جمهورية العراق
REPUBLIC OF IRAQ
وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education & Scientific Research

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Thi-Qar University **College of Medicine**

Year One - Lecture No. (1) **Theoretical Medical physics**

Dep. Of physiology and medical physics

(Academic years 2023-2024)

Terminology, Modeling, and Measurement

Purpose of this lecture

- **Understanding some terminology related to medical physics**
- **Get acquainted with different types of mathematical models**
- **Learn the basic principles for diagnostic of a patient**
- **Describe the types of measurement in our body**

Introduction to Medical Physics **Medical Physics : is the application of our concept of physics in medicine**

Aims of the Medical physics:

Application of the concepts and methods of physics to understanding the function of human body in health and disease

1 .Physics of the body

is to understanding physical aspect of the body such as ; forces on and in the body , work , energy ,power of the body, heat ,blood flow , respiration , electricity , ,circulation, and hearing.

2.Application of physics in medicine

a. Medical physics Techniques are used for

a. Diagnostic :

Stethoscope

Manometer (blood pressure)

Sphygmomanometer

Electrocardiograph(ECG)

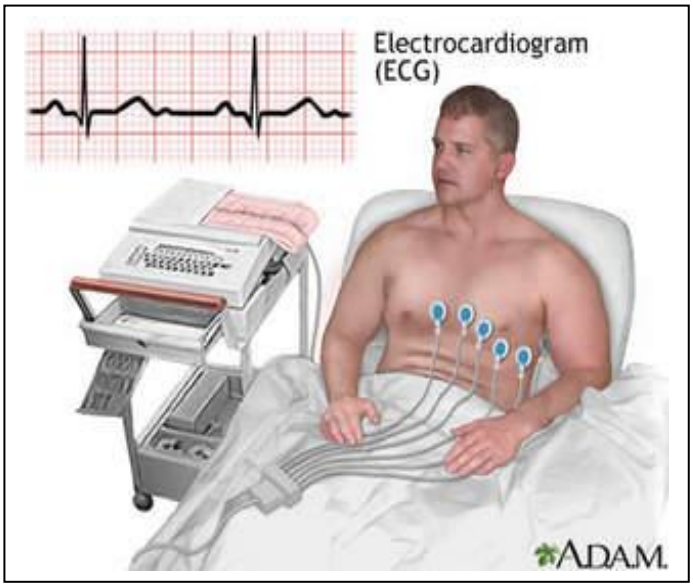
X- Ray,

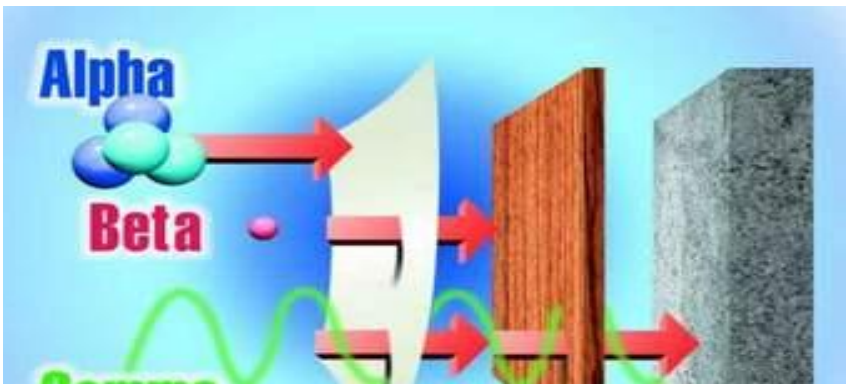
Electroencephalograph(EEG)

Electromyography (EMG)

Computer tomography (CT scan) ,

Ultrasound





b. *Therapy*

Radiotherapy

Ultrasound

infrared

Radio frequency

Heating

Laser

c. *Patient monitoring*

ECG , spirometer , blood pressure ,and thermometer

Terminology:

The field of medical physics overlaps the two very large fields of **medicine** and **physics.**

The term **medical physics** refers to **two** major areas: -

1. The applications of physics to the function of the human body in *health and disease.*
   - ✓ This could be called the physics of physiology.
2. *The applications of physics in the practice of medicine.*
   - ✓ This includes such things as the physics of the stethoscope, the tapping of the chest (**percussion**), and the medical applications of **LASER, ultrasound, radiation,** and so forth.

❖ **Physical medicine:** It's the branch of medicine that deals with diagnosis and treatment of disease and injury by means of physical agents such as **manipulation**, **massage**, **exercise**, **heat**, and **water**.

❖ **Physical therapy:** It's the treatment of disease or bodily weakness by physical means such as **massage** and **gymnastic** rather than by **drugs**.

The field of medical physics has several subdivision:

- ***Radiological physics:*** This involves the applications of physics to radiological problems and includes the use of radiation in the diagnosis and treatment of disease as well as the use of radionuclides in medicine (**nuclear medicine**).
- ***Health physic:*** This involves **radiation protection** of patients, workers, and the general public. Also includes radiation protection outside of the hospital such as around nuclear power plants and in industry.
- ***Medical engineering:*** This field of physics, deals with the electronics of the medical instrumentation.

- ***Bioengineering:*** This word has a much broader meaning. Bioengineering involves the application of any engineering to any biological area.

Medical physics is generally split into two major subgroups, specifically a)**Radiation therapy.**

b)Radiology.

*Medical physics of radiation therapy can involve work such as:

Dosimetry. (Radiation dosimetry in the fields of health physics and radiation protection is the measurement, calculation and assessment of the ionizing radiation dose absorbed by an object, usually the human body

***Medical physics of radiology involves: medical imaging techniques such as**

1-magnetic resonance imaging.

2-ultrasound.

3-computed tomography.

4-positron emission tomography. **5-x-ray**.

In the case of clinical work, the term medical physicists the title of a specific healthcare profession, usually working within a hospital or other clinic. Medical physicists are often found in the following healthcare specialties**:**

#Radiation oncology.

 # Diagnostic and interventional radiology(also known as medical imaging).
#Nuclear medicine.

#Radiation protection.

- ***Modeling:***

Models are of two types:

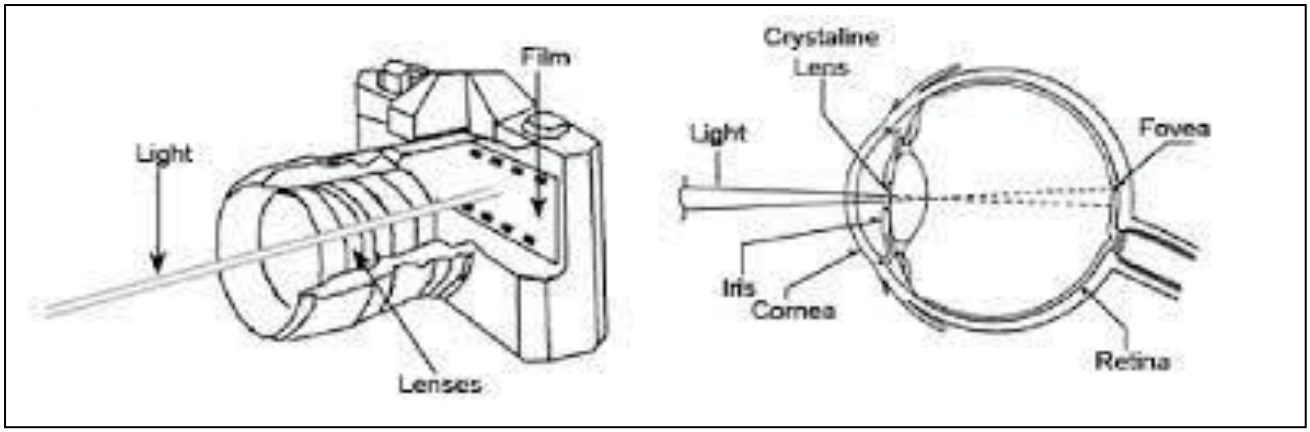
- Models involving another physical phenomenon to understand

Our subject.

ϖ In trying to understand the physical aspects of the body, we often resort to analogies; physicists often teach and think by analogy. Keep in mind that analogies are never perfect.

For Example: -

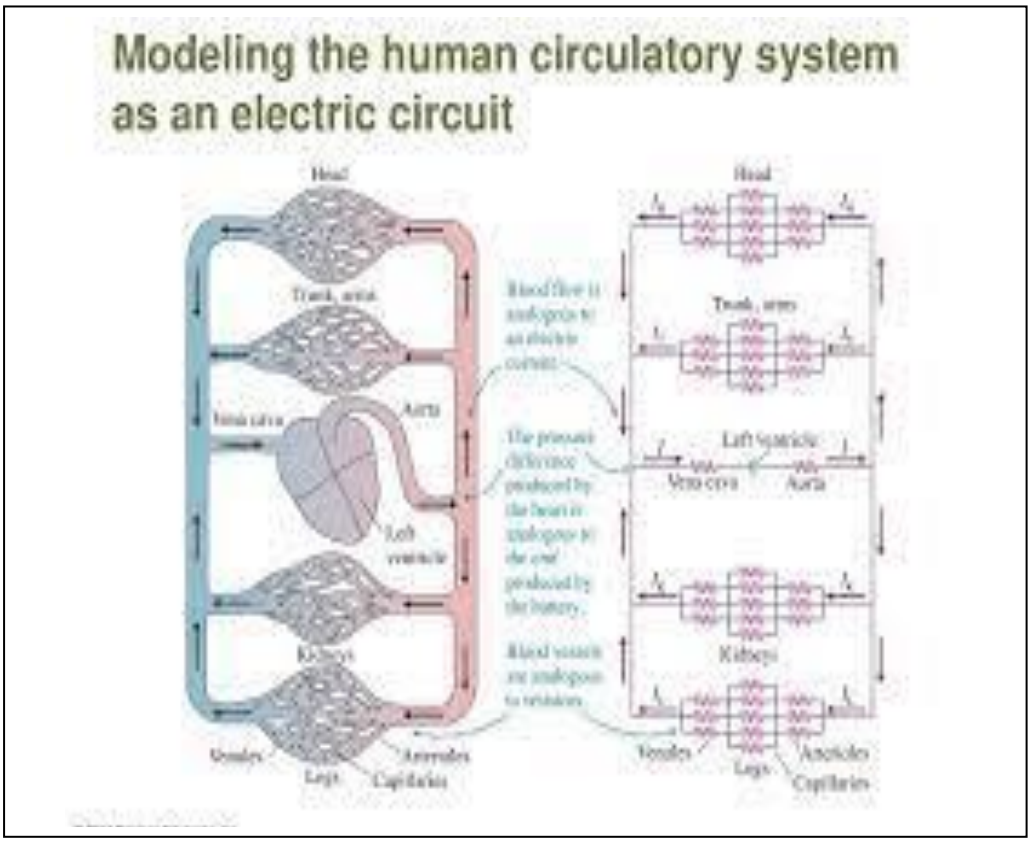
In many ways the eye is analogous to a camera; however, the analogy is poor when the film, which must be developed and replaced, is compared to the retina, the light detector of the eye



Some models involve physical phenomena that appear to be completely unrelated to the subject being studied.

For Example: -

A model in which the flow of blood is represented by the flow of electricity is often used in the study of the body's circulatory system. This electrical model can simulate very well many phenomena of the cardiovascular system. Of course, if you do not understand electrical phenomena the model does not help much. Also, as mentioned before, all analogies have their limitations. Blood is made up of red blood cells and plasma, and the percentage of the blood occupied by the red blood cells (the hematocrit) changes as the blood flows toward the extremities. This phenomenon is difficult to simulate with the electrical model



 # Mathematical model *(equation)* to describe the physical behavior of some systems. In the everyday world of physics we have many such equations. Some are of such general use that they are referred to as **laws**

ϖ Other models are mathematical; equations are mathematical models that can be used to describe and predict the physical behavior of some systems. In the everyday world of physics we have many such equations. Some are of such general use that they are referred to as laws.

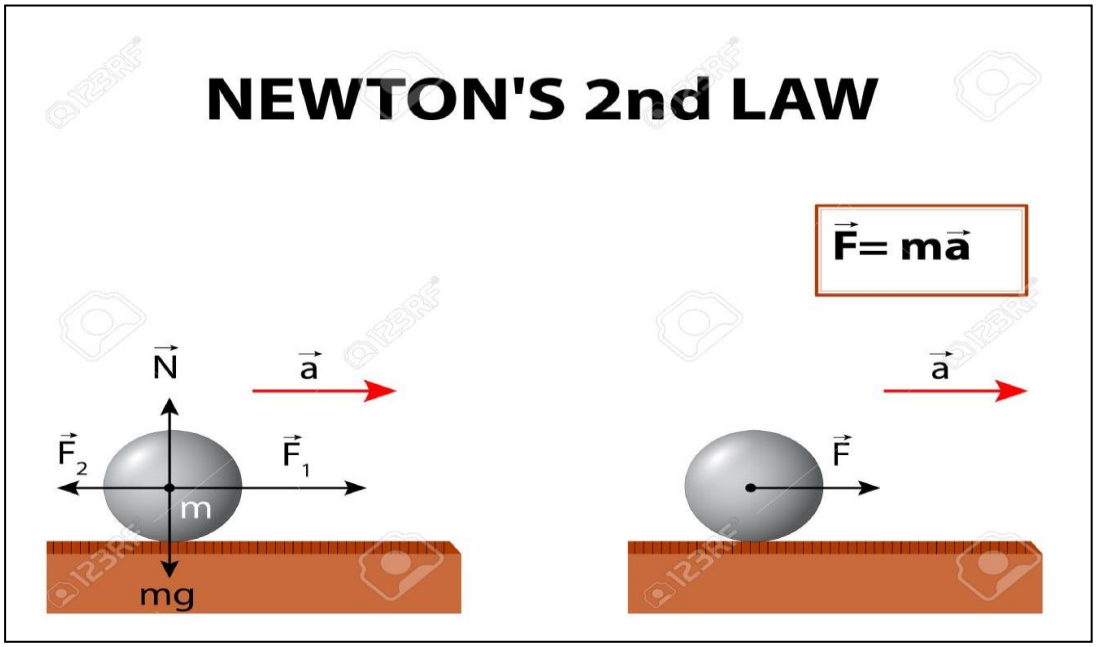
For Example: -

The relationship between force F, mass m, and acceleration a, usually written as **F=ma,** is known as Newton's second law. There are other mathematical expressions of this law that may look quite different to a lay person but are recognized by a physicist as other ways of saying the same thing. **Newton's second law** is used in the form **F=Δmv/Δt,** where v is the velocity, t is the time, and Δ indicates a small change of the quantity. The quantity mv is the momentum, and the part of the equation **P/Δt** means rate of the change **(of momentum)** with time

For Example:

-

The relationship between force ***F***, mass ***m***, and acceleration ***a***, usually written as ***F=ma***, is known as **Newton's second law**.



HOMEOSTASIS REGULATION – POSITIVE AND NEGATIVE FEEDBACK

Many function of the body are controlled by homeostasis "which is analogous to feedback control "in engineering .In it , some of what is being produced is used as a signal to control the production to the desired level.

If the system is designed so that an increase in the amount that is fed back decreases the production, and a decrease in the sample increases the production, the fed back is (NAGATIVE)

.

NEGATIVE FEED BACK

The dynamic stability of homeostasis is mostly maintained by physiologic processes called negative feedback

A good example of a negative feedback mechanism is a home thermostat (heating system). The thermostat contains the receptor (thermometer) and control center. If the heating system is set at 70 degrees Fahrenheit, the heat (effector) is turned on if the temperature drops below 70 degrees Fahrenheit. After the heater heats the house to 70 degrees Fahrenheit, it shuts off effectively maintaining the ideal temperature.

EXAMPLES OF A FEEDBACK MECHANISM IN OUR BODY.

1. When the blood pressure all of a sudden increases or reduces, it starts a series of responses that aims to bring the blood pressure to regular levels.
2. When thyroxine secretion is more, it prevents the secretion of thyroid stimulating hormone from pituitary so that, thyroxine is not produced from the thyroid gland.
3. In the regulation of CO_2 concentration, a high CO_2 concentration increase pulmonary ventilation = decrease CO_2 concentration, so high concentration first act on leads to decrease concentration which is the initiating stimulus and vice versa
4. When blood sugar rises, receptors in the body sense a change . In turn, the control center (pancreas) secretes insulin into the blood effectively lowering blood sugar levels. Once blood sugar levels reach homeostasis, the pancreas stops releasing insulin.

POSITIVE FEEDBACK MECHANISM

A positive feedback mechanism is the exact opposite of a negative feedback mechanism. With negative feedback, the output reduces the original effect of the stimulus. In a positive feedback system, the output enhances the original stimulus.

EXAMPLES OF A FEEDBACK MECHANISM IN OUR BODY.

1- Child birth. During labor, a hormone called oxytocin is released that intensifies and speeds up contractions. The increase in contractions causes more oxytocin to be released and the cycle goes on until the baby is born. The birth ends the release of oxytocin and ends the positive feedback mechanism.

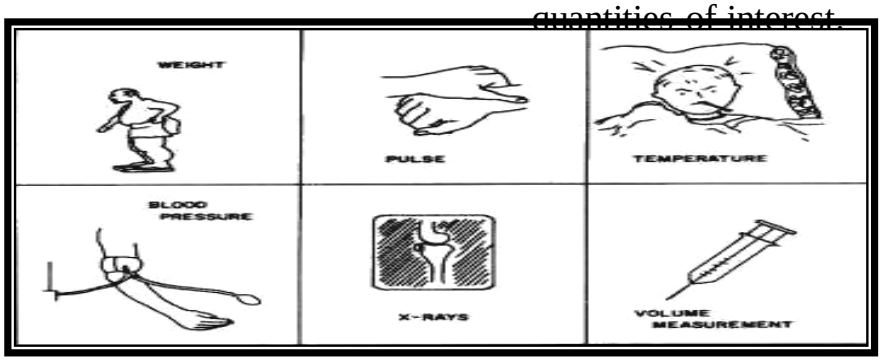
2- Blood clotting. Once a vessel is damaged, platelets start to cling to the injured site and release chemicals that attract more platelets. The platelets continue to pile up and release chemicals until a clot is formed.

3- Sucking reflex - baby sucking milk , impulses to hypothalamus that will send impulse to post pituitary to secrete the oxytocin which will increase milk secretion .

The negative fed back produces a stable control, while "POSITIVE" fed back ,in which a change in the sample causes a change in the same direction, produces an unstable control

Measurement:

One of the main characteristics of science is its ability to reproducibly measure quantities of interest.



The following figure illustrates a few of the common measurements used in the practice of medicine. Some of these measurements are more reproducible than others.

There are many other physical measurements involving the body and time. We can divide them into **two** groups: -

1. **Measurements of repetitive processes, such as pulse.**
2. **Measurements of nonrepetitive processes, such as how long it takes the kidneys to remove a foreign substance from the blood.**

Measurements of the **repetitive** processes usually involve the number of repetitions per second, minute, hour, and so forth.

For Example: -

- ✓ The pulse rate is about 70/min.
- ✓ The breathing rate is about 15/min.

Nonrepetitive time processes in the body range from the action potential of a nerve cell (**1msec**) to the lifespan of an individual.

How To Make a Full Diagnosis?

Today physician can diagnose a disease by using the following information:

- ☒ Medical history of the patient.
- ☒ The findings of the physical examination(for example ,tapping the chest, measure the pulse rate, breathing rate,,,,,,,)
- ☒ The results of the clinical laboratory measurements(for example, blood sugar, blood urea,,,,,etc)

After a physician has reviewed a patient's medical history, the findings of the physical examination and the results of clinical laboratory measurement ,he or she must decide if the patient is ill or not…..

Data collection to assessment body health

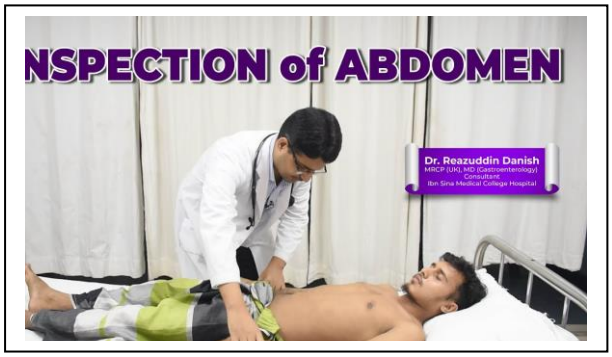
A) The Physical Examination During a health assessment, diagnosing an illness, disorder or a condition is like a puzzle. Diagnosis often includes laboratory studies, radiology studies to look at certain organs, and the physical exam itself. This process is called data collection. Before modern technology, it was important for doctor to perfect their physical examination techniques, because x-ray machines, scanners, and echocardiograms were non-existent. 7 Findings that are present on the physical exam may by themselves diagnose, or be helpful to diagnose, many diseases. The components of a physical exam include:

i) **Inspection** Your examiner will look at, or "inspect" specific areas of your body for normal color, shape and consistency. Certain findings on "inspection" may alert your examiner to focus other parts of the physical exam on certain areas of your body. For example, your legs may be swollen.

ii) **Palpation** This is when the examiner uses their hands to feel for abnormalities during a health assessment. Things that are commonly palpated during an exam include your lymph nodes, chest wall (to see if your heart is beating harder than normal), and your abdomen. He or she will use palpation to see if there are any masses or lumps, anywhere in your body.

iii) **Percussion** This is when the examiner uses their hands to "tap" on an area of your body. The "tapping" produces different sounds. Depending on the kind of sounds that are produced over your abdomen, on your back or chest wall, your examiner may determine anything from fluid in your lungs, or a mass in your stomach. This will provide further clues to a possible diagnosis.

iv) **Ausculation** This is an important physical examination technique used by your doctor, where he or she will listen to your heart, lungs, neck or abdomen, to identify if any problems are present. Auscultation is often performed by using a stethoscope. The stethoscope will amplify sounds heard in the area that is being listened to. If there is an abnormal finding on your examination, further testing may be suggested



B) The Neurologic Examination:

C) Analysis of Body Fluids

- Blood
- Urine
- Fluid that surrounds the spinal cord and brain (cerebrospinal fluid(CSF))
- Fluid within a joint (synovial fluid) Less often, sweat, saliva, and fluid from the digestive tract (such as gastric juices) are analyzed. Sometimes the fluids analyzed are present only if a disorder is present, as when fluid collects in the abdomen, causing ascites, or in the space between the two- 9 layered membrane covering the lungs and lining the chest wall (pleura), causing pleural effusion.

D) Measurement of Body Functions Often, body functions are measured by recording and analyzing the activity of various organs. For example, electrical activity of the heart is measured with electrocardiography (ECG), and electrical activity of the brain is measured with electroencephalography (EEG). The lungs'

ability to hold air, to move air in and out, and to exchange oxygen and carbon dioxide is measured with pulmonary function tests.

E) Biopsy Tissue samples are removed and examined, usually with a microscope. The examination often focuses on finding abnormal cells that may provide evidence of inflammation or of a disorder, such as cancer. Tissues that are commonly examined include skin, breast, lung, liver, kidney, and bone.

F) Analysis of Genetic Material (Genetic Testing) Usually, cells from skin, blood, or bone marrow are analyzed. Cells are examined to check for abnormalities of chromosomes, genes (including DNA), or both.

The decisions are two types: -

1. Right decisions.
2. Wrong decisions.

It is not surprising that sometimes wrong decisions are made. These wrong decisions are of **two** types: -

1. False Positives.
2. False Negatives.

- ✓ A **false positive** error occurs when a patient is diagnosed to have a particular disease when he or she does not have it.
- ✓ A **false negative** error occurs when a patient is diagnosed to be free of a particular disease when he or she does have it.

Note: -

In some situations a diagnostic error can have a great impact on a patient's life.

For Example: -

A young woman was thought to have a rheumatic heart condition and spent several years in complete bed rest before it was discovered that a false positive diagnosis had been made-she really had arthritis, a disease in which activity should be maintained to avoid joint stiffening.

In the early stages of many types of cancer it is easy to make a false negative diagnostic error because the tumor is small. Since the probability of cure depends on early detection of the cancer, a false negative diagnosis can greatly reduce the patient's chance of survival.

Diagnostic errors (false positives and false negatives) can be reduced by:

1. Research into the causes of misleading laboratory test values.
2. Development of new clinical tests and better instrumentation.

Errors or uncertainties from measurements can be reduced by: -

1. Using care in taking the measurement. 3-Repeating measurements.
2. Using reliable instruments. 4- Properly calibrating the instruments