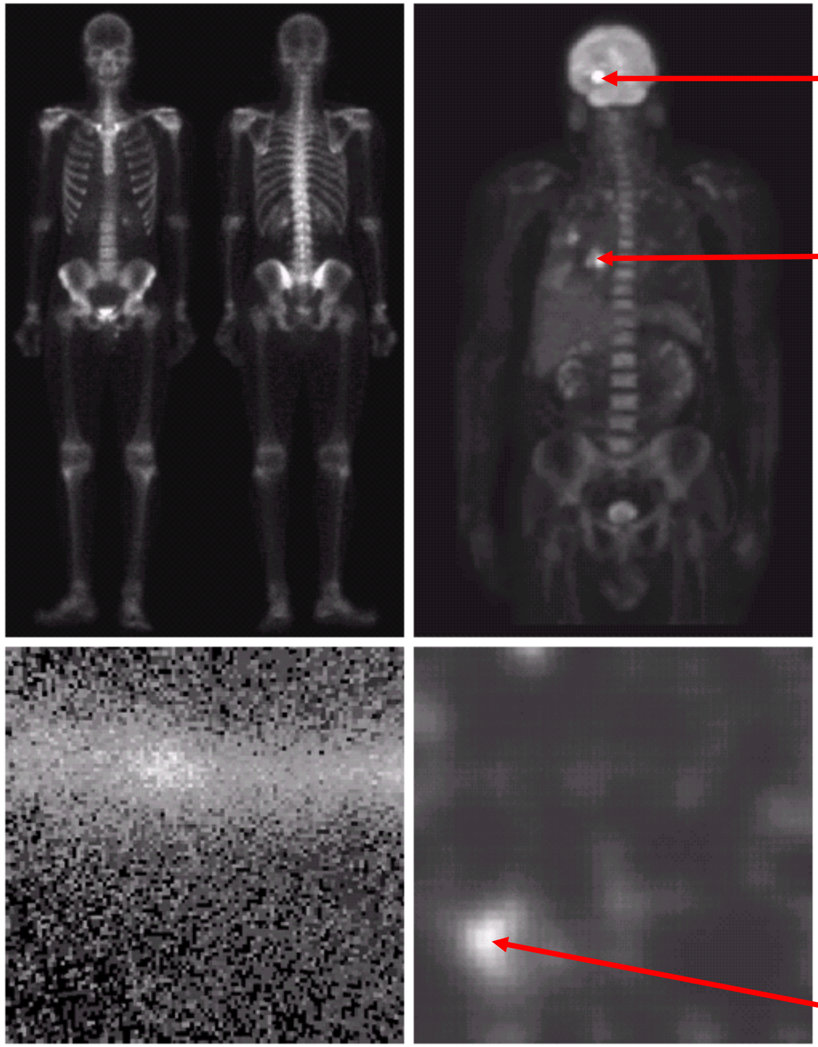
Cygnus Loop in the constellation of Cygnus

# Examples of Gamma-ray imaging

Bone Scan PET Scan

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.)



notice the tumor in the brain and in the lung

Cygnus loop is a gas cloud generated by a start in the constellation of Cygnus

Gamma radiation from a valve in a nuclear reactor

notice the area of strong radiation

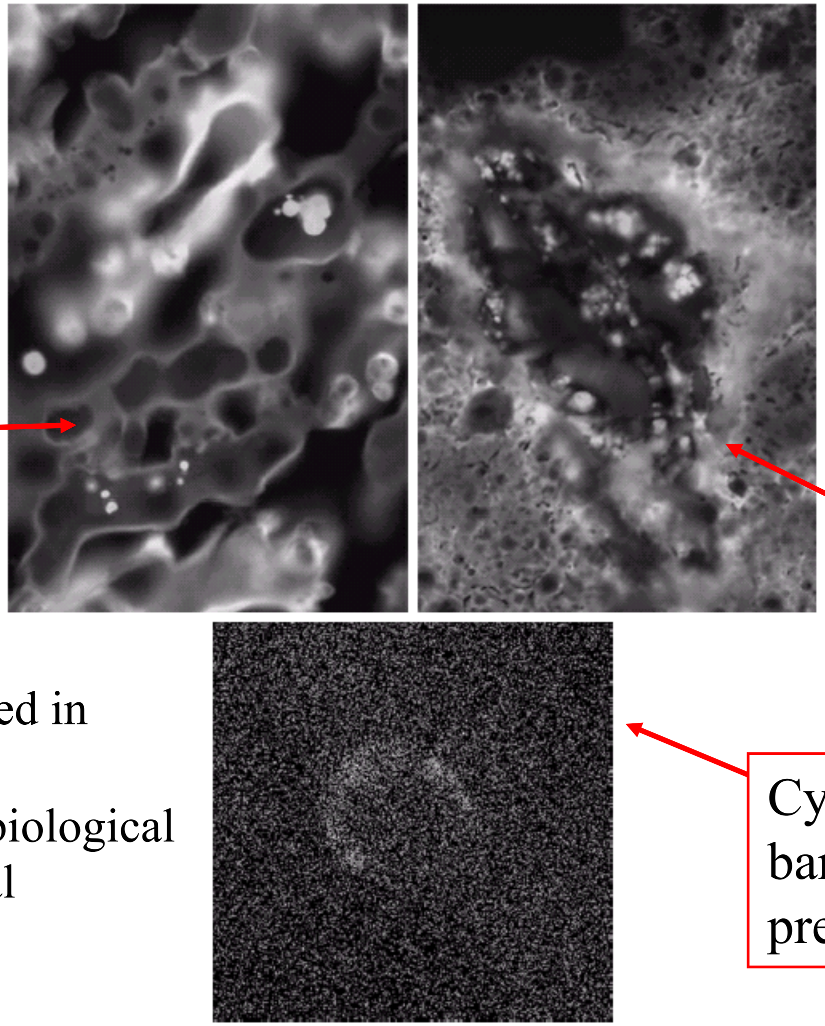
# Chapter 1: Introduction

## Examples of ultraviolet imaging

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.)

Normal corn



UV is used in fluorescence microscopy, a method to study material which can be made to fluoresce.

Infected corn (by smut)

Ultraviolet imaging is used in lithography, industrial inspection, microscopy, biological imaging and astronomical observations

Cygnus loop in the UV band (compare it with previous slide)

As of April 1, 2020, there were a total of **2,666 satellites** in Space, of which 1,918 were in low Earth orbit (LEO) (300 – 2000 km).

**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 |

NASA's Landsat satellite captures and transmits images of Earth from space for the purpose of monitoring environmental conditions on the planet. It uses both visible and infrared regions of the spectrum. (Landsat 3 is at an altitude of 920km).

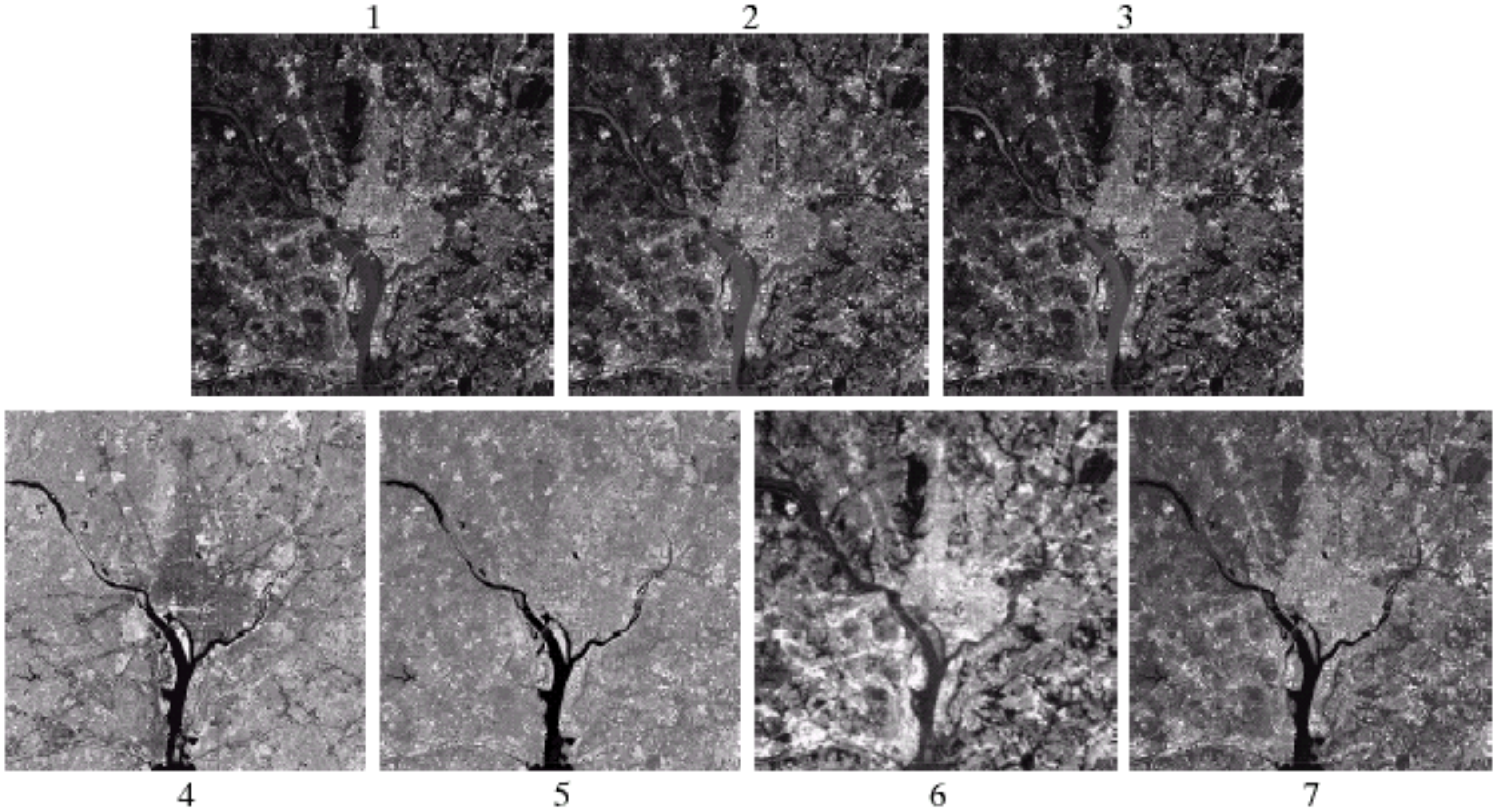



**FIGURE 1.10** LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

# Chapter 1: Introduction

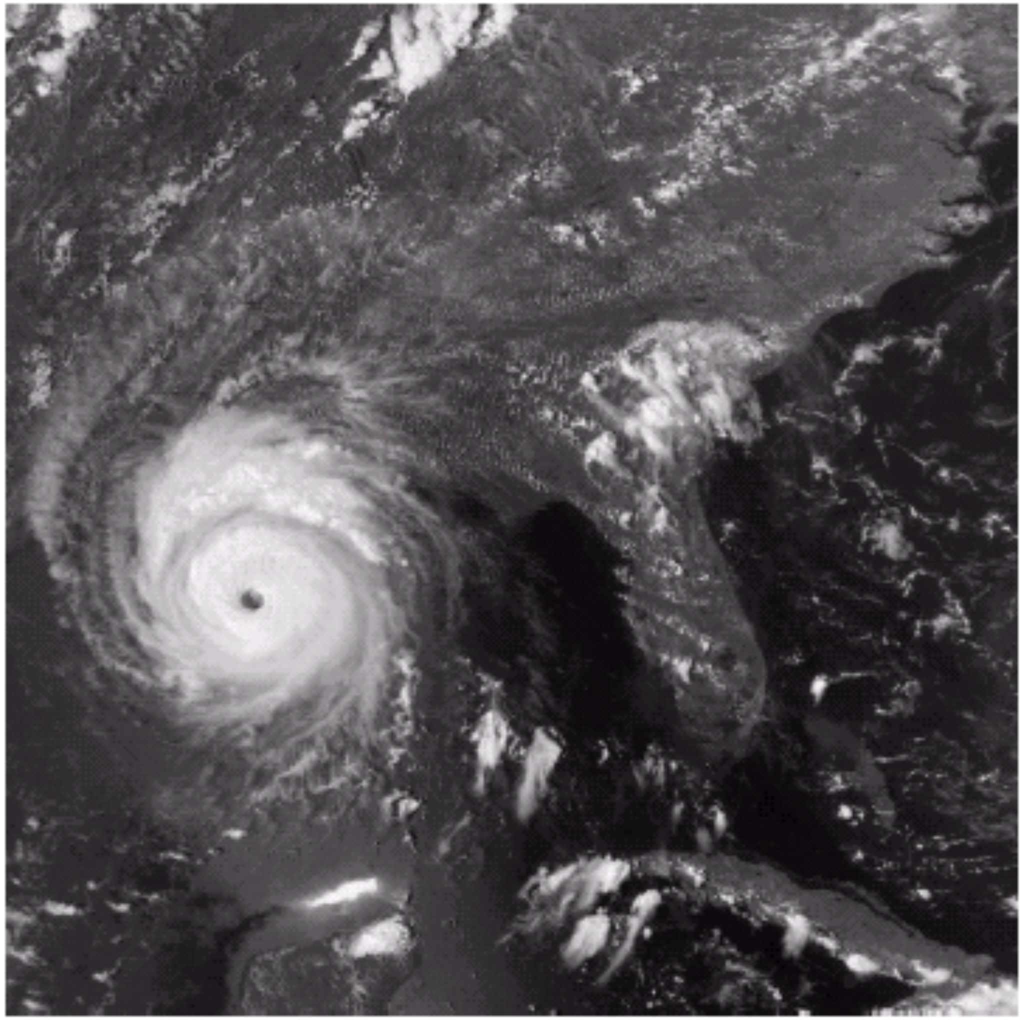
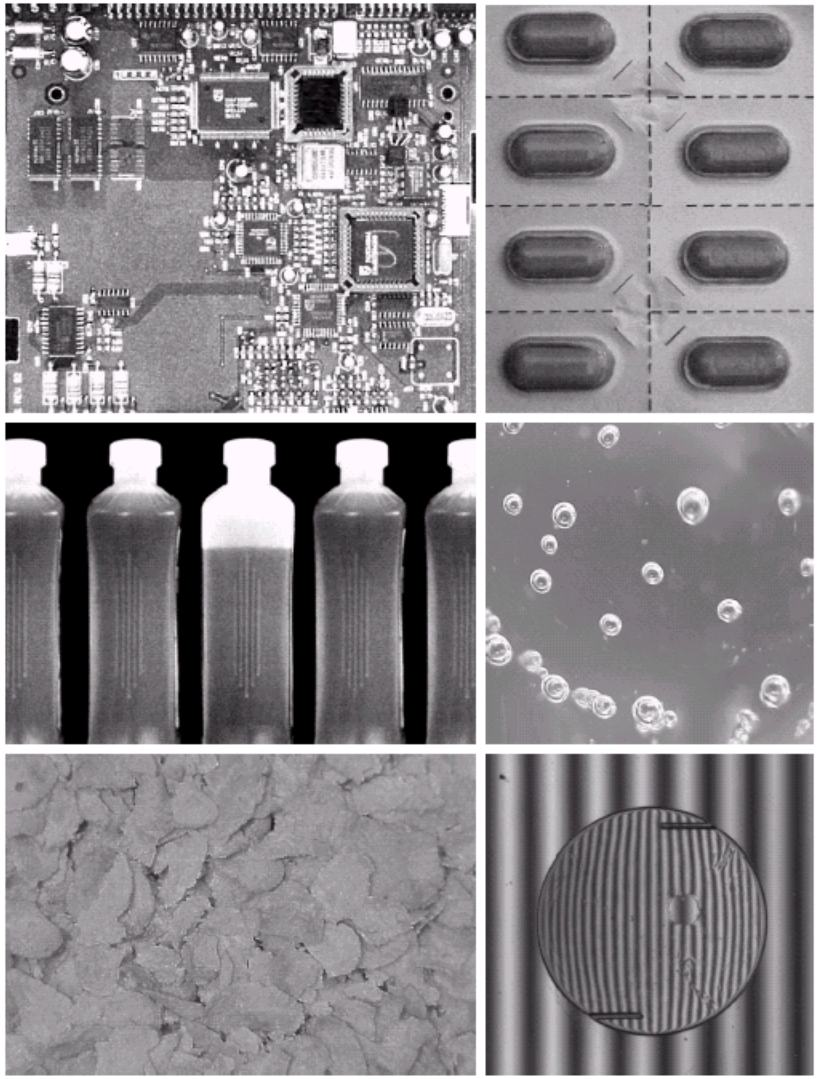


**FIGURE 1.11**
Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

More hurricane pictures from Plymouth State University Weather Center

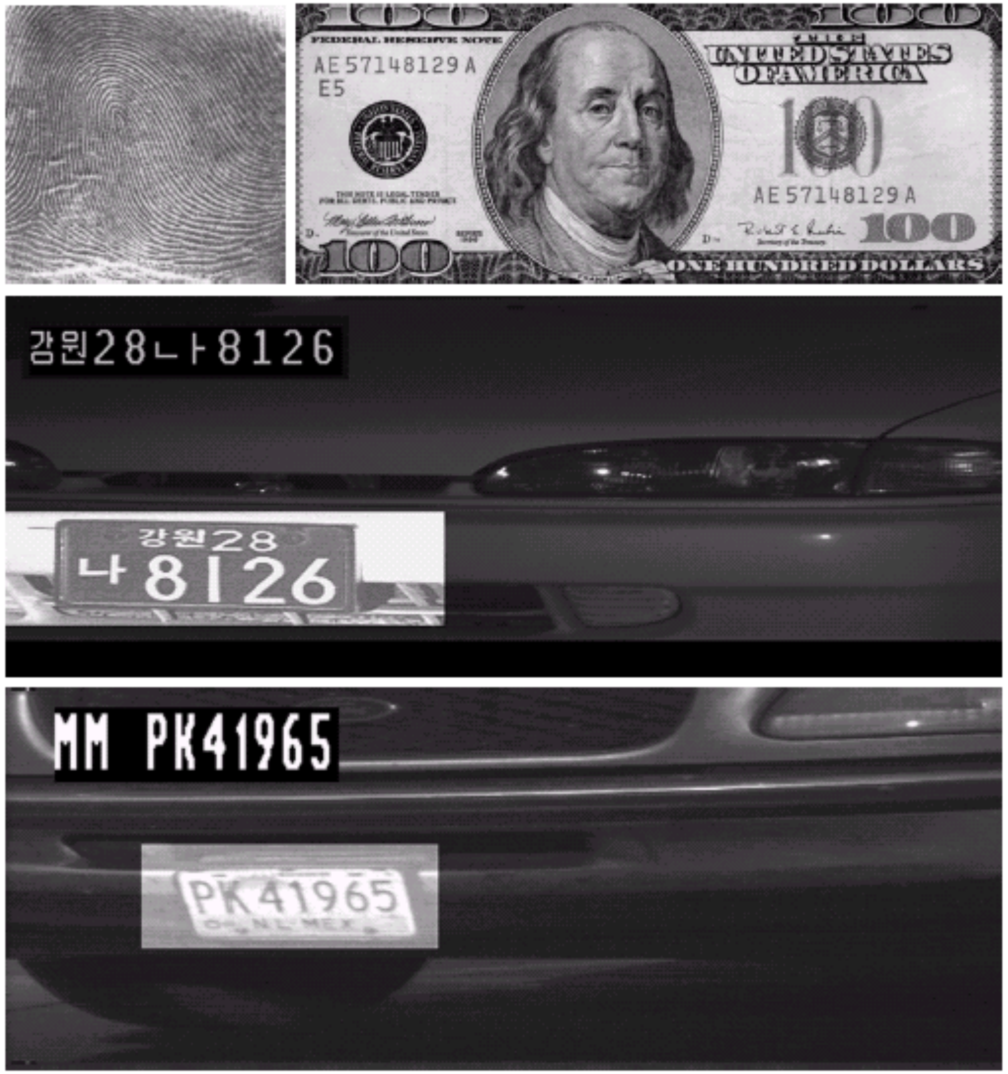
# Chapter 1: Introduction
## Industrial imaging



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
## Imaging applications

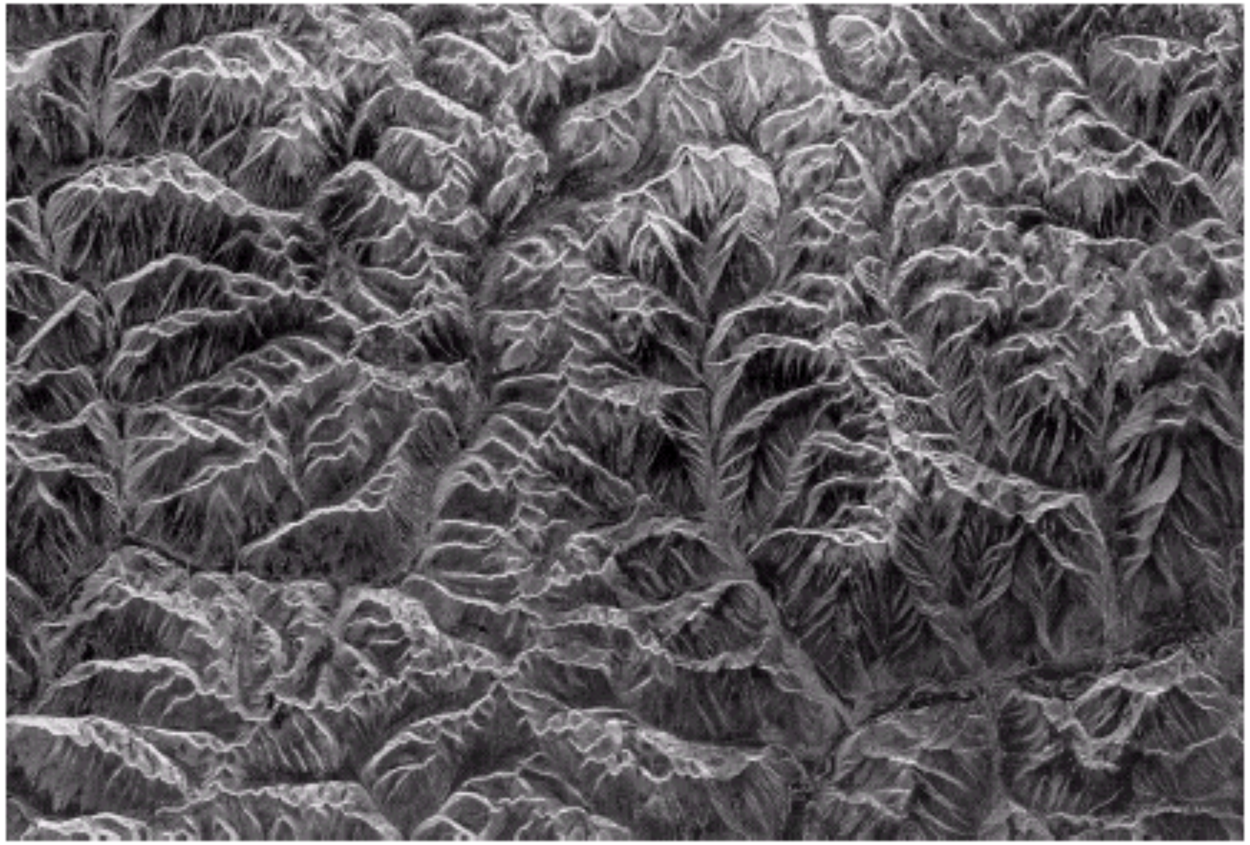



a b
c
d

**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.)

## Radar imaging

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



# Chapter 1: Introduction
## Space and deep underground imaging

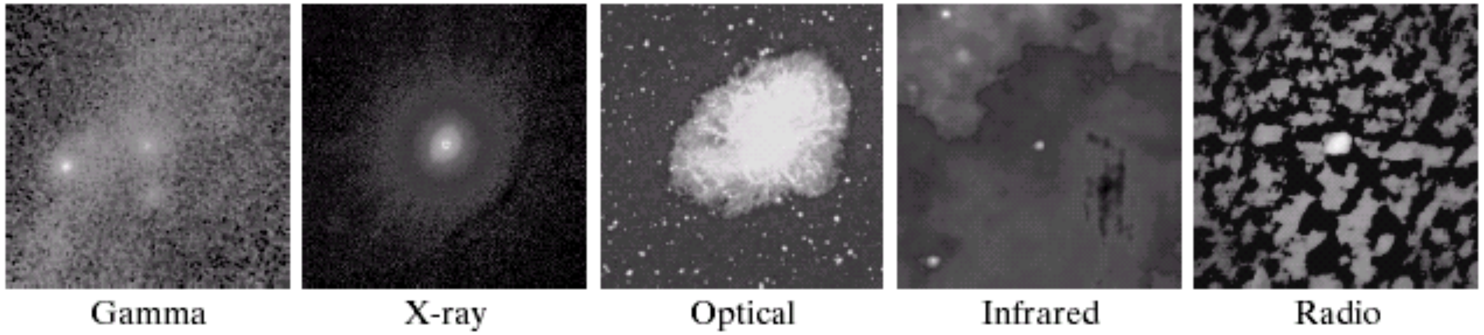
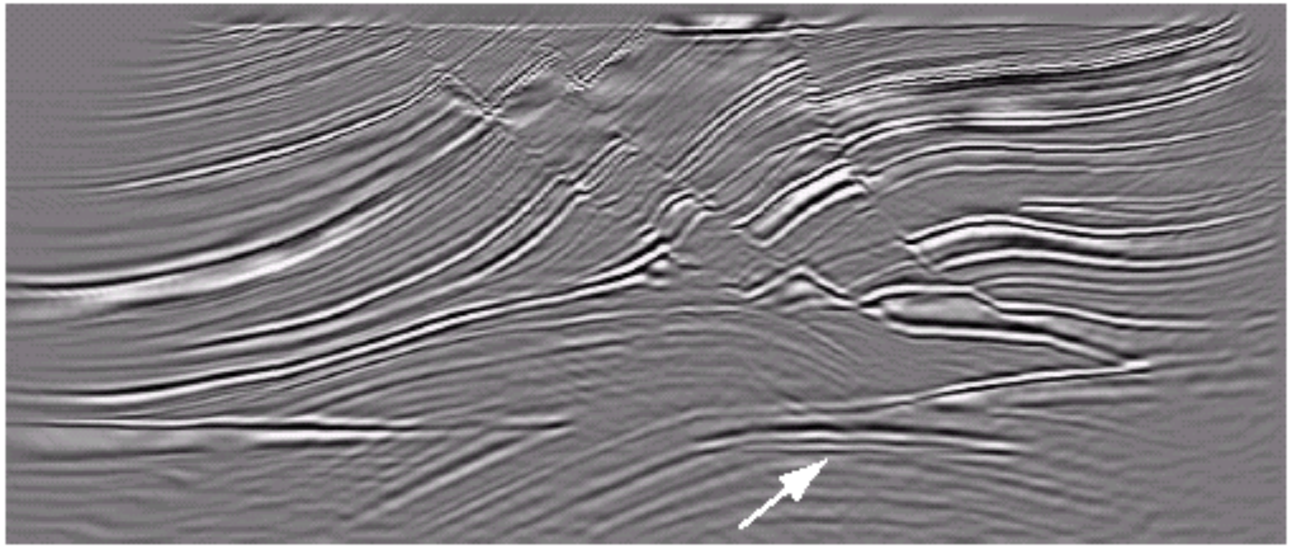


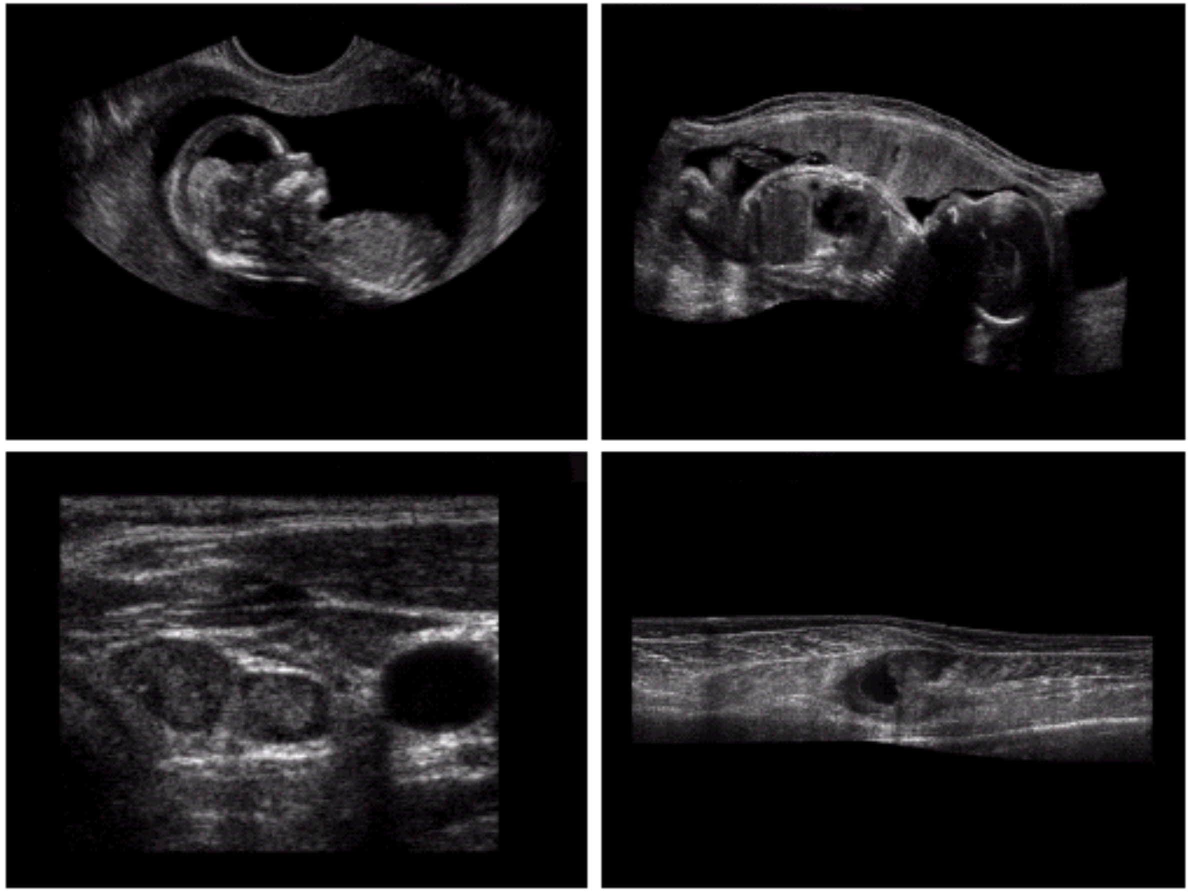

**FIGURE 1.18** Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

**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.)



Ultrasound imaging

# Chapter 1: Introduction
## Ultrasound (echo) imaging



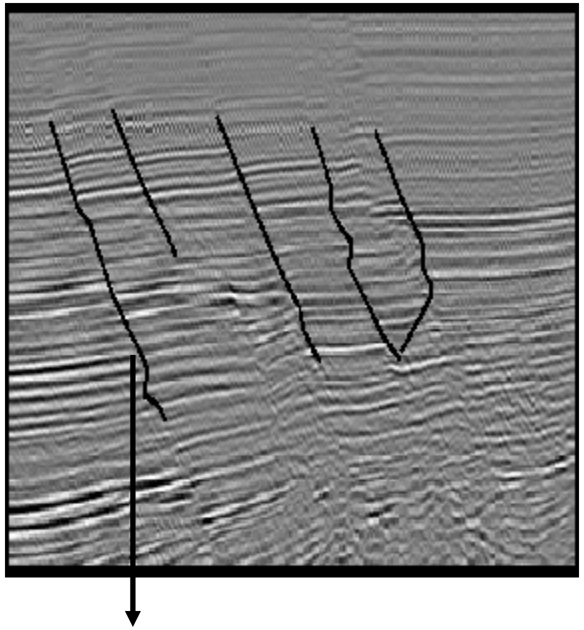
| a | b |
|---|---|
| c | d |

**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.)

# Acoustic Imaging

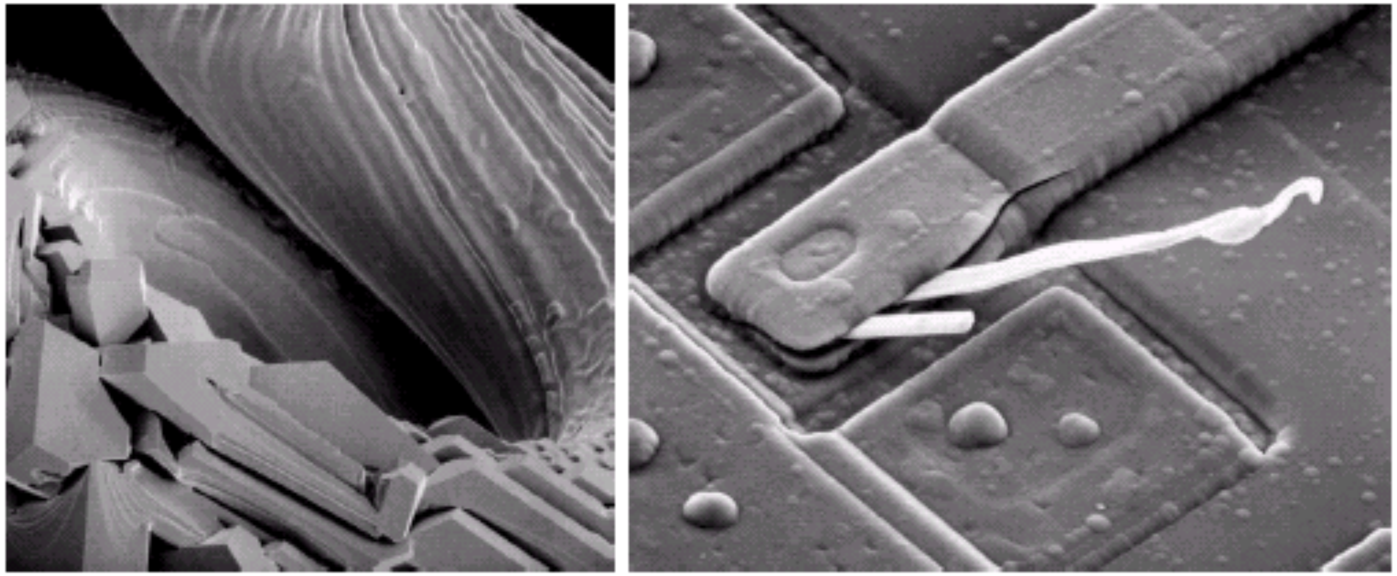
visible

seismic



potential locations of oil/gas

## Examples of Scanning Electron Microscope (SEM) images

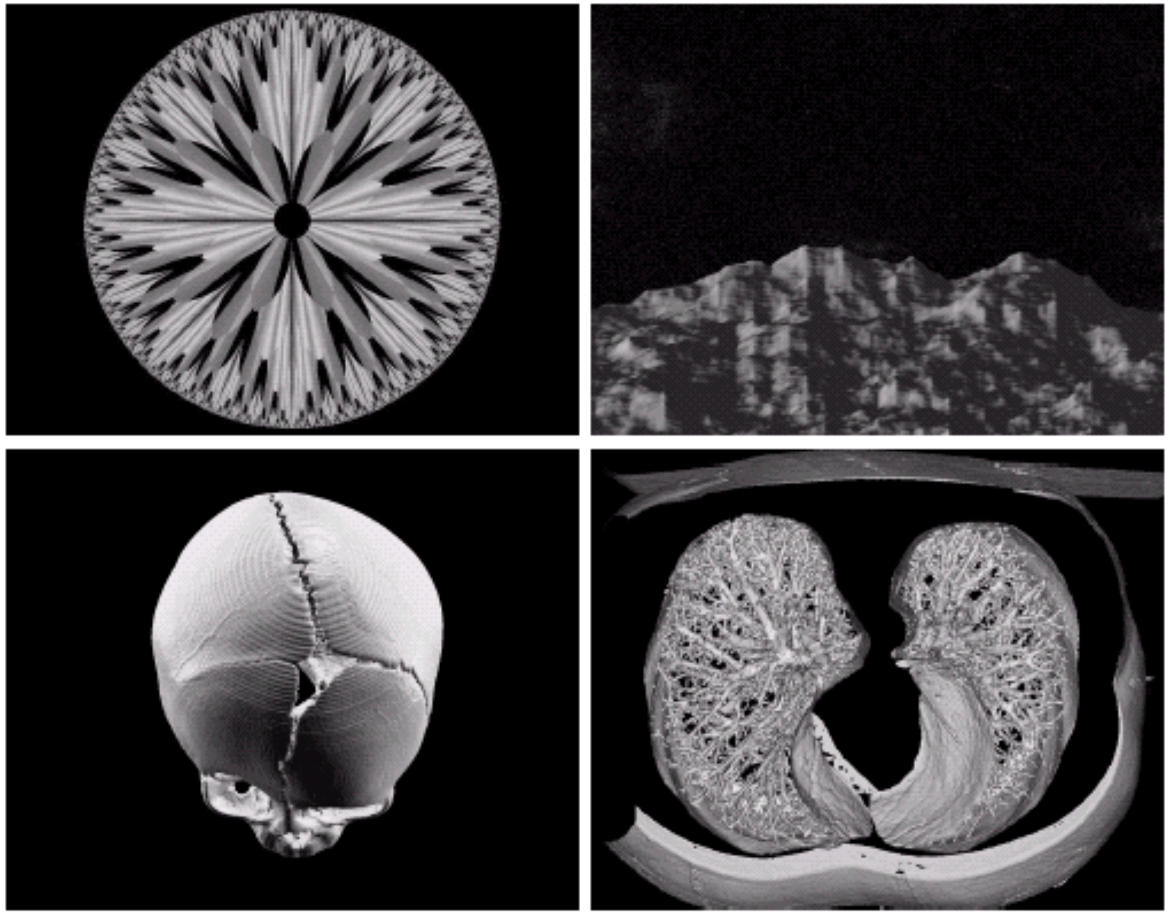


a b

**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.)

# Chapter 1: Introduction

## Computer generated images



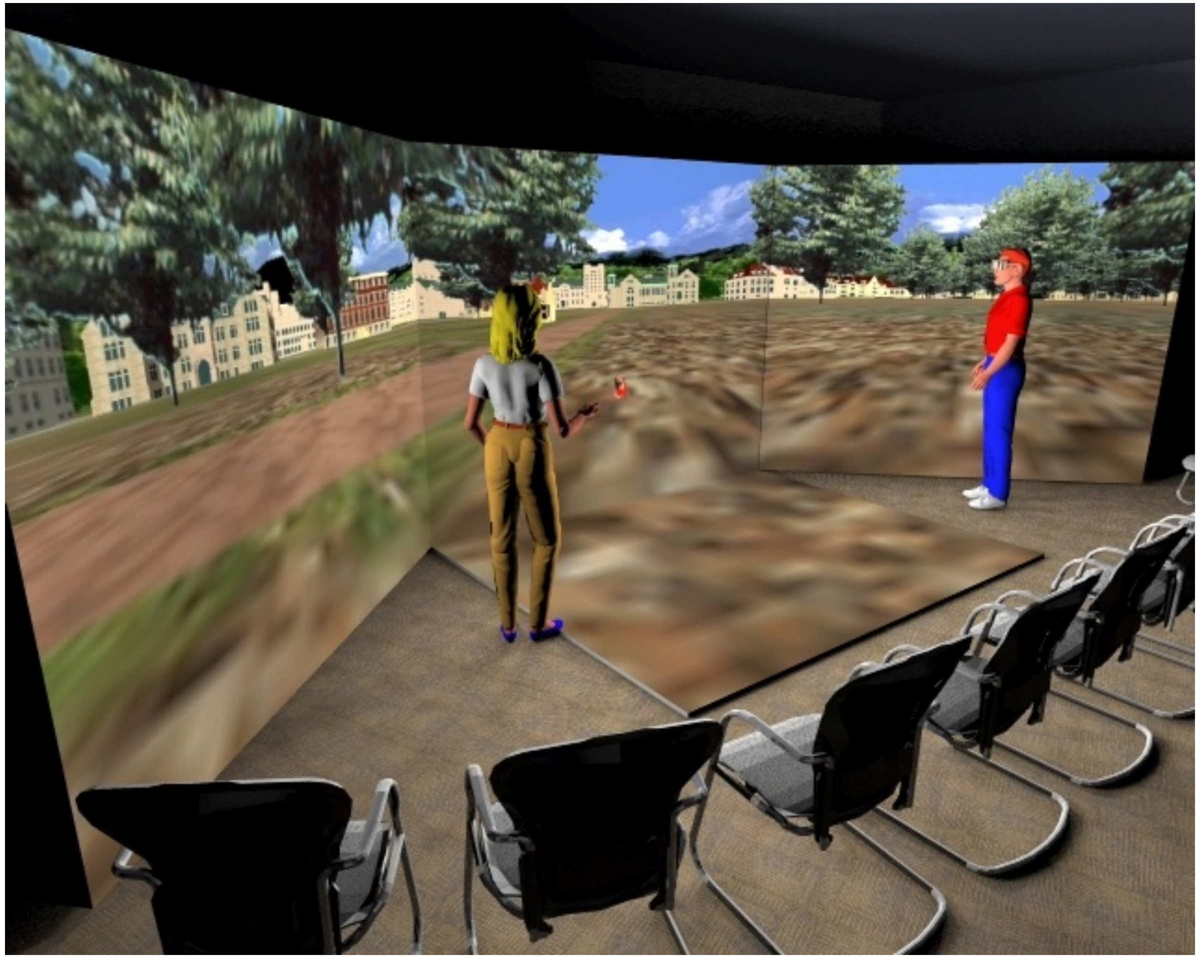
a b
c d

**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.)

# Synthetic Images in Gaming


*Warcraft III* by Blizzard

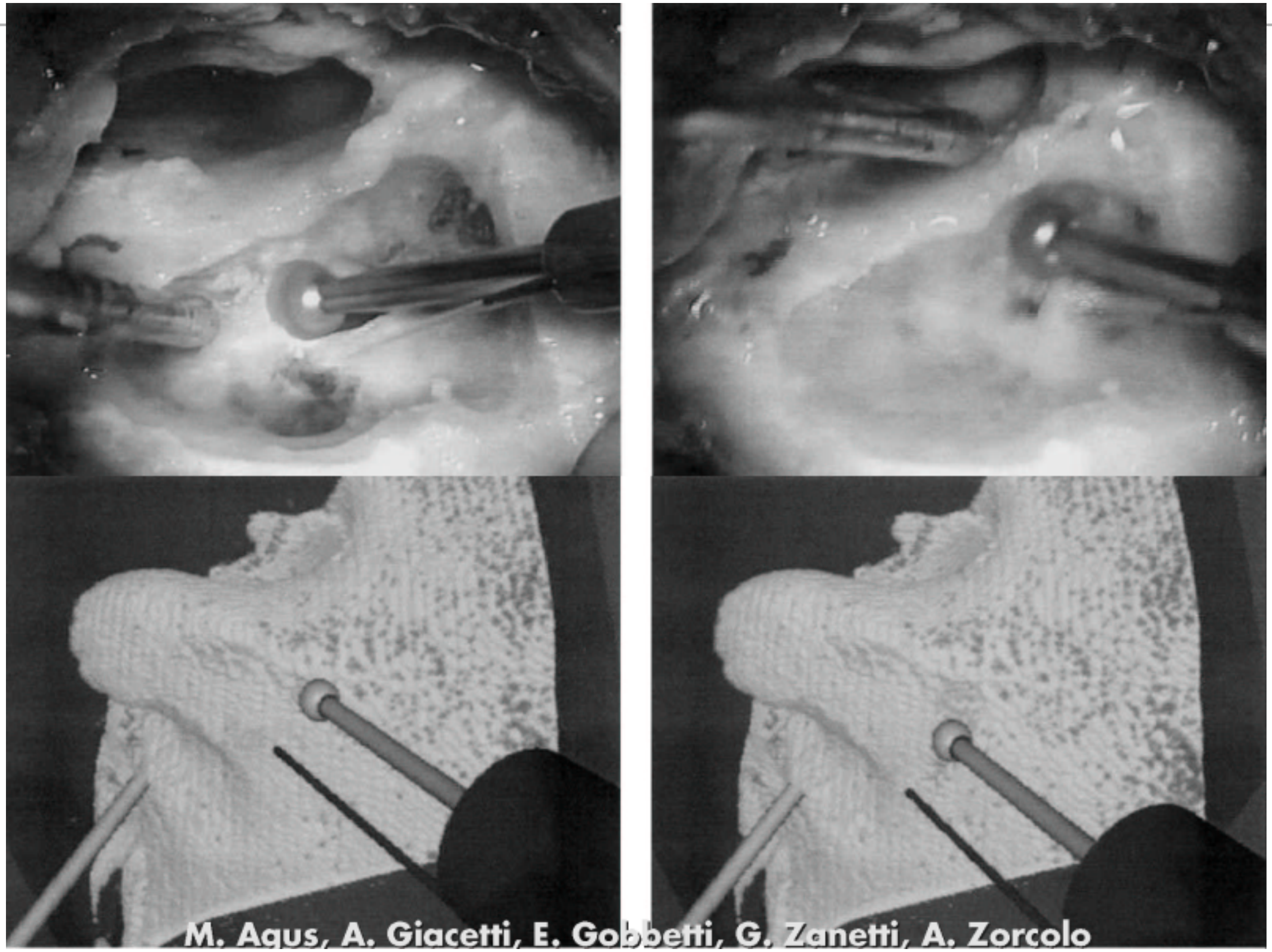
# Virtual Reality (Photorealistic)



# Graphics in Art

Discovered by Denis Zorin

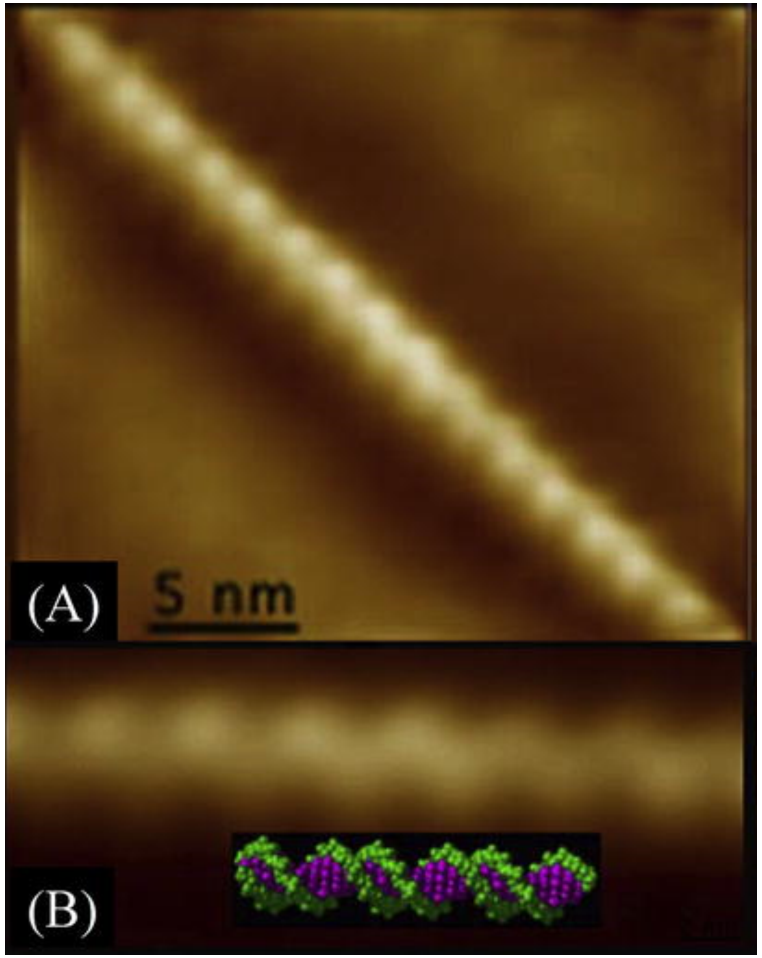
# Graphics in Medicine



# Mixture of Graphics and Photos

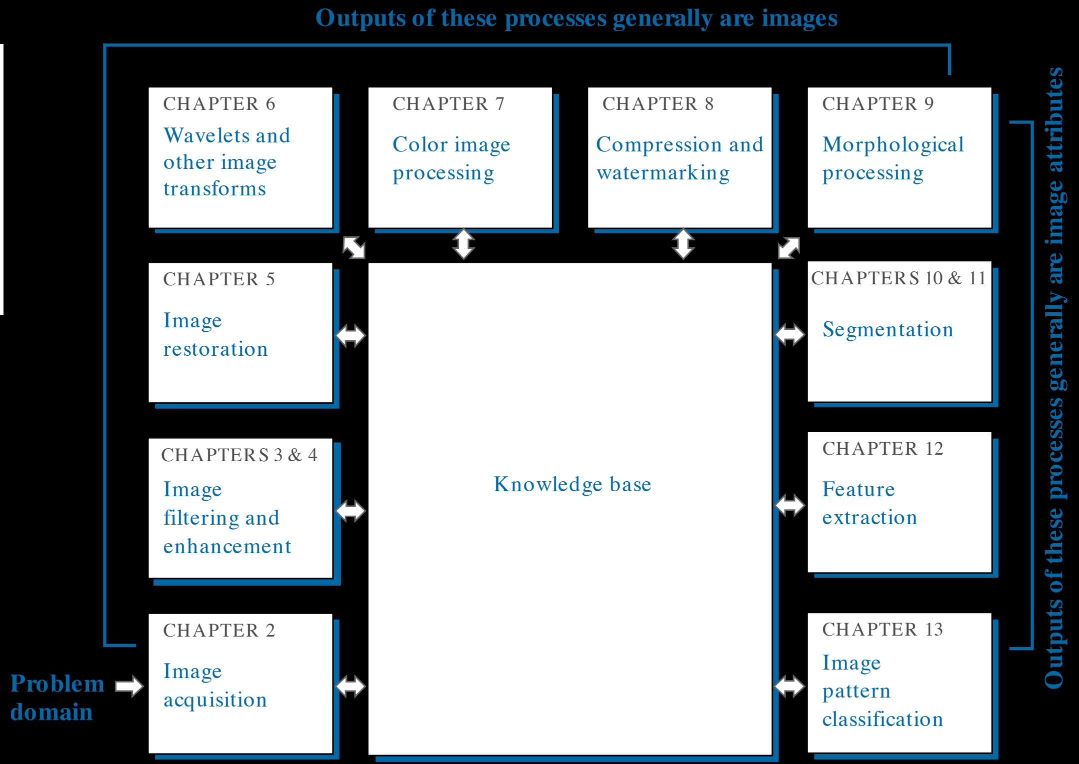

Morgantown, WV in Google Map

# Toward the Future: Nano-scale Imaging




New imaging technology that can reveal fine structures at the nano-scale is going to be useful in biology (e.g., protein sequencing and folding)

**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.



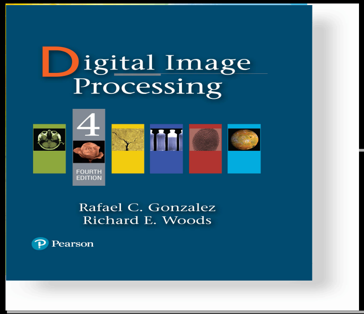
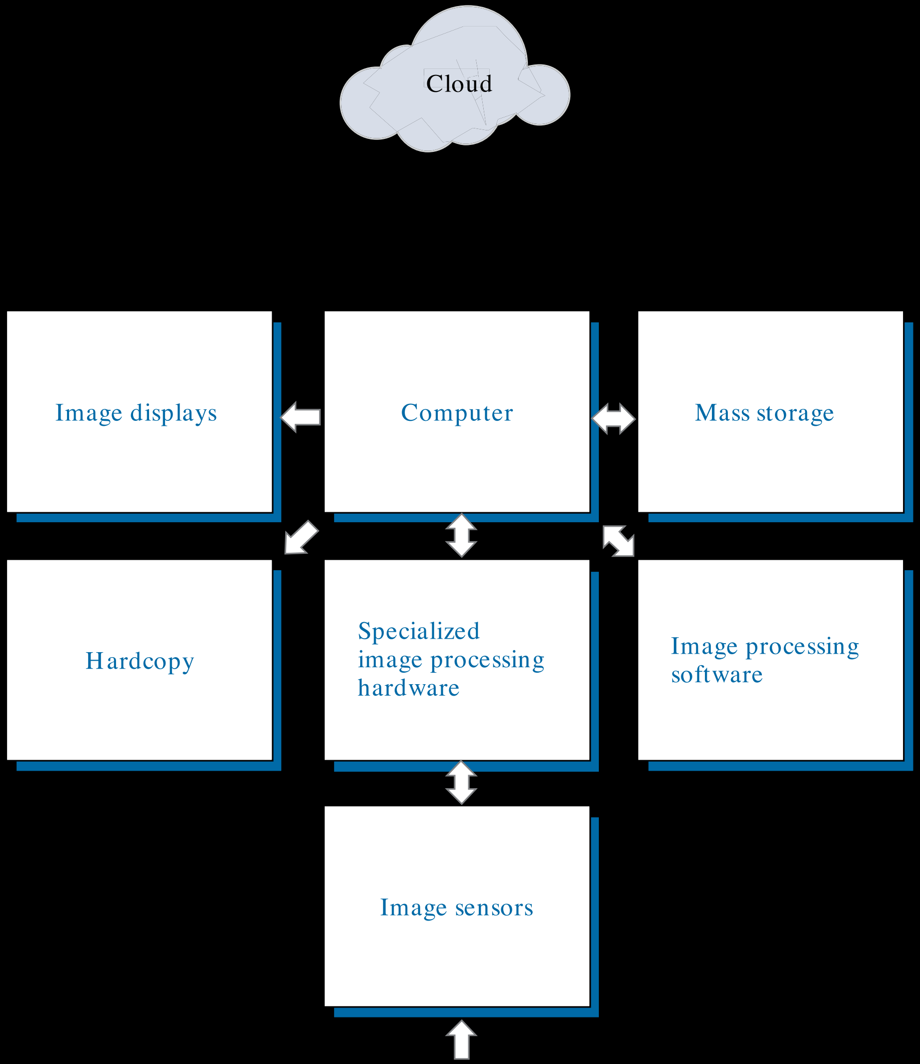



**FIGURE 1.24** Components of a general-purpose image processing system.



# Types of Image Degradations (1/2)

lack of contrast

image enhancement

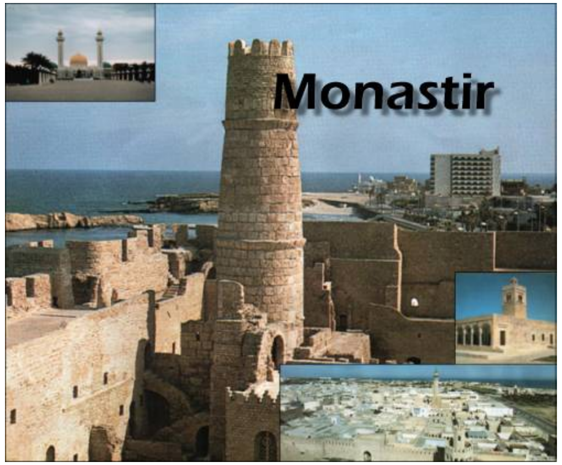
motion blur


image restoration

# Types of Image Degradations (2/2)

BLURRING

image restoration





NOISE


image restoration

# Images as functions