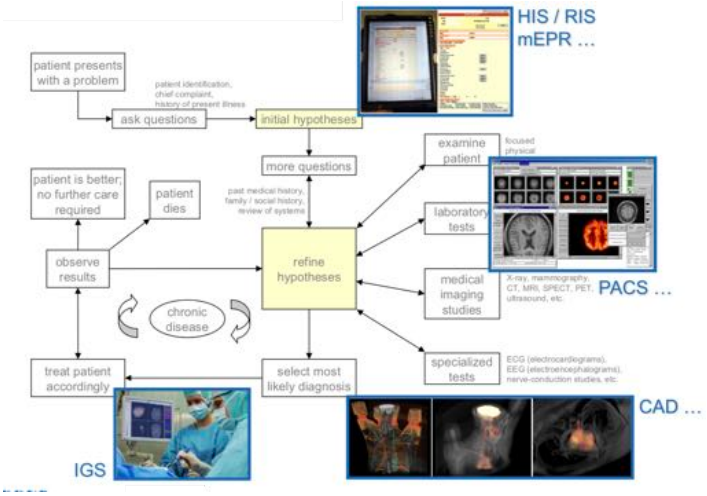
COMP5424 – Semester 1

L0: The Computer Meets Medicine and Biology: Emergence of a Discipline – ITB



Background - The Hypothetico-Deductive Approach

- **The Hypothetico-Deductive Approach is an iterative process for medical data collection and interpretation**
  - Data collection adds to growing database of observations to help refine or reform active hypotheses until one hypothesis reaches a threshold level of certainty for a therapeutic decision to be made
- **The hypothetical-directed** process of data collection, diagnosis, and treatment is **inherently knowledge based** and requires individual expertise.
- Important to **balance financial costs and health risks of data collection** against **the perceived health benefits** from the gained data (e.*g. minimal costs through asking questions but X-rays or coronary angiography may have risks*) → this assessment of cost-benefit trade-offs differs between physicians

THE NATURE OF MEDICAL DATA

- The nature of medical data is primarily gathering data and interpreting their meaning and this is central to the healthcare process.
  - This helps categorizing the problems a patient has and help inform physician the best treatment approach or appropriate diagnosis

Medical Data Type	
1. **Narrative or textual data**	Use focused questions to gather patient's description of medical problem and is recorded the data as text in the medical record
2. **Numerical measurements**	Laboratory tests (e.g. blood glucose levels, temperature) during physical exam
3. Recorded signals	analog data in the form of continuous signals are particularly important. (.e.g. EEG, ECG)
4. Drawings	Sketches of physician
5. Visual images/Photographs	Machine produced images (CT, MRI, X-rays) → for comparison

USE OF MEDICAL DATA

Medical data is used to **support patient health care** and **contribute to the benefit of society**:

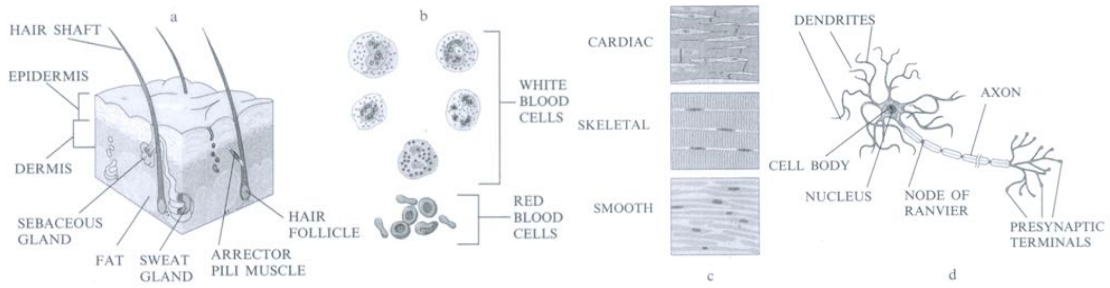
- Create the basis for the medical historical record
- Support communication among providers
- Anticipate future health problems
- Record standard preventive measures
- Identify deviations from expected trends
- Provide a legal record
- Support clinical research

L1: Medical data sampling and acquisition

Introduction to basic anatomy and physiology

- **Anatomy** refers to the internal and external structures of the body and their physical relationships,
- **Physiology** refers to the study of the functions of those structures.

4 primary types of tissue in the human body: epithelial, connective, muscle, and nervous.



A combination of tissues forms an organ. The human body has **11 major organ systems**:

- Integumentary (protection → skin)
- Endocrine (hormones)
- Lymphatic (lymph nodes)
- digestive,
- urinary
- reproductive,
- circulatory,
- respiratory,
- nervous,
- skeletal,
- muscular.

The nature of medical images

Pathological Processes

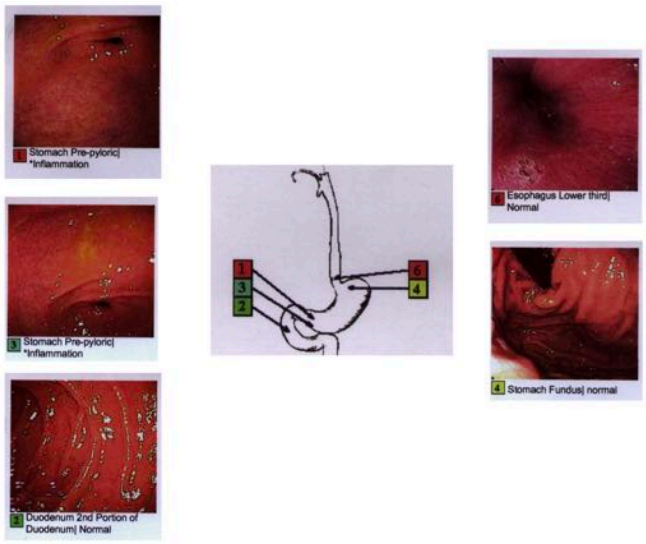
- Diseases or defects in normal physiological system can cause **pathological processes** that disrupt performance, and health of the system.
- We need to **possess a good understanding of the system of interest to observe the corresponding signals and features, and assess the state of the system**.
    - Understanding pathological processes is **easy IF the** signal is simple and appears on the outer surface of the body → but most systems and organs are enclosed internally
- Need non-invasive method to probe and investigate these hidden systems

METHODS FOR NON-INVASIVE INVESTIGATIVE PROCEDURE

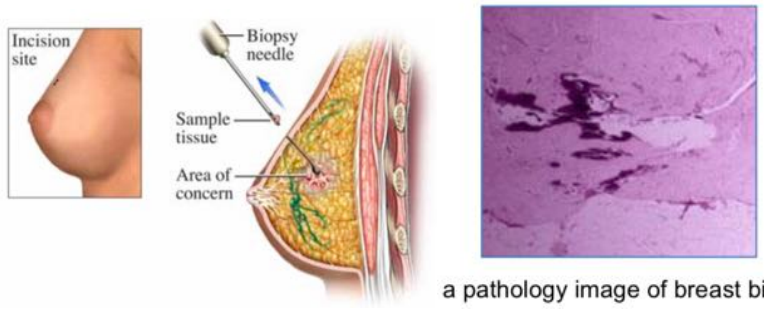
1. Focused Physical Examination	Investigating the patient body (main organ systems) for signs of disease by inspection, palpation, percussion and auscultation,
2. Medical Thermology Imaging	A 2D representation of the heat radiated from the human body can be obtained by taking a picture of the body using a thermal camera
3. Medical Transillumination Imaging	Providing the shining of visible light or near-infrared radiation through a part of the body, and viewing or imaging the transmitted radiation

METHODS FOR INVASIVE INVESTIGATIVE PROCEDURE

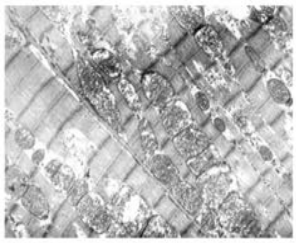
1) Medical Endoscopy Imaging



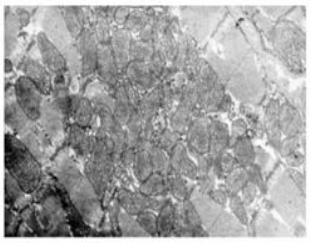
2) Biopsy →Medical Light and Electron microscopy



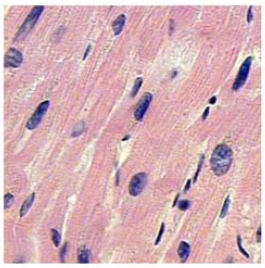
a pathology image of breast biopsy



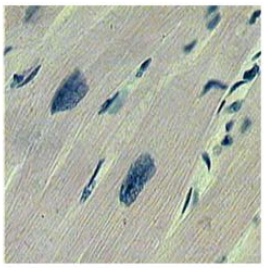
Normal (x 15,000)
Electron micrograph of longitudinal section of normal cardiac muscle. Note the rows of mitochondria along myofibrils.



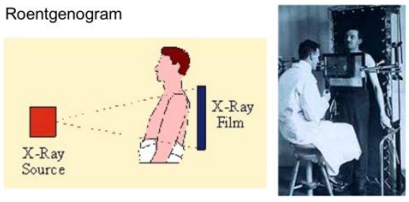
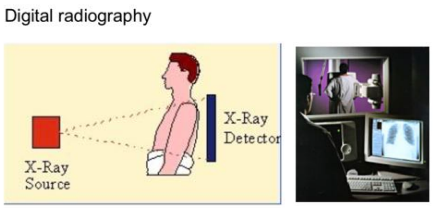
Hypertrophic (x 15,000)
Electron micrograph of longitudinal section of hypertrophic cardiac muscle. Note the increased number of mitochondria.



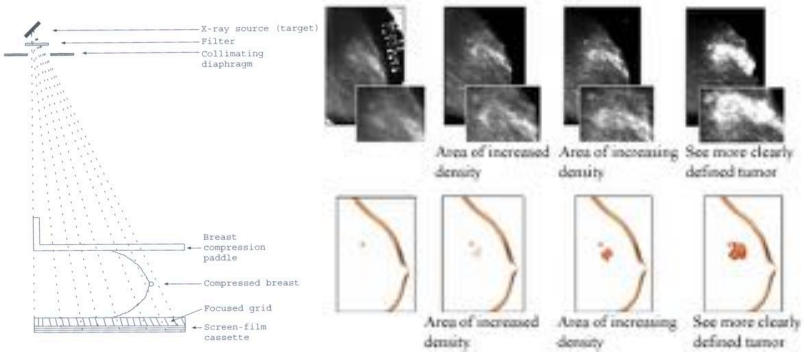
Normal (x 400)
Longitudinal section of the cardiac muscle showing branching muscle fibers and centrally placed nuclei. Hematoxylin and eosin staining.



Hypertrophic* (x 400)
Longitudinal section of the cardiac muscle showing enlarged cardiac fibers with large nuclei. Hematoxylin and eosin staining.

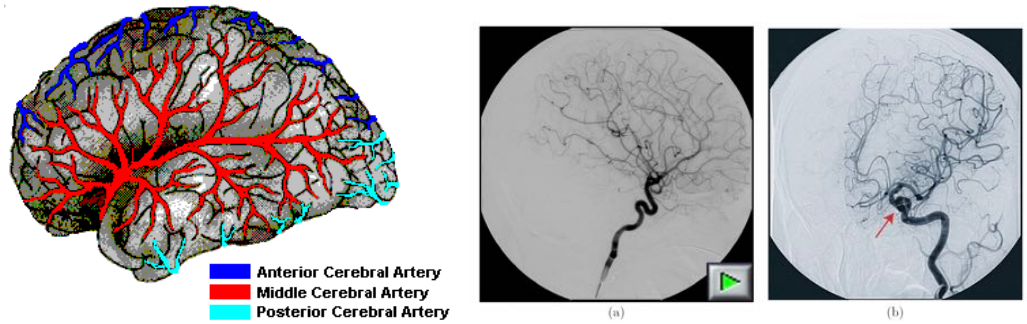
	Conventional X-ray Imaging	**Digital X-ray Imaging**
		
Differences	• Rays photons are produced when electrons of high energy strike a heavy metal target (e.g. Tungsten) • **X-Ray absorption is proportional to *tissue density***	• X-Rays photons excite a phosphor screen • CCDs (Charge-Coupled Device), TFTs convert light from phosphor to digital signal • Filmless radiology (no print out) • Images can be digitally stored, transmitted and manipulated
Contrast and resolution	**Needs contrast media can be used to outline structures (e.g. vessels, lumina)**	(2K x 2K x 16 bits grey scale)
Advantages	X-ray imaging is **simple** and low-cost	
Disadvantages	Image is 2D with organ image being superpositioned and difficult to distinguish	

Digital Mammography: X-ray Imaging of the Breast



Digital Angiography: X-ray Imaging of the Blood Vessels

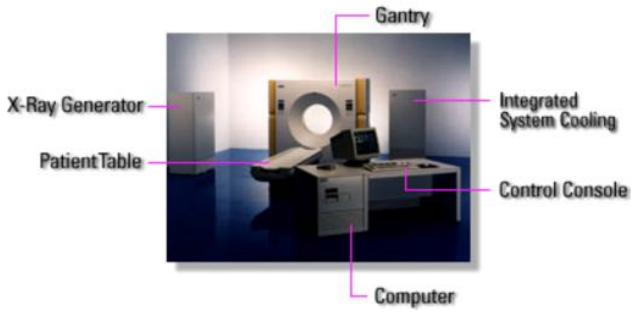
As blood has the same radio-density as the surrounding tissues, a **radio-contrast agent** (which absorbs X-rays) is added to the blood to make angiography visualization possible.

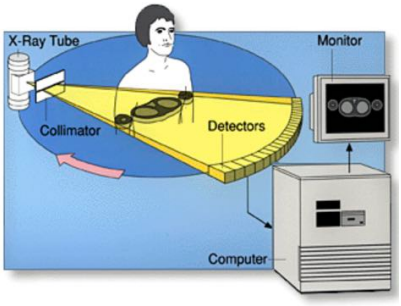


*(a) Cerebral angiogram obtained by injecting a **iodine containing fluid into the arteries**. The contrast dye subsequently fills the cerebral arteries, capillaries and veins.*

(b) Cerebral angiogram showing an aneurysm or saccular dilation of a cerebral artery.

X-ray Computer Tomography (X-ray CT)

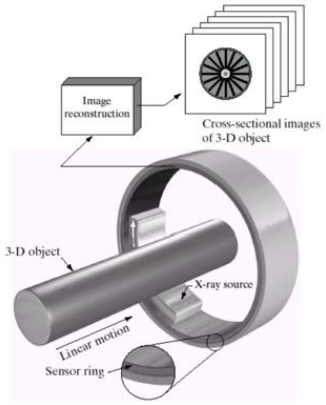




- X-ray CT is a product of X-ray technology with advanced digital image processing
- It can generate a cross-sectional ("slice") display of the body

How does it work?

- A **rotating X-ray source** illuminates X-ray energy that pass through object and is collected by a portion of sensors opposite
    - Basis of **computerized axial tomography (CAT).**
- The output of the sensors must be processed by ***image reconstruction algorithms*** which transform sensed data into meaningful cross-sectional images *(i.e. images are not obtained directly from the sensors but require extensive processing)*
- A 3D digital volume generated by compiling stacked images → since imaging of object is taken perpendicular to the sensor ring.



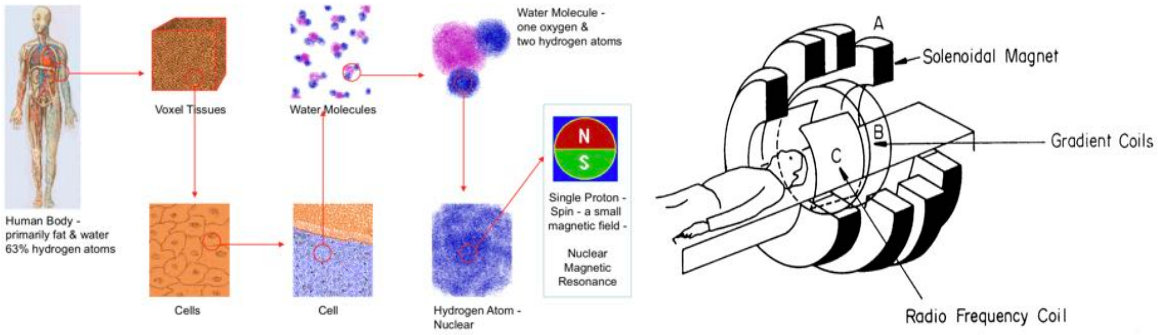
A 3D digital volume consisting of stacked images can be generated by X-ray CT

Sample Image --- CT Scan of Chest

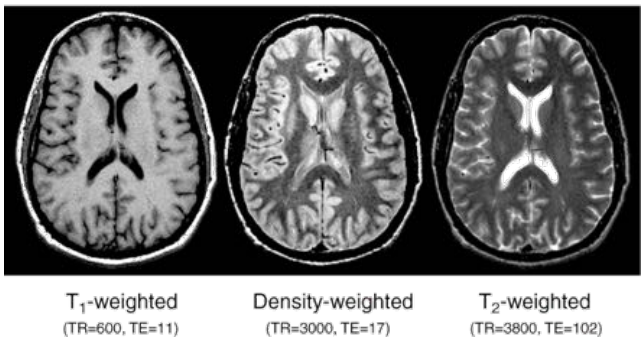
Hounsfield Attenuation Scale (2000 units wide)

- Water has a value of 0 Hounsfield Units (HU)
- Air has a value of -1000 HU
- Fat is approximately -100 HU
- Soft tissues are in the range +20 to +70 HU
- Bone is greater than +400 HU

Magnetic Resonance Imaging (MRI)



Function	• Determine spatial information from the returned RF signals through filtered back- projection reconstruction or Fourier analysis and display it in a 2D section or a 3D volume of the objects. • MRI modality forms images of objects by measuring the magnetic moments of protons using radio frequency (RF) and a strong magnetic field.
How It Works?	• MRI uses a powerful magnetic field to align the magnetization of hydrogen nuclei in the body (e.g. water) • A radio wave at just the right frequency causes the protons to absorb energy and be pushed out of alignment • When these protons snap back to alignment, they produce a detectable rotating magnetic field • Since protons in different areas of the body (eg, fat v. muscle) realign at different speeds, the different structures of the body can be revealed. • MRI scanning mechanism is completely electronic → **no moving parts required to perform scan**.
Advantages	• Non-invasive • No ionizing radiation (e.g. X-rays) • Flexible technique enabling contrast between one tissue to another (fine details) • Apply additional magnetic fields to create different images
Disadvantages	• Expensive • Time-consuming



- *First image where CSF is black / last image CSF is bright.*
- *Contrast is manipulated during image acquisition by adjusting several parameters, such as the **repetition time TR** and the **echo time TE** (in milliseconds), which control the sensitivity of the signal to the local tissue relaxation times T1 and T2 and the local proton density.*