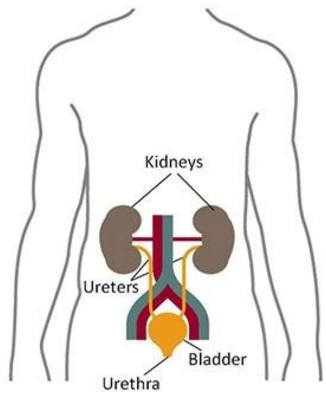
Kidney and Blood flow

- The kidneys are two bean-shaped organs, each about the size of a fist. They are located just below the rib cage, one on each side of your spine.
- Healthy kidneys filter about a half cup of blood every minute, removing wastes and extra water to make urine. The urine flows from the kidneys to the bladder through two thin tubes of muscle called ureters, one on each side of your bladder. Your bladder stores urine. Your kidneys, ureters,and bladder are part of your urinary tract.



Why are the kidneys important?

Your kidneys remove wastes and extra fluid from your body. Your kidneys also remove acid that is produced by the cells of your body and maintain a healthy balance of water, salts, and minerals—such as sodium, calcium, phosphorus, and potassium—in your blood.

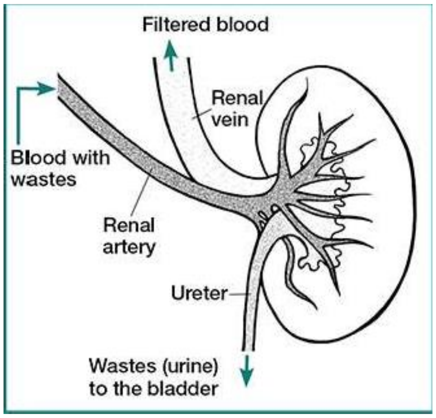
Without this balance, nerves, muscles, and other tissues in your body may not work normally.

How does kidneys work?

Each of your kidneys is made up of about a million filtering units called nephrons. Each nephron includes a filter, called the glomerulus, and a tubule. The nephrons work through a two-step process: the glomerulus filters your blood, and the tubule returns needed substances to your blood and removes wastes

How does blood flow through kidneys?

Blood flows into your kidney through the renal artery. This large blood vessel branches into smaller and smaller blood vessels until the blood reaches the nephrons. In the nephron, your blood is filtered by the tiny blood vessels of the glomeruli and then flows out of your kidney thrcugh the renal vein. Your blood circulates through your kidneys many times a day. In a single day, your kidneys filter about 150 quarts of blood. Most of the water and other substances that filter through your glomeruli are returned to your blood by the tubules. Only 1 to 2 quarts become urine.



Biomechanics of Bone

The mechanical response of bone to compression, tension, and other complex loads depends on the complex structure of bones. bones are living tissues with blood supplies, made of a high percentage of water (25% of bone mass), and having considerable deposits of calcium salts and other minerals. The strength of bone depends strongly on its density of mineral deposits and collagen fibers, and is also strongly related to dietary habits and physical activity. The loading of bones in physical activity results in greater osteoblast activity, laying down bone. Immobilization or inactivity will result in dramatic decreases in bone density, stiffness, and mechanical strength. Bones remodel (lay down greater mineral deposits) according to the mechanical stress in that area of bone. This laying down of bone where it is stressed and reabsorption of bone in the absence of stress is called Wolff's Law. Bone remodelling is well illustrated by the formation of bone around the threads of screws in the hip prosthetic in the x-ray.

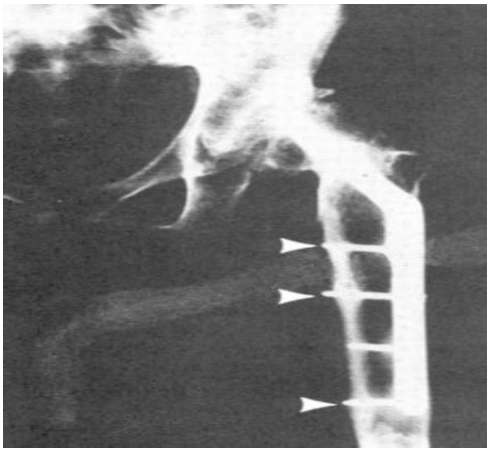


Fig: X-ray of a fractured femur with a metal plate repair. Note the remodelling of bone around the screws that transfer load to the plate

The macroscopic structure of bone shows a dense, external layer called cortical (compact) bone and the less-dense internal cancellous (spongy) bone. The mechanical

response of bone is dependent on this “sandwich” construction of cortical and cancellous bone. This design of a strong and stiff material with a weaker and more flexible interior (like fiberglass) results ina composite material that is strong for a given weight.
This is much like a surf board constructed of fiberglass bonded over a foam core. Cortical bone is stiffer (maximum strain about 2%), while cancellous bone is less stiff and can withstand greater strain (7%) before failure. In general, this design results in ultimate strengths of bone of about 200 MPa (29,000 lbs/in2) in compression, 125 MPa (18,000 lbs/in2) in tension, and 65 MPa (9,500 lbs/in2) in shear. This means that an excessive bending load on the femur would most likely cause a fracture to begin on the lateral aspect that is under tensile loading. Using sports rules to protect athletes from lateral blows (like blocking rules in American football) is wise because bone is weakest under shearing loads. It is also important to understand that the ultimate strength of bone depends on nutritional, hormonal, and physical activity factors

Biomechanics of soft tissues

What do we mean by soft tissues?
A primary group of tissue which binds, supports and protects our human body and structures such as organs is soft connective tissue. It is a wide-ranging biological material in which the cells are separatedby extracellular material. Connective tissue may be distinguished from hard (mineralized) tissues such as bones for their high flexibility and their soft mechanical properties.
Examples for soft tissues are tendons, ligaments, blood vessels, skins or articular cartilages

Soft tissues behave anisotropically because of their fibers which tend to have preferred directions. In a microscopic sense they are non-homogeneous materials because of their composition. The tensile response of soft tissue is nonlinear stiffening and tensile strength depends on the strain rate. In contrast to hard tissues, soft tissues may undergo large deformations. Some soft tissues show viscoelastic behaviour (relaxation and/or creep), which has been associated with the shear interaction of collagen with the matrix of proteoglycans [16] (the matrix provides a viscous lubrication between collagen fibrils). In a simplified way we explain here the tensile stress-strain behaviour for skin, an organconsisting mainly of connective tissues, which is representative of the mechanical behaviour of many (collagenous) soft connectives tissues. For the connective tissue parts of the skin the three-dimensional network of fibers appears to have preferred directions parallel to the surface. However, in order toprevent out-of-plane shearing, some fiber orientations also have components out-of-plane. Figure 1 shows a schematic diagram of a typical J-shaped (tensile) stress-strain curve for skin
This form, representative for many soft tissues, differs significantly from stress-strain curves of hard tissues or from other types of (engineering) materials. In addition, Figure 1 shows how the collagen fibers straighten with increasing stress.

Material	Ultimate tensile strength [Mpa]	Ultimate tensile strain [%]	Collagen (% dry weight)	Elastin (% dry weight)
Tendon	50-100	10-15	75-85	< 3
Ligament	50-100	10-15	70-80	10-15
Aorta	0.3-0.8	50-100	25-35	40-50
Skin	1-20	30-70	60-80	5-10
Articular Cartilage	9-40	60-120	40-70	-

Physiological signals and transducers

The Human body produces vari ɕus physiological signals. The accessibility to these signals is important because

(1) they can be internal (blood pressure)
(2) they may emanate from the body (infrared radiation)
(3) they may be derived from a tissue sample (blood or tissue biopsy)

All physiological signals can be grouped into the following categories –

(1)biopotential
(2)pressure
(3)flow
(4) dimensions(imaging)
(5) displacement(velocity,force,acceleration)
(6)impedance
(7) temperature
(8) chemical concentration and composition.

Sources of Physiological Signals

Physiological signals are generated by the body during the functioning of various physiological systems. Hence physiological signals hold information which can be extracted from these signals tofind out the state of the functioning of these physiological systems. The process of extracting information can be very simple as feeling the pulse to find the state of heart beats and it can be complex which may require analysis of the structure of tissue by a sophisticated machine. Depending on type of energy, the physiological signals can be:

(a) Bioelectrical signals: These signals are generated by nerve cells and muscle cells. The source of these signals are cells which undergo change of state from resting potential to action potential under certain conditions. The change of potential in many cells generate an electric field which fluctuatesand, in this process, it is to emit bioelectric signal. ECG and EEG are obtained from the bio signals from heart and brain respectively.

(b) Biomechanical Signals: These signals are generated by some mechanical function of a physiological system. These signals are related to motion, displacement, pressure and flow of the physiological system. The respiratory physiological system functions with the movement of chest which can be analysed.

(c) Bioacoustics Signals: These are created by the physiological systems which are dealing with the flow of blood and air. The flow of the blood in the heart, the opening and closing of chest in respiratory system generate unique acoustic signals.

(d) Biomagnetic Signals: Weak magnetic fields are generated by various organs like heart, brain and lungs while functioning. Magneto encephalograph is obtained from the Biomagnetic signals from the brain.

(e) Biochemical signals: The information is obtained by chemical measurements from the living tissues or analysis of the samples obtained from the body. The concentrations of various constituents in the blood and the measurement of partial pressure of oxygen and carbon dioxide in respiration arefound out by this method.

(f) Bioimpedance Signals: The impedence of the skin depends upon the composition of skin, blood distribution and blood volume through the skin. The measurement of impedance helps in finding the state of skin and functioning of various physiological systems. The voltage drop by the tissue impedence is nothing but a bioimpedance signal.

(g) Bio optical Signals: These signals are produced by the optical variations by the functioning of the physiological system. The blood oxygenation can be measured by measuring transmitted and reflected light from the blood vessel.

Transducer

Transducer is a device which converts one form of variable or energy into another form of variable or energy. Generally, transducer is required to convert physiological variables into electrical signals which are easier to be processed. The relationship between input and output variable can be linear, logarithmic or square. The transducer can be active or passive depending upon conversion of non- electrical variable into electrical signal. The active transducer directly converts input variable into electrical signals while passive transducer modifies either excitation voltages or modulates the carrier signals. The passive transducers are externally powered while active transducers are self-generating

Transducers

- Transducer is a device which converts one form of energy into electrical form. Because of the advantages of electric and electronic method of measurement.
- In Biomedical Instrumentation the main concern is conversion of Bioelectric signal to electric signal. Here transducer is a component which has a nonelectrical variable as its input and an electrical signal as its output.
- To conduct its function properly, one (or more) parameters of the electrical output signal in the form of voltages, current frequency or pulse width must be a non-ambiguous function of the nonelectricalvariables at the input.
- As long as the transduction function is non-ambiguous it is possible to determine the magnitude of the input variable from the electrical output signal at least in principle. Certain other variables may interface with the transduction process such as hysteresis error, frequency response and base line drift.
- There are two different principles used to convert nonelectrical variables into electrical signals. One of these is energy conversion transducers based on this principle are called Active transducers. The other principle involves control of an excitation voltage or modulationsof a carrier signal. Transducers based on this principle are called passive transducers. The two transducer types will be described separatelyin the following sections. A physical principle can be employed for converting nonelectrical activity in active transducers. But not all principles are of practical importance in the design of actual transducers, specially for biomedical applications.

Active Transducer

A physical principle can be employed for converting nonelectrical activityin active transducers. But, not all principles are of practical importancein the design of actual transducers, specially for biomedical applications.In active transducers, in some cases the same transduction principleused to convert from a nonelectrical form of energy can also be used inreverse direction to convert electrical energy to non-electrical energy.

Passive Transducer

A d.c excitation voltage or an ac carrier signal utilize the principle of controlling passive transducers. The transducer consists of a usually passive circuit element which changes its value as a function ofthe physical variable to be measured. The transducer is a part of circuitelement, normally an arrangement like Wheatstone bridge, which is powered by an ac or d.c excitation, signal. The voltageat the output reflects the physical variable. There are only three passive circuit elements which can be utilized as passive transducers namely: resistors, capacitorsand inductors. It may also be noted. That active components like transistors can also occasionally be used. The active and passive have different meaning in components and transducers. Passive transducers cannot be operated. in the reverse direction unlike active transducers.

Selection criteria for Transducer

- **Operating range**: The range of transducer should be appropriate for measurement to get a good resolution.
- **Operating Principle**: The transducers are selected on the basis of operating principle it may be resistive, inductive, capacitive, optical etc.
- **Accuracy**: The accuracy should be as high as possible or as per the measurement.

- **Range**: The transducer can give good result within its specified range, so select transducer asper the operating range.
- **Sensitivity**: The transducer should be more sensitive to produce the output or sensitivityshould be as per requirement.
- **Environmental compatibility**: The transducer should maintain input and outputcharacteristic for the selected environmental condition.
- **Loading effect**: The transducer’s input impedance should be high and output impedanceshould be low to avoid loading effect.
- **Errors**: The error produced by the transducer should be low as possible.