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.
2. The applications of physics in the practice of medicine.

The first of these could be called the physics of physiology; the second includes such things as the physics of the stethoscope, the tapping of the chest (percussion), and the medical applications of lasers, ultrasound, radiation, and so forth.

The word physical appears in a number of medical contexts. Only a generation ago in England a professor of physics was actually a professor of medicine.

The words physicist and physician have a common root in the Greek word physiké (science of nature).

The branch of medicine referred to as physical medicine deals with the diagnosis and treatment of disease and injury by means of physical agents such as manipulation, massage, exercise, heat, and water.

Physical therapy is the treatment of disease or bodily weakness by physical means such as massage and gymnastic instead of drugs.

<u>The field of medical physics has several subdivisions: -</u>

1. Most medical physicists work in the field of 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).
2. Another major subdivision of medical physics involves radiation protection of patients, workers, and the general public. This field is often called health physics. Health physics also includes radiation protection outside of the hospital such as around nuclear power plants and in industry.
3. Very often an applied field of physics is called engineering. Thus, medical physics could be called medical engineering. However, for practical purposes if you meet an individual who refers to himself as a medical physicist it is highly probable that he is working in the area of radiological physics; a person who refers to himself as a medical engineer or biomedical engineer is likely to be working on medical instrumentation, usually of an electronic nature.
4. The word medical is sometimes replaced with the word clinical if the job is closely connected with patient problems in hospitals, i.e., clinical engineering or clinical physics.

Modeling

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: -

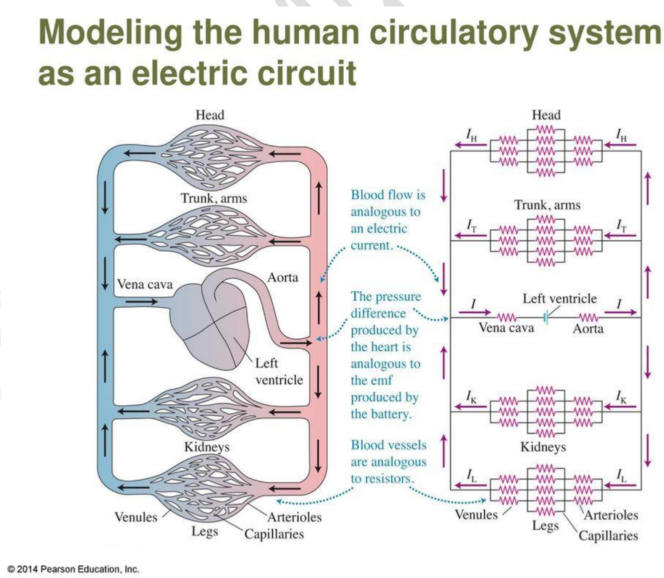
In many ways the eye is analogous to a camera; however, the analogy is poor when the film, which must be developed and replaced, is compared to the retina, the light detector of the eye.

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.



Scientific modeling, the generation of a physical or mathematical representation of a real phenomenon that is difficult to observe directly. Scientific models are used to explain and predict the behavior of real objects or systems and are used in a variety of Scientific disciplines, ranging from medicine, physics and chemistry to encology sciences.

- The purpose of scientific modeling varies. Some models, such as the three-dimensional double-helix model of DNA, are used primarily to visualize an object or system, often being created from experimental data. Other models are intended to describe an abstract or hypothetical behavior or phenomenon.

<u>For Example: -</u>

Three- dimensional models of proteins are used to gain insight into protein function and to assist with drug design.

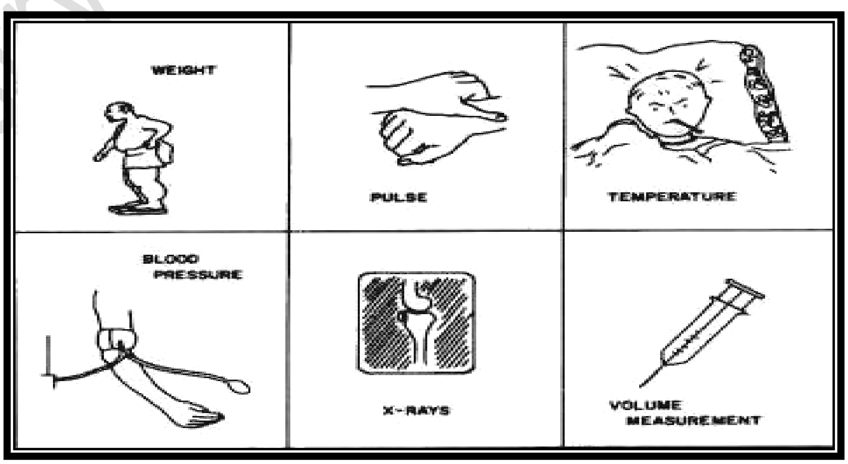
Measurement

One of the main characteristics of science is its ability to reproducibly measure quantities of interest. The growth of science is closely related to the growth of the ability to measure.

<u>For Example: -</u>

Even though body temperature and pulse rate could be measured during the seventeenth century, these measurements were not routinely made until the nineteenth century. In this century there has been a steady growth of science in medicine as the number and accuracy of quantitative measurements used in clinical practice have increased.

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.



For Example: -

An X-ray gives only qualitative information about the inside of the body.

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 (**1-2 msec**) to the lifespan of an individual.

In science accuracy and precision have different meanings: -

- **Accuracy**

Refers to how close a given measurement is to an accepted standard.

For Example: -

A person's height measured as **1.765m** may be accurate to 0.003m (**3mm**) compared to the standard meter.

- **Precision**

Refers to the reproducibility of a measurement and is not necessarily related to the accuracy of the measurement.

For Example: -

An ill person measured her temperature ten times in a row and got the following values in degrees Celsius (**formerly called degrees centigrade**): 36.1, 36.0, 36.1, 36.2, 36.4, 36.0, 36.3, 36.3, 36.4, and 36.2. The precision was fairly good, with a variation of **0.2ºC** from the average value of **36.2ºC**.

In general, it is desirable to have both good accuracy and good precision. However, sometimes an accurate measurement cannot be obtained even with a measuring technique that has good precision.

It is an accepted fact in science that the process of measurement may significantly alter the quantity being measured. This is especially true in medicine.

For Example: -

The process of measuring the blood pressure may introduce errors (**uncertainties**). Although the data are scarce, it is generally believed that when an attractive woman is performing the measurement, the blood pressure of a young man will increase. Similarly, a handsome man may affect the blood pressure measurement of a female patient. This type of error may also be introduced in taking a patient's history.

When a physician must decide if the patient is ill or not, and what the illness is?

After a physician has reviewed a patient's: -

1. Medical history.
2. The findings of the physical examination.
3. The results of the clinical laboratory measurements.

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.

<u>Diagnostic errors (false positives and false negatives) can be reduced by: -</u>

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

<u>Errors or uncertainties from measurements can be reduced by: -</u>

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

The Standard Human, and Scaling

Much of the problem we have in comprehending specialists in any field is in understanding their jargon, and not in understanding their ideas. This is particularly true for medicine. Medical terminology might seem to be intimidating, but when you examine each part of the term it becomes clearer. For example, what does "hypertrophic cardiomyopathy" mean? "Hyper" means something that is more than normal or expected. "Trophic" denotes size. "Cardio" refers to the heart. "Myo" means muscle. "Pathy" refers to disease. So hypertrophic cardiomyopathy is a disease or disorder due to the enhanced size of the heart muscle (due to thickened heart muscle). Use of acronyms as part of the medical jargon can also be a barrier.

What is HCM? It is "h" ypertrophic "c" ardio "m" yopathy. Much of medical jargon of interest to us is the terminology used in anatomy, and much of that in anatomy relates to directions and positions. To make things clearer for people who think in more physics-type terms, we will relate some of the anatomical coordinate systems used in medicine to coordinate systems that would be used by physicists to describe any physical system. In all of our discussions we will examine a typical human. To be able to do this, we will define and characterize the concept of a standard human.

Anatomical Terminology

The first series of anatomical "coordinate systems" relate to direction, and the first set of these we encounter is right versus left. With the xyz coordinate system of the body shown in Fig. 1.1, we see that right means $y < 0$ and left means $y > 0$.

Right and left, as well as all other anatomical terms, are always from the "patient's" point of view. (Stages in theaters have a similar convention, with stage left and stage right referring to the left and right sides of an actor on stage facing the audience. The second direction is superior (or cranial), which means towards the head or above, i.e., to larger z. Inferior (or caudal (kaw'-dul)) means away from the head,

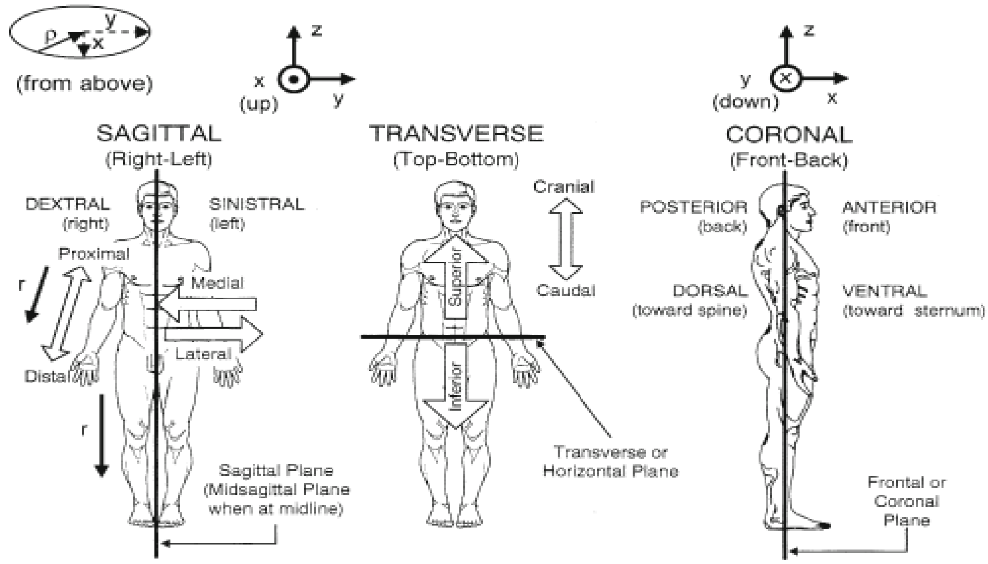


Fig. 1.1 Directions, orientations, and planes used to describe the body in anatomy, along with common coordinate systems described in the text. We will assume both terms in the following pairs mean the same: superior/cranial, inferior/caudal, anterior/ventral, and posterior/dorsal, even though there may be fine distinctions in what they mean, as is depicted here

i.e., to smaller z—in an algebraic sense, so more and more inferior means smaller positive numbers and then more highly negative values of z. (This is relative to a defined $z = 0$ plane. We could choose to define the origin of the coordinate system at the center of mass of the body) So, the head is superior to the feet, which are inferior to the head. After supplying the body with oxygen, blood returns to the heart through two major veins, the superior and inferior vena cava (vee'-nuh cave'-uh), which collect blood from above and below the heart, respectively. Anterior (or ventral) means towards or from the front of the body, i.e., to larger x. Posterior (or dorsal) means towards or from the back, corresponding to smaller algebraic x. The nose is anterior to the ears, which are posterior to the nose. There is another pair of terms that relate to the y coordinate, specifically to its magnitude. Medial means nearer the midline of the body, i.e., towards smaller $|y|$. Lateral means further from the midline, i.e., towards larger $|y|$. Other anatomical terms require other types of coordinate systems. One set describes the distance from the point of attachment of any of the two arms and two legs from the trunk. Figure 1.1 depicts this with the coordinate r, where $r = 0$ at the trunk. r is never negative. Proximal means near the point of attachment, i.e., to smaller r. Distal means further from the point of attachment, or larger r. The last series of directional terms relates to the local surface of the body. This can be depicted by the coordinate ρ (inset in Fig. 1.1), which is related to x and y in an $x - y$ plane. $\rho = 0$ on the local surface of the body. Superficial means towards or on the surface of the body, or to smaller ρ. Deep means away from the surface, or towards larger ρ.

These directional terms can refer to any locality of the body. Regional terms designate a specific region in the body (Tables 1.1 and 1.2). This is illustrated by an example we will use several times later. The region between the shoulder and elbow joints is called the brachium (brae'-kee-um). The adjective used to describe this region in anatomical terms is brachial (brae'-kee-al). The muscles in our arms that we usually call the biceps are really the brachial biceps or biceps brachii, while our triceps are really our brachial triceps or triceps brachii. The terms biceps and triceps refer to any muscles with two or three points of origin, respectively.

The final set of terms describes two-dimensional planes, cuts or sections of the body. They are illustrated in Fig. 1.1. A transverse or horizontal section separates the body into superior and inferior sections. Such planes have constant z. Sagittal sections separate the body into right and left sections, and are planes with constant y. The midsagittal section is special; it occurs at the midline and is a plane with y = 0. The frontal or coronal section separates the body into anterior and posterior portions, as described by planes with constant x. Much of our outright confusion concerning medical descriptions is alleviated with the knowledge of these three categories of anatomical terminology.

Table 1.1 Anatomical terms in anterior regions

Anatomical term	Common term
Abdominal	Abdomen
Antebrachial	Forearm
Axilliary	Armpit
Brachial	Upper arm
Buccal	Cheek
Carpal	Wrist
Cephalic	Head
Cervical	Neck
Coxal	Hip
Crural	Front of leg
Digital	Finger or toe
Frontal	Forehead
Inguinal	Groin
Lingual	Tongue
Mammary	Breast
Mental	Chin
Nasal	Nose
Oral	Mouth
Palmar	Palm
Pedal	Foot
Sternal	Breastbone
Tarsal	Ankle
Thoracic	Chest
Umbilical	Navel

The Standard Human

We will often, but not always, model humans assuming numerical values for mass, height, etc. of a "standard" human, a 70 kg man with parameters similar to those in Table 1.5. The distributions of body heights and weights, and of course their averages, differ in different regions and change with time. For example, heights of for example, their typical heights and weights are lower and their percentage of body fat is higher

Age	30 yr
Height	1.72 m
Mass	70 Kg
Weight	690 N
Surface area	1.85 m^2
Body core temperature	37.0 ^oC
Body skin temperature	34.0 ^oC
Body fat	15%
Body fluids volume	51 L
Heart rate	65-73 beats/min
Blode volume	5.2 L
Blood Hematocrit	0.43
Cardiac output (at rest)	5 L/min
Systolic blood pressure	120 mmHg
Diastolic blood pressure	80 mmHg
Breathing rate	15 /min
Total lung cah pacity	6.0 L