

MEDICAL ELECTRONICS

ECE

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CHAPTER-1

ELEMENTARY IDEAS OF CELL STRUCTURE

Cells were first described by Robert Hooke in his book *Micrographia*, published in 1665. Using a microscope, he described the structure of cork as closely resembling prison chambers or monks' quarters (there is some debate about this). He used the term "cell" to describe these hollow chambers. The Cell Theory was first described in 1839. While the Cell Theory has been altered and revised, most biologists today list three or four general characteristics shared by all cells:

1. The cell is the basic unit of life. Anything smaller than a cell is not alive by definition.
2. All organisms are composed of one or more cells.
3. Cells arise from pre-existing cells.
4. All cells, at some point in their life cycle, contain the genetic material for the entire organism.

Cell Wall: Technically is not part of the living cell since it is outside the membrane. It provides rigid structural support in plant, fungi, some algae, and prokaryotic cells. The thickness and chemical composition of cell walls can vary between organisms.

Cell membrane: This is the barrier between the living part of the cell and the nonliving environment. It is a selective barrier, allowing some materials but not others to pass. Water and small particles can slip through the phospholipid bilayer while larger and more complex materials must pass through one of the protein channels embedded in the membrane. All cells have membranes.

Cytoplasm: The fluid matrix of the cell. The cytoplasm contains dissolved ions and other materials, allows for the movement of materials within the cell, and allow for movement of organelles during cyclosis. All living cells have cytoplasm.

Nucleus: The nucleus is the "control center" of the cell. The DNA is stored in the nucleus. The DNA is the set of instructions for the cell to function, not only for reproduction, but enzymes and other functions. Only eukaryotic cells have a nucleus.

Plastids: These are structures related to photosynthesis. Different pigments trigger different functions. Chloroplasts are the site of photosynthesis, chromoplasts may be photosynthetic and/or related to seed dispersal, leucoplasts store starch. All plastids begin as proplastids before differentiation. Only autotrophs have plastids.

Mitochondrion: The powerhouse of the cell, the site of aerobic respiration. Pyruvate is broken down in the Krebs Cycle and chemiosmosis then produces ATP from ADP and phosphate in the presence of oxygen. All eukaryotic cells contain mitochondria.

Vacuole: These membranous sacs have many functions. Material can be transported within the cell, from one organelle to another organelle, Vacuoles can take materials to the membrane for expulsion, or can be formed at the membrane to bring materials into the cell. Plants and eukaryotic algae have a large central vacuole to store metabolic waste and water. Heterotrophs produce vacuoles containing digestive enzymes to break down food particles (called lysosomes). All cells can have vacuoles, but number and types can vary.

Endoplasmic reticulum: E.R. is an organelle that extends throughout the cell. It may be smooth (no ribosomes) or rough (with ribosomes) and is associated with packaging, synthesis, and transport of materials in the cell. These are found in eukaryotic cells.

Golgi Bodies: Stacks of membranes within the cell. They package materials and form vesicles for transport out of the cell. Eukaryotic cells have Golgi Bodies.

Ribosomes: Ribosomes are not organelles, but structures of the cell. They are in the cytoplasm, on rough e.r. and in the nucleus. One of the primary roles of ribosomes is the location of protein synthesis. All cells possess ribosomes.

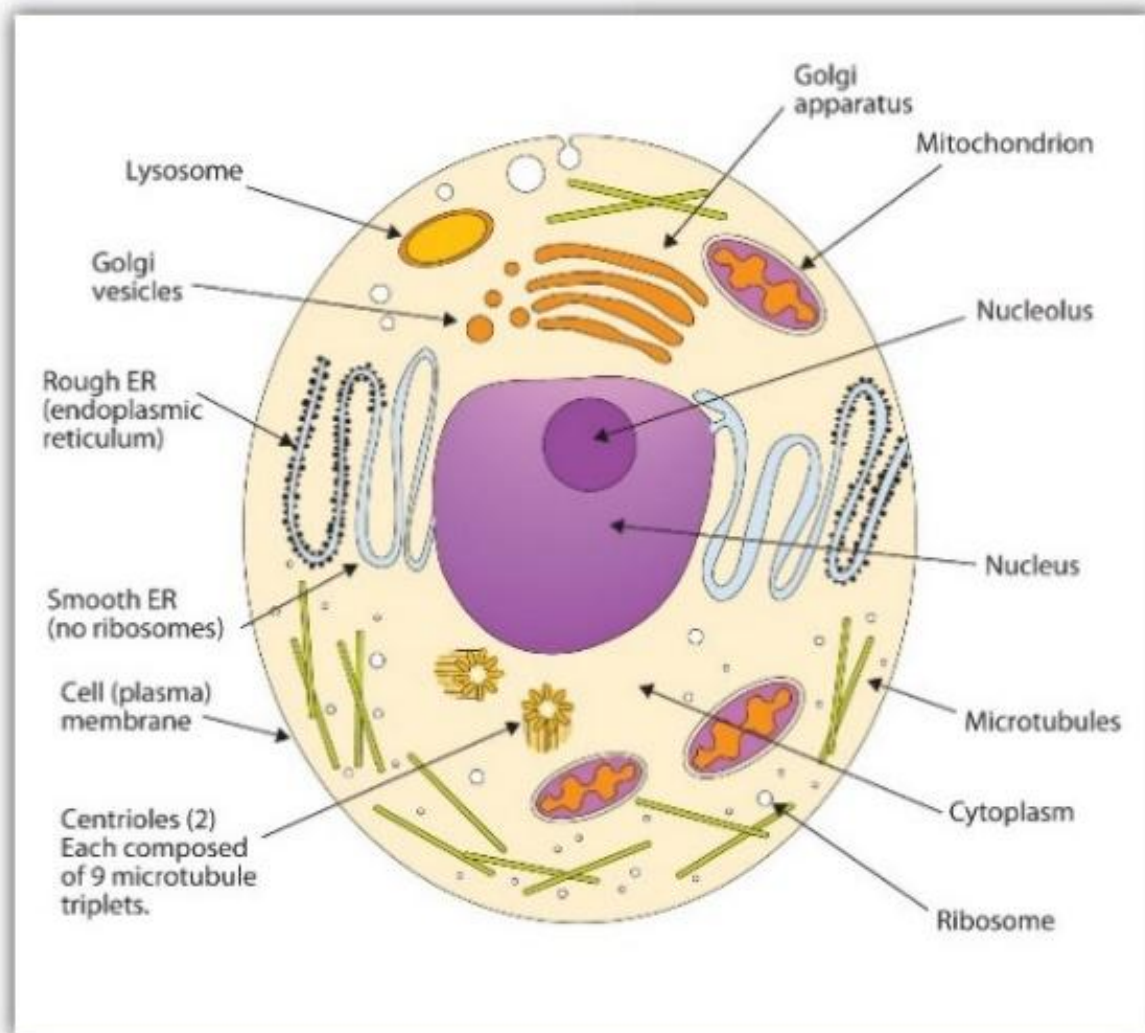
Cytoskeleton: The cytoskeleton is made of three different structures – microtubules, microfilaments, and intermediate filaments. They are responsible for maintaining the internal shape of the cell, acting as a framework for all the other parts. The cytoskeleton also assists in the movement of organelles and materials in cyclosis and they form the spindle structure during cell division. The cytoskeleton is present in all cells.

The largest cells are nerve cells. The giant squid has nerve cells over 12 meters in length while in humans the longest nerve cell is 1.5 meters. The smallest cell is a bacterium measuring 0.1 microns. The smallest human cells are sperm

cells (40 microns). The most massive cell is the ostrich egg, weighing up to 1.4 kg.

HEART AND CIRCULATORY SYSTEM

The circulatory system is composed of the heart and blood vessels, including arteries, veins, and capillaries. Our bodies actually have two circulatory



systems: The pulmonary circulation is a short loop from the heart to the lungs and back again, and the systemic circulation (the system we usually think of as our circulatory system) sends blood from the heart to all the other parts of our bodies and back again.

The heart is the key organ in the circulatory system. As a hollow, muscular pump, its main function is to propel blood throughout the body. It usually

beats from 60 to 100 times per minute, but can go much faster when necessary. It beats about 100,000 times a day, more than 30 million times per year, and about 2.5 billion times in a 70-year lifetime.

The heart gets messages from the body that tell it when to pump more or less blood depending on an individual's needs. When we're sleeping, it pumps just enough to provide for the lower amounts of oxygen needed by our bodies at rest. When we're exercising or frightened, the heart pumps faster to increase the delivery of oxygen.

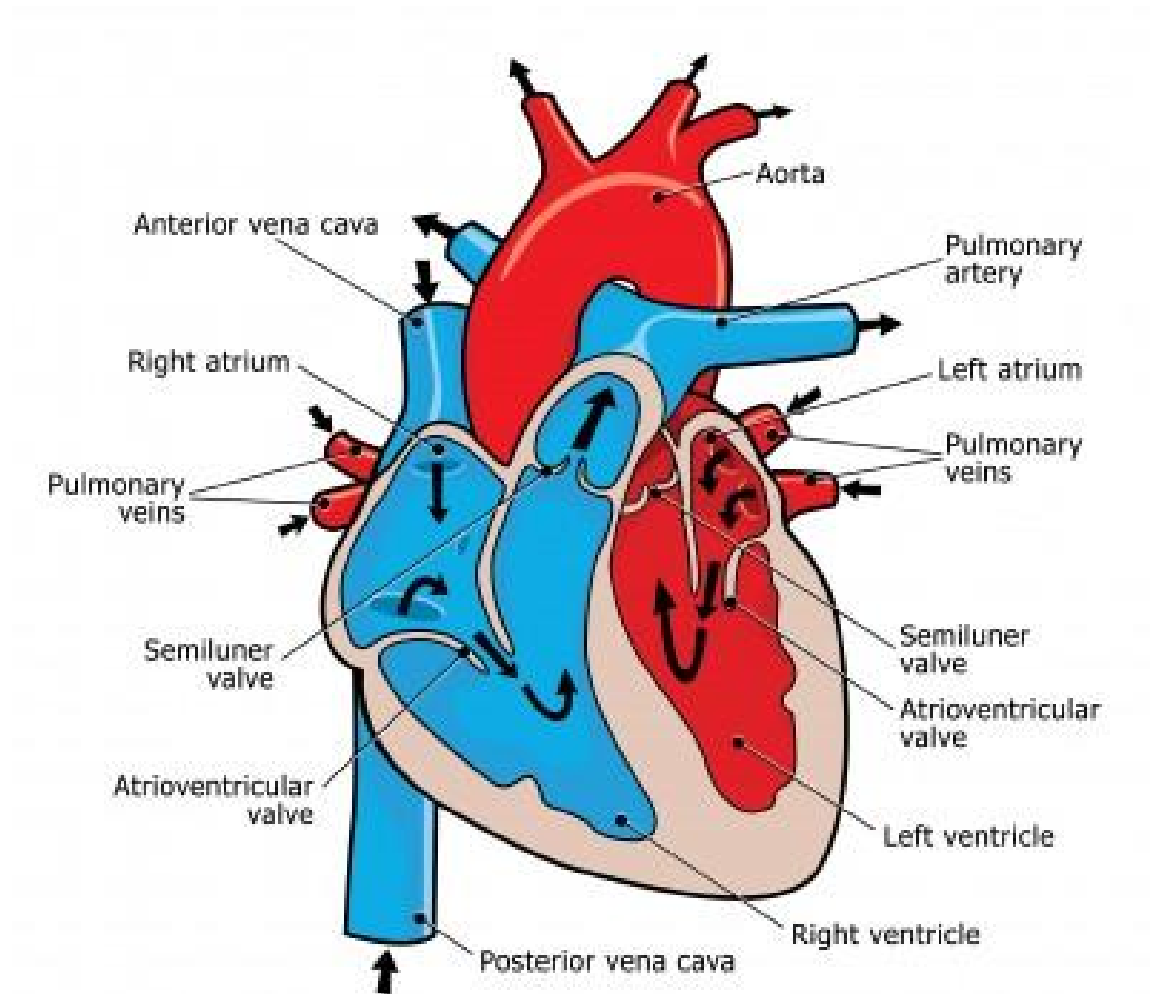
The heart has four chambers that are enclosed by thick, muscular walls. It lies between the lungs and just to the left of the middle of the chest cavity. The bottom part of the heart is divided into two chambers called the right and left ventricles, which pump blood out of the heart. A wall called the inter-ventricular septum divides the ventricles.

The upper part of the heart is made up of the other two chambers of the heart, the right and left atria. The right and left atria receive the blood entering the heart. A wall called the interatrial septum divides the right and left atria, which are separated from the ventricles by the atrioventricular valves. The tricuspid valve separates the right atrium from the right ventricle, and the mitral valve separates the left atrium and the left ventricle.

Two other cardiac valves separate the ventricles and the large blood vessels that carry blood leaving the heart. These are the pulmonic valve, which separates the right ventricle from the pulmonary artery leading to the lungs, and the aortic valve, which separates the left ventricle from the aorta, the body's largest blood vessel.

Arteries carry blood away from the heart. They are the thickest blood vessels, with muscular walls that contract to keep the blood moving away from the heart and through the body. In the systemic circulation, oxygen-rich blood is pumped from the heart into the aorta. This huge artery curves up and back from the left ventricle, then heads down in front of the spinal column into the abdomen. Two coronary arteries branch off at the beginning of the aorta and divide into a network of smaller arteries that provide oxygen and nourishment to the muscles of the heart.

Unlike the aorta, the body's other main artery, the pulmonary artery, carries oxygen-poor blood. From the right ventricle, the pulmonary artery divides into right and left branches, on the way to the lungs where blood picks up oxygen.



The circulatory system works closely with other systems in our bodies. It supplies oxygen and nutrients to our bodies by working with the respiratory system. At the same time, the circulatory system helps carry waste and carbon dioxide out of the body.

One complete heartbeat makes up a cardiac cycle, which consists of two phases:

In the first phase, the ventricles contract (this is called systole), sending blood into the pulmonary and systemic circulation. To prevent the flow of blood backwards into the atria during systole, the atrioventricular valves close, creating the first sound (the lub). When the ventricles finish contracting, the aortic and pulmonary valves close to prevent blood from flowing back into the ventricles. This is what creates the second sound (the dub).

1. Then the ventricles relax (this is called diastole) and fill with blood from the atria, which makes up the second phase of the cardiac cycle.

A unique electrical conduction system in the heart causes it to beat in its regular rhythm. The sinoatrial or SA node, a small area of tissue in the wall of the right atrium, sends out an electrical signal to start the contracting of the heart muscle. This node is called the pacemaker of the heart because it sets the rate of the heartbeat and causes the rest of the heart to contract in its rhythm.

These electrical impulses cause the atria to contract first, and then travel down to the atrioventricular or AV node, which acts as a kind of relay station. From here the electrical signal travels through the right and left ventricles, causing them to contract and forcing blood out into the major arteries.

In the systemic circulation, blood travels out of the left ventricle, to the aorta, to every organ and tissue in the body, and then back to the right atrium. The arteries, capillaries, and veins of the systemic circulatory system are the channels through which this long journey takes place.

Once in the arteries, blood flows to smaller arterioles and then to capillaries. While in the capillaries, the bloodstream delivers oxygen and nutrients to the body's cells and picks up waste materials. Blood then goes back through the capillaries into venules, and then to larger veins until it reaches the vena cavae.

Blood from the head and arms returns to the heart through the superior vena cava, and blood from the lower parts of the body returns through the inferior vena cava. Both vena cavae deliver this oxygen-depleted blood into the right atrium. From here the blood exits to fill the right ventricle, ready to be pumped into the pulmonary circulation for more oxygen.

In the pulmonary circulation, blood low in oxygen but high in carbon dioxide is pumped out the right ventricle into the pulmonary artery, which branches off in two directions. The right branch goes to the right lung, and vice versa.

In the lungs, the branches divide further into capillaries. Blood flows more slowly through these tiny vessels, allowing time for gases to be exchanged between the capillary walls and the millions of alveoli, the tiny air sacs in the lungs.

During the process called oxygenation, oxygen is taken up by the bloodstream. Oxygen locks onto a molecule called hemoglobin in the red blood cells. The

newly oxygenated blood leaves the lungs through the pulmonary veins and heads back to the heart. It enters the heart in the left atrium, then fills the left ventricle so it can be pumped into the systemic circulation.

CENTRAL NERVOUS SYSTEM

The nervous system is made up of all the nerve cells in your body. It is through the nervous system that we communicate with the outside world and, at the same time, many mechanisms inside our body are controlled. The nervous system takes in information through our senses, processes the information and triggers reactions, such as making your muscles move or causing you to feel pain. For example, if you touch a hot plate, you reflexively pull back your hand and your nerves simultaneously send pain signals to your brain. Metabolic processes are also controlled by the nervous system.

There are many billions of nerve cells, also called neurons, in the nervous system. The brain alone has about 100 billion neurons in it. Each neuron has a cell body and various extensions. The shorter extensions (called dendrites) act like antennae: they receive signals from, for example, other neurons and pass them on to the cell body. The signals are then passed on via a long extension (the axon), which can be up to a meter long.

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The nervous system has two parts, called the central nervous system and the peripheral nervous system due to their location in the body. The central

nervous system (CNS) includes the nerves in the brain and spinal cord. It is safely contained within the skull and vertebral canal of the spine. All of the other nerves in the body are part of the peripheral nervous system (PNS).

Regardless of where they are in the body, a distinction can also be made between voluntary and involuntary nervous system. The voluntary nervous system (somatic nervous system) controls all the things that we are aware of and can consciously influence, such as moving our arms, legs and other parts of the body.

The involuntary nervous system (vegetative or autonomic nervous system) regulates the processes in the body that we cannot consciously influence. It is constantly active, regulating things such as breathing, heart beat and metabolic processes. It does this by receiving signals from the brain and passing them on to the body. It can also send signals in the other direction – from the body to the brain – providing your brain with information about how full your bladder is or how quickly your heart is beating, for example. The involuntary nervous system can react quickly to changes, altering processes in the body to adapt. For instance, if your body gets too hot, your involuntary nervous system increases the blood circulation to your skin and makes you sweat more to cool your body down again.

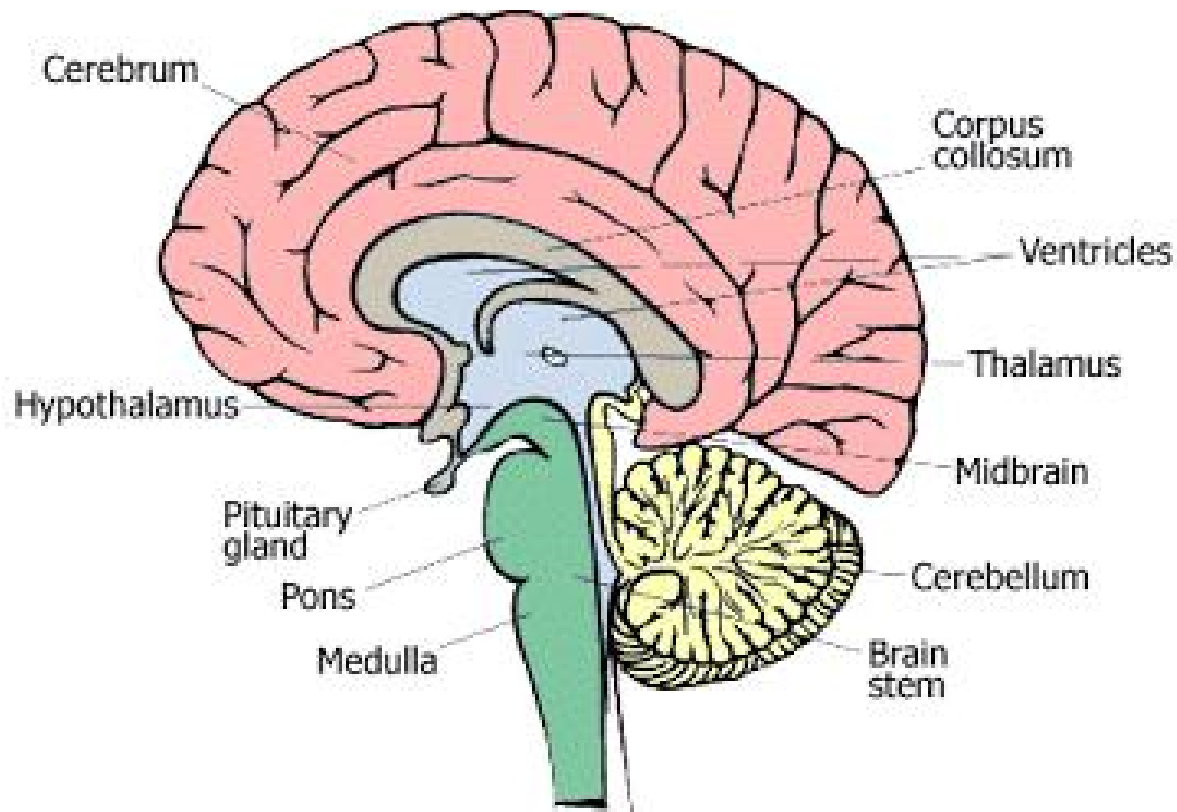
HUMAN BRAIN

The brain is one of the largest and most complex organs in the human body.

It is made up of more than 100 billion nerves that communicate in trillions of connections called synapses.

The brain is made up of many specialized areas that work together:

- The cortex is the outermost layer of brain cells. Thinking and voluntary movements begin in the cortex.
- The brain stem is between the spinal cord and the rest of the brain. Basic functions like breathing and sleep are controlled here.
- The basal ganglia are a cluster of structures in the center of the brain. The basal ganglia coordinate messages between multiple other brain areas.
- The cerebellum is at the base and the back of the brain. The cerebellum is responsible for coordination and balance.



The brain is also divided into several lobes:

- The frontal lobes are responsible for problem solving and judgment and motor function.
- The parietal lobes manage sensation, handwriting, and body position.
- The temporal lobes are involved with memory and hearing.
- The occipital lobes contain the brain's visual processing system.

The brain is surrounded by a layer of tissue called the meninges. The skull (cranium) helps protect the brain from injury.

MUSCLE ACTION

HOW MUSCLES WORK

A voluntary muscle usually works across a joint. It is attached to both the bones by strong cords called tendons.

When the muscles contract, usually just one bone moves.

For example, when the biceps in the arm contract, the radius moves but the scapula does not.

ORIGIN AND INSERTION

When a muscle contracts, usually just one bone moves. The other is stationary. The origin is where the muscle joins the stationary bone. The insertion is where it joins the moving bone. When a muscle contracts, the insertion moves towards the origin.

TENDONS

Tendons are the cords and straps that connect muscles to bones. At the bone, the fibers of the tendon are embedded in the periosteum of the bone. This anchors the tendon strongly and spreads the force of the contraction, so the tendon won't tear away easily.

MUSCLE WORKING IN PAIRS

Muscles usually work in pairs or groups, e.g. the biceps flex the elbow and the triceps extends it.

This is called antagonistic muscle action. The working muscle is called the prime mover or agonist. (it's in agony!) The relaxing muscle is the antagonist. The other main pair of muscle that work together are the quadriceps and hamstrings.

The prime mover is helped by other muscles called synergists. These contract at the same time as the prime mover. They hold the body in position so that the prime mover can work smoothly.

When muscles cause a limb to move through the joint's range of motion, they usually act in the following cooperating groups:

Agonists

These muscles cause the movement to occur. They create the normal range of movement in a joint by contracting. Agonists are also referred to as prime movers since they are the muscles that are primarily responsible for generating the movement.

Antagonists

These muscles act in opposition to the movement generated by the agonists and are responsible for returning a limb to its initial position.

Synergists

These muscles perform, or assist in performing, the same set of joint motion as the agonists. Synergists are sometimes referred to as neutralizers because they help cancel out, or neutralize, extra motion from the agonists to make sure that the force generated works within the desired plane of motion.

Fixators

These muscles provide the necessary support to assist in holding the rest of the body in place while the movement occurs. Fixators are also sometimes called stabilizers.

TYPES OF CONTRACTION

The contraction of a muscle does not necessarily imply that the muscle shortens; it only means that tension has been generated. Muscles can contract in the following ways:

Isometric Contraction

This is a contraction in which no movement takes place, because the load on the muscle exceeds the tension generated by the contracting muscle. This occurs when a muscle attempts to push or pull an immovable object.

Isotonic Contraction

This is a contraction in which movement does take place, because the tension generated by the contracting muscle exceeds the load on the muscle. This occurs when you use your muscles to successfully push or pull an object.

Isotonic contractions are further divided into two types:

Concentric Contraction

This is a contraction in which the muscle decreases in length (shortens) against an opposing load, such as lifting a weight up.

Eccentric Contraction

This is a contraction in which the muscle increases in length (lengthens) as it resists a load, such as lowering a weight down in a slow, controlled fashion.

During a concentric contraction, the muscles that are shortening serve as the agonists and hence do all of the work. During an eccentric contraction the muscles that are lengthening serve as the agonists (and do all of the work).

RESPIRATORY SYSTEM

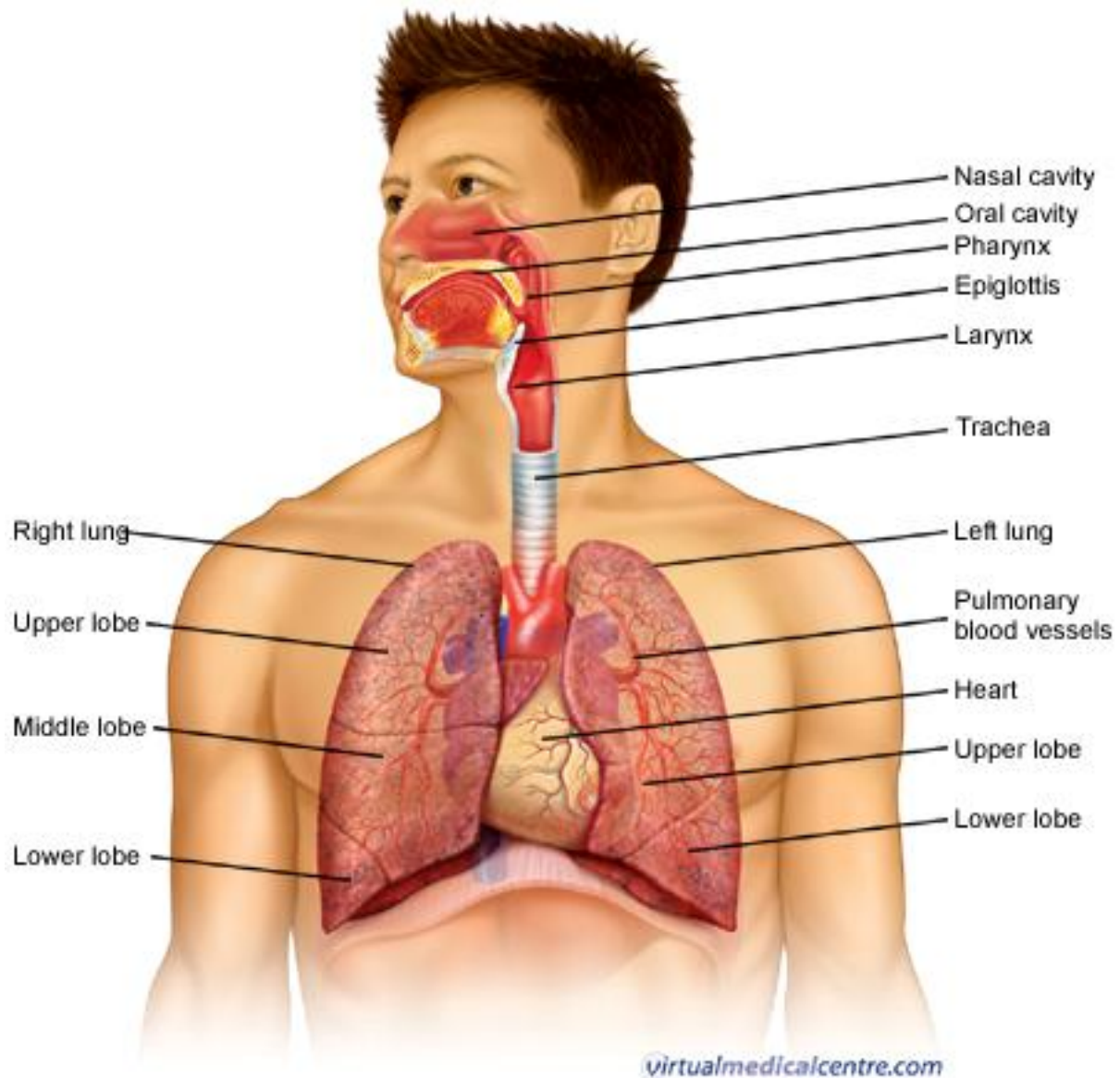
The respiratory system consists of all the organs involved in breathing. These include the nose, pharynx, larynx, trachea, bronchi and lungs. The respiratory system does two very important things: it brings oxygen into our bodies, which we need for our cells to live and function properly; and it helps us get rid of carbon dioxide, which is a waste product of cellular function. The nose, pharynx, larynx, trachea and bronchi all work like a system of pipes through which the air is funneled down into our lungs. There, in very small air sacs called alveoli, oxygen is brought into the bloodstream and carbon dioxide is pushed from the blood out into the air. When something goes wrong with part of the respiratory system, such as an infection like pneumonia, it makes it harder for us to get the oxygen we need and to get rid of the waste product carbon dioxide. Common respiratory symptoms include breathlessness, cough, and chest pain.

The Upper Airway and Trachea

When you breathe in, air enters your body through your nose or mouth. From there, it travels down your throat through the larynx (or voice box) and into the trachea (or windpipe) before entering your lungs. All these structures act to funnel fresh air down from the outside world into your body. The upper airway is important because it must always stay open for you to be able to breathe. It also helps to moisten and warm the air before it reaches your lungs.

The lungs are paired, cone-shaped organs which take up most of the space in our chests, along with the heart. Their role is to take oxygen into the body,

which we need for our cells to live and function



properly, and to help us get rid of carbon dioxide, which is a waste product. We each have two lungs, a left lung and a right lung. These are divided up into 'lobes', or big sections of tissue separated by 'fissures' or dividers. The right lung has three lobes, but the left lung has only two, because the heart takes up some of the space in the left side of our chest. The lungs can also be divided up into even smaller portions, called 'bronchopulmonary segments'.

These are pyramidal-shaped areas which are also separated from each other by membranes. There are about 10 of them in each lung. Each segment receives its own blood supply and air supply.

How they work

Air enters your lungs through a system of pipes called the bronchi. These pipes start from the bottom of the trachea as the left and right bronchi and branch many times throughout the lungs, until they eventually form little thin-walled air sacs or bubbles, known as the alveoli. The alveoli are where the important work of gas exchange takes place between the air and your blood. Covering each alveolus is a whole network of little blood vessel called capillaries, which are very small branches of the pulmonary arteries. It is important that the air in the alveoli and the blood in the capillaries are very close together, so that oxygen and carbon dioxide can move (or diffuse) between them. So, when you breathe in, air comes down the trachea and through the bronchi into the alveoli. This fresh air has lots of oxygen in it, and some of this oxygen will travel across the walls of the alveoli into your bloodstream. Travelling in the opposite direction is carbon dioxide, which crosses from the blood in the capillaries into the air in the alveoli and is then breathed out. In this way, you bring in to your body the oxygen that you need to live, and get rid of the waste product carbon dioxide.

Blood Supply

The lungs are very vascular organs, meaning they receive a very large blood supply. This is because the pulmonary arteries, which supply the lungs, come directly from the right side of your heart. They carry blood which is low in oxygen and high in carbon dioxide into your lungs so that the carbon dioxide can be blown off, and more oxygen can be absorbed into the bloodstream. The newly oxygen-rich blood then travels back through the paired pulmonary veins into the left side of your heart. From there, it is pumped all around your body to supply oxygen to cells and organs.

THE WORK OF BREATHING

The Pleurae

The lungs are covered by smooth membranes that we call pleurae. The pleurae have two layers, a 'visceral' layer which sticks closely to the outside surface of your lungs, and a 'parietal' layer which lines the inside of your chest wall (ribcage). The pleurae are important because they help you breathe in and out smoothly, without any friction. They also make sure that when your ribcage expands on breathing in, your lungs expand as well to fill the extra space.

The Diaphragm and Intercostal Muscles

When you breathe in (inspiration), your muscles need to work to fill your lungs with air. The diaphragm, a large, sheet-like muscle which stretches across your chest under the ribcage, does much of this work. At rest, it is shaped like a dome curving up into your chest. When you breathe in, the diaphragm contracts and flattens out, expanding the space in your chest and drawing air into your lungs. Other muscles, including the muscles between your ribs (the intercostal muscles) also help by moving your ribcage in and out. Breathing out (expiration) does not normally require your muscles to work. This is because your lungs are very elastic, and when your muscles relax at the end of inspiration your lungs simply recoil back into their resting position, pushing the air out as they go.

BODY TEMPERATURE

Normal human body temperature, also known as normothermia or euthermia, is the typical temperature range found in humans. The normal human body temperature range is typically stated as 36.5–37.5 °C (97.7–99.5 °F)

Individual body temperature depends upon the age, exertion, infection, sex, and reproductive status of the subject, the time of day, the place in the body at which the measurement is made, and the subject's state of consciousness (waking, sleeping or sedated), activity level, and emotional state. It is typically maintained within this range by thermoregulation.

Human body temperature is of interest in medical practice, human reproduction, and athletics.

REPRODUCTION SYSTEM

The reproductive system is necessary for the production of new living organisms. The ability to reproduce is a basic characteristic of life. In sexual reproduction, two individuals produce offspring that have genetic characteristics from both parents. The primary function of the reproductive system is to produce male and female sex cells and to ensure the growth and development of offspring. The reproductive system is comprised of male and female reproductive organs and structures. The growth and activity of these organs and structures is regulated by hormones. The reproductive system is

closely associated with other organ systems, particularly the endocrine system and urinary system.

Male and Female Reproductive Organs

Both male and female reproductive organs have internal and external structures. Reproductive organs are considered to be either primary or secondary organs. The primary reproductive organs are the gonads (ovaries and testes), which are responsible for gamete (sperm and egg cell) and hormone production. The other reproductive structures and organs are considered secondary reproductive structures. Secondary organs aid in the growth and maturation of gametes and developing offspring.

Structures of the female reproductive system include:

- Labia majora - Larger lip-like external structures that cover and protect sexual structures.
- Labia minora - Smaller lip-like external structures found inside the labia majora. They provide protection for the clitoris and for the urethra and vaginal openings.
- Clitoris - Very sensitive sexual organ located in front of the vaginal opening. It contains thousands of sensory nerve endings and responds to sexual stimulation.
- Vagina - Fibrous, muscular canal leading from the cervix (opening of the uterus) to the external portion of the genital canal.
- Uterus - Muscular internal organ that houses and nurtures female gametes after fertilization. Also called the womb, the uterus is where a developing fetus resides during pregnancy.
- Fallopian tubes - Uterine tubes which transport egg cells from the ovaries to the uterus. Fertilization typically occurs in these tubes.
- Ovaries - Female primary reproductive structures that produce gametes and sex hormones. There is one ovary on each side of the uterus.

The male reproductive system consists of sexual organs, accessory glands, and a series of duct systems that provide a pathway for fertile sperm cells to exit the body. Male reproductive structures include the penis, testes, epididymis, seminal vesicles, and prostate gland.

Male Reproductive System Organs

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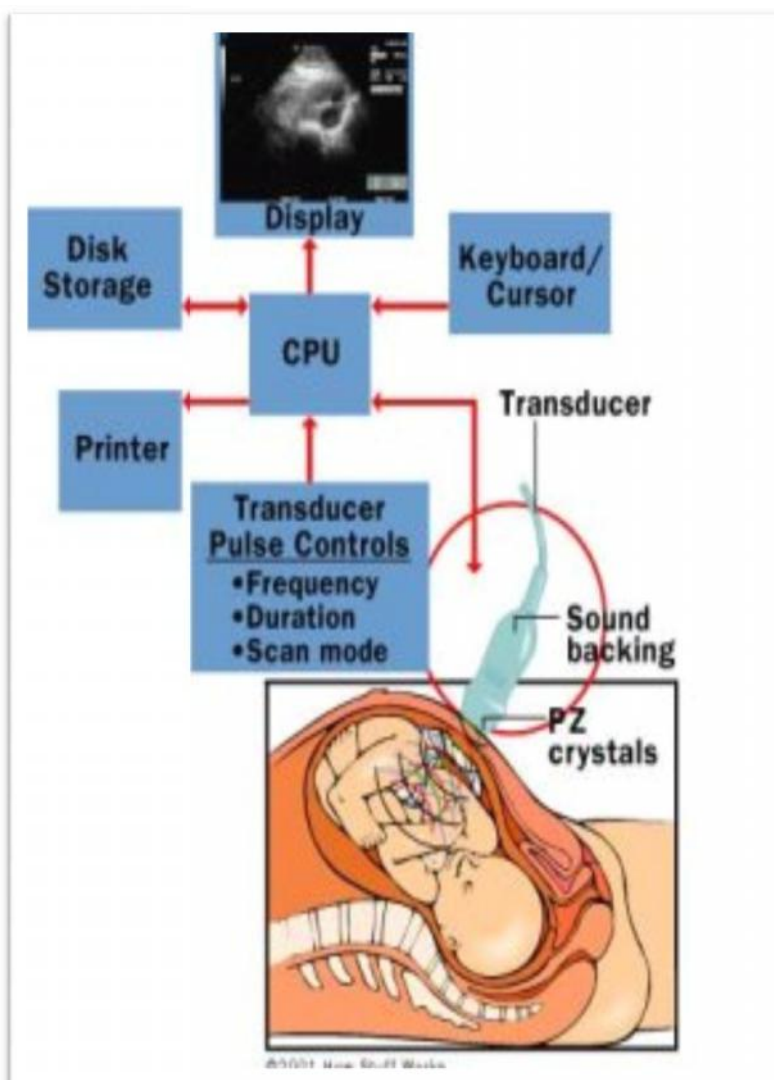
- Penis - Main organ involved in sexual intercourse. This organ is composed of erectile tissue, connective tissue, and skin. The urethra extends through the length of the penis, allowing urine and sperm to pass.
- Testes - Male primary reproductive structures that produce male gametes (sperm) and sex hormones.
- Scrotum - External pouch of skin that contains the testes. Because the scrotum is located outside of the abdomen, it can reach temperatures that are lower than that of internal body structures. Lower temperatures are necessary for proper sperm development.
- Epididymis - System of ducts that receive immature sperm from the testes. Its function is to develop immature sperm and to house mature sperm.
- Ductus Deferens or Vas Deferens - Fibrous, muscular tubes that are continuous with the epididymis and provide a pathway for sperm to travel from the epididymis to the urethra
- Ejaculatory Duct - Duct formed from the union of the ductus deferens and seminal vesicles. Each ejaculatory duct empties into the urethra.
- Urethra - Tube that extends from the urinary bladder through the penis. This canal allows for the excretion of reproductive fluids (semen) and urine from the body. Sphincters prevent urine from entering the urethra while semen is passing through.
- Seminal Vesicles - Glands that produce fluid to nurture and provide energy for sperm cells. Tubes leading from the seminal vesicles join the ductus deferens to form the ejaculatory duct.
- Prostate Gland - Gland that produces a milky, alkaline fluid which increases sperm motility. The contents of the prostate empty into the urethra.
- Bulbourethral or Cowper's Glands - Small glands located at the base of the penis. In response to sexual stimulation, these glands secrete an alkaline fluid which helps to neutralize acidity from urine in the urethra and acidity in the vagina.

Similarly, the female reproductive system contains organs and structures that promote the production, support, growth, and development of female gametes (egg cells) and a growing fetus.

CHAPTER-2

ULTRASONOGRAPHY

- Transducer probe - probe that sends and receives the sound waves
- Central processing unit (CPU) - computer that does all of the calculations and contains the electrical power supplies for itself and the transducer probe
- Transducer pulse controls - changes the amplitude, frequency and duration of the pulses emitted from the transducer probe
- Display - displays the image from the ultrasound data processed by the



CPU

- Keyboard/cursor - inputs data and takes measurements from the display

- Disk storage device (hard, floppy, CD) - stores the acquired images
- Printer - prints the image from the displayed data

The transducer probe is the main part of the ultrasound machine. The transducer probe makes the sound waves and receives the echoes. It is, so to speak, the mouth and ears of the ultrasound machine. The transducer probe generates and receives sound waves using a principle called the piezoelectric (pressure electricity) effect, which was discovered by Pierre and Jacques Curie in 1880. In the probe, there are one or more quartz crystals called piezoelectric crystals. When an electric current is applied to these crystals, they change shape rapidly. The rapid shape changes, or vibrations, of the crystals produce sound waves that travel outward. Conversely, when sound or pressure waves hit the crystals, they emit electrical currents. Therefore, the same crystals can be used to send and receive sound waves. The probe also has a sound absorbing substance to eliminate back reflections from the probe itself, and an acoustic lens to help focus the emitted sound waves.

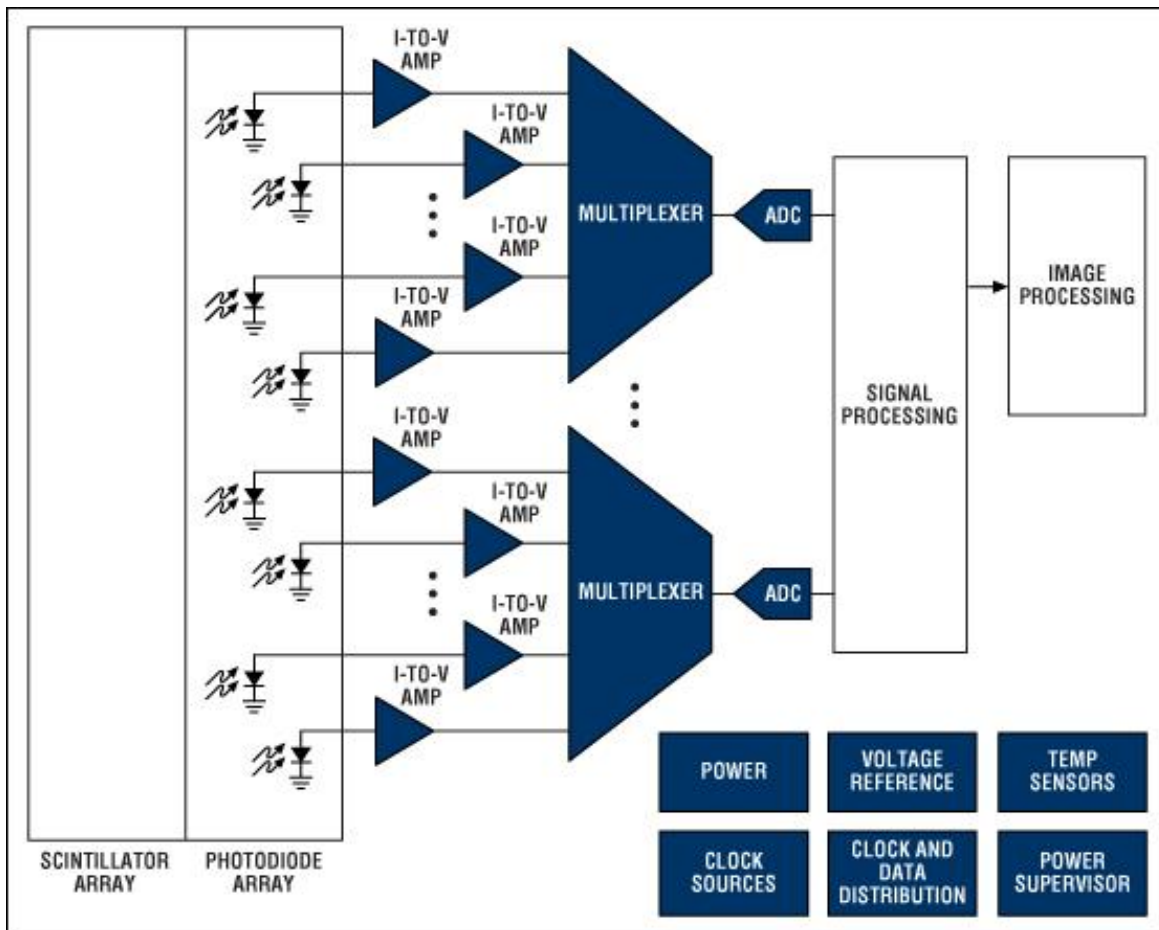
Transducer probes come in many shapes and sizes, as shown in the photo above. The shape of the probe determines its field of view, and the frequency of emitted sound waves determines how deep the sound waves penetrate and the resolution of the image. Transducer probes may contain one or more crystal elements; in multiple-element probes, each crystal has its own circuit. Multiple-element probes have the advantage that the ultrasound beam can be "steered" by changing the timing in which each element gets pulsed; steering the beam is especially important for cardiac ultrasound (see Basic Principles of Ultrasound for details on transducers). In addition to probes that can be moved across the surface of the body, some probes are designed to be inserted through various openings of the body (vagina, rectum, oesophagus) so that they can get closer to the organ being examined (uterus, prostate gland, stomach); getting closer to the organ can allow for more detailed views.

The CPU is the brain of the ultrasound machine. The CPU is basically a computer that contains the microprocessor, memory, amplifiers and power supplies for the microprocessor and transducer probe. The CPU sends electrical currents to the transducer probe to emit sound waves, and also receives the electrical pulses from the probes that were created from the returning echoes. The CPU does all of the calculations involved in processing the data. Once the raw data are processed, the CPU forms the image on the monitor. The CPU can also store the processed data and/or image on disk.

The transducer pulse controls allow the operator, called the ultrasonographer, to set and change the frequency and duration of the ultrasound pulses, as well as the scan mode of the machine. The commands from the operator are translated into changing electric currents that are applied to the piezoelectric crystals in the transducer probe.

COMPUTED TOMOGRAPHY (CT)

medical-imaging systems generate three-dimensional (3-D) images of internal body structures using complex x-ray and computer-aided tomographic imaging techniques.



The x-ray images used to generate the tomographic images are generated first by exposing the patient to a fan-shaped x-ray beam and then detecting the projected image on a thin semi-circular, digital x-ray detector. The patient is

placed between the source and detector, and the detector is configured with its geometric centre located at the x-ray source. Each image is an x-ray projection of a very thin transverse slice of the body. To collect the multitude of x-ray projections necessary to generate a tomographic CT image, both the x-ray source and detector are rotated about a patient within a supporting gantry. While the source and detector rotate, images are collected and stored. As in a traditional x-ray, the signal levels in the image slice represent the relative radio density of the patient along a line from the x-ray source to the corresponding pixel location.

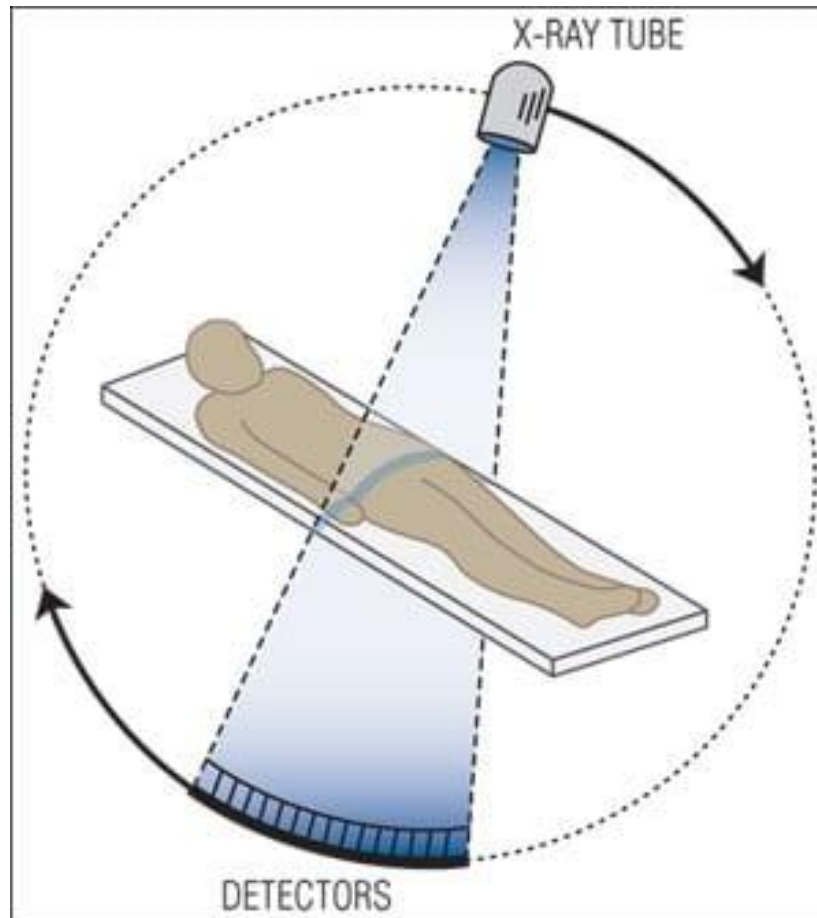
To improve image-capture times and resolution, manufacturers utilize multislice CT imaging techniques. Instead of a single 2D detector array which provides only a single image slice, multislice imaging uses a 3-D array. The added imaging dimension allows the system to generate multiple slices in parallel. Photodetector arrays used in CT imaging have as many as 1000 detectors in the long dimension along the semi-circular detector arch; 16 or more detectors are positioned in the shorter dimension tangential to the arch. The number of detectors in the short dimension determines the number of available image slices.

The patient is exposed to a fan-shaped x-ray beam and the projected image is detected on a thin, semi-circular digital x-ray detector.

Modern CT imaging systems can also generate images in any plane within the body by using a technique called spiral CT. In a spiral-CT system the patient is slowly moved into the centre of the gantry while the x-ray source and detector rotate about the patient. Very-high-speed computers are necessary to process the images collected in this manner. Sophisticated tomographic imaging techniques are used to produce the required image.

X-RAY DETECTION

Early CT imaging systems accomplished x-ray detection using both scintillation crystals and photo-multiplier tubes. The scintillation crystals converted x-rays to light and the photomultiplier tubes converted these light signals to a usable electrical signal. Modern CT systems now employ more sophisticated scintillation crystal materials and solid-state photodetector diodes for this purpose.



The output from each photodiode is a current proportional to the light striking the diode. These currents can be directly converted to a voltage by a low-noise trans impedance amplifier (TIA), or integrated over time using a capacitor or active integrator op-amp circuit to produce a voltage output. Integration of the current from each diode can be accomplished in multiple ways. Capacitance in the photodiode detector array itself can be used for this purpose. The signals from these capacitors are multiplexed using FET switches in the diode-array detector. The signals are then routed to the digital acquisition system (DAS) which amplifies and converts the signals to a digital format using high-resolution analog-to-digital converters (ADCs). An alternative method routes the signals from every photodiode to an integrator in the DAS. In these implementations, the integrated current signals are converted to a voltage, sampled at the same time, and multiplexed into the input of an ADC.

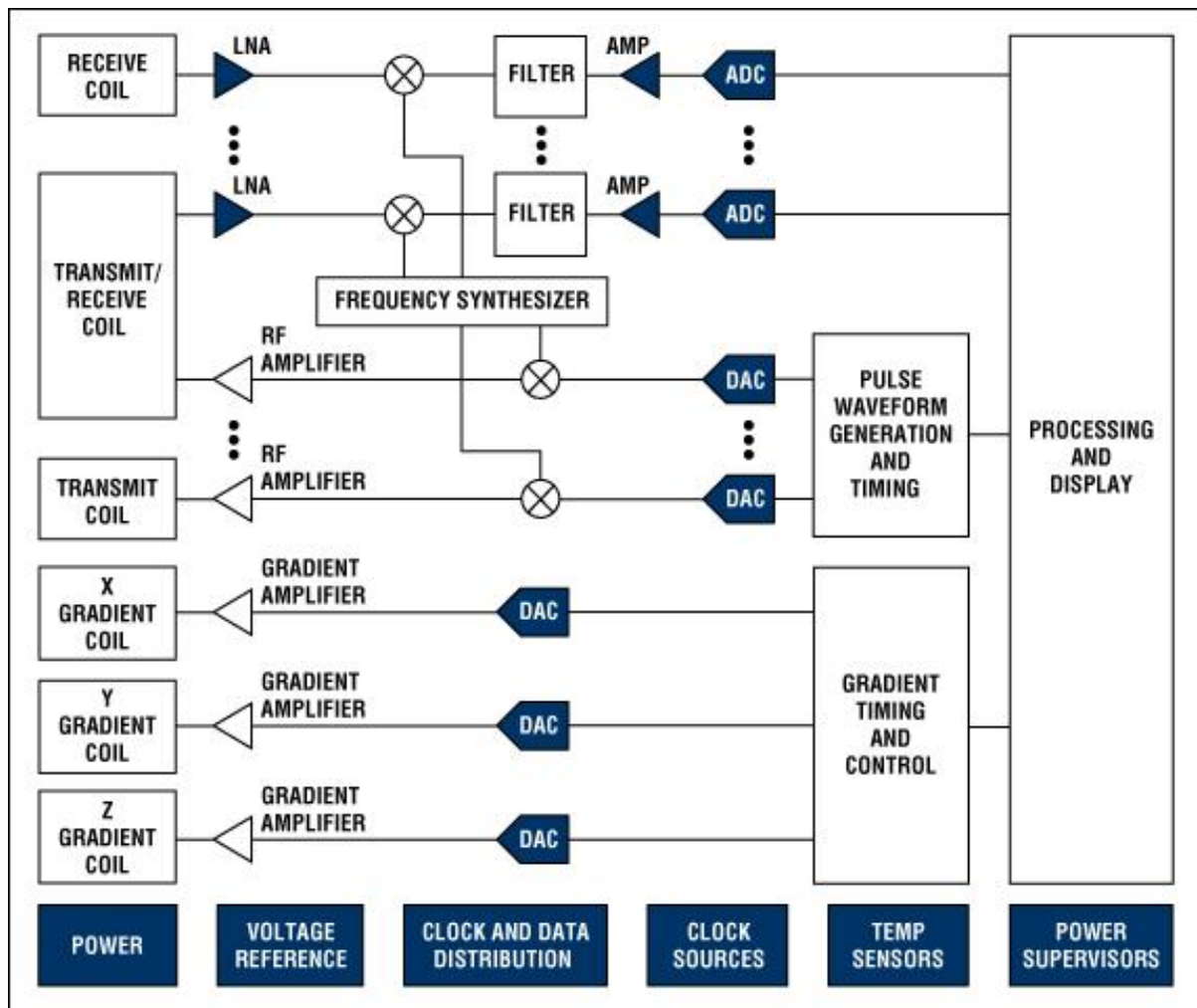
Tomographic Imaging

The resulting x-ray image data set is converted to an image by the image processor. The image processor is typically a very-high-speed computer which

performs the massive calculations required for the tomographic image reconstruction. The resulting image will commonly have a very large dynamic range (i.e., 16-bit grayscale images). Further image processing is necessary to map this large dynamic range most effectively into the limited visible display range.

MRI SCAN

Magnetic resonance imaging (MRI) systems provide highly detailed images of tissue in the body. The systems detect and process the signals generated when hydrogen atoms, which are abundant in tissue, are placed in a strong magnetic field and excited by a resonant magnetic excitation pulse.



Magnetic resonance imaging (MRI) system.

Proper stimulation by a resonant magnetic or RF field at the resonant frequency of the hydrogen nuclei can force the magnetic moments of the nuclei to partially, or completely, tip into a plane perpendicular to the applied field. When the applied RF-excitation field is removed, the magnetic moments of the nuclei process in the static field as they realign. This realignment generates an RF signal at a resonant frequency determined by the magnitude of the applied field. This signal is detected by the MRI imaging system and used to generate an image.

Static Magnetic Field

MRI imaging requires the patient to be placed in a strong magnetic field in order to align the hydrogen nuclei. There are typically three methods to generate this field: fixed magnets, resistive magnets (current passing through a traditional coil of wire), and super-conducting magnets. Fixed magnets and resistive magnets are generally restricted to field strengths below 0.4T and cannot generate the higher field strengths typically necessary for high-resolution imaging. As a result, most high-resolution imaging systems use super-conducting magnets. The super-conducting magnets are large and complex; they need the coils to be soaked in liquid Helium to reduce their temperature to a value close to absolute zero.

The magnetic fields generated by these methods must not only be strong, but also highly uniform in space and stable in time. A typical system must have less than 10ppm variation over the imaging area. To achieve this accuracy, most systems generate weaker static magnetic fields using specialized shim coils to "shim" or "tweak" the static field from the super conductor and thereby correct for field inaccuracies.

Gradient Coils

To produce an image, the MRI system must first stimulate hydrogen nuclei in a specific 2D image plane in the body, and then determine the location of those nuclei within that plane as they process back to their static state. These two tasks are accomplished using gradient coils which cause the magnetic field within a localized area to vary linearly as a function of spatial location.

RF Receiver

An RF receiver is used to process the signals from the receiver coils. Most modern MRI systems have six or more receivers to process the signals from

multiple coils. The signals range from approximately 1MHz to 300MHz, with the frequency range highly dependent on applied-static magnetic field strength. The bandwidth of the received signal is small, typically less than 20kHz, and dependent on the magnitude of the gradient field.

A traditional MRI receiver configuration has a low-noise amplifier (LNA) followed by a mixer. The mixer mixes the signal of interest to a low-frequency IF frequency for conversion by a high-resolution, low-speed, 12-bit to 16-bit analog-to-digital converter (ADC). In this receive architecture, the ADCs used have relatively low sample rates below 1MHz. Because of the low-bandwidth requirements, ADCs with higher 1MHz to 5MHz sample rates can be used to convert multiple channels by time-multiplexing the receive channels through an analog multiplexer into a single ADC.

With the advent of higher-performance ADCs, newer receiver architectures are now possible. High-input-bandwidth, high-resolution, 12-bit to 16-bit ADCs with samples rates up to 100MHz can also be used to directly sample the signals, thereby eliminating the need for analog mixers in the receive chain.

Transmitter

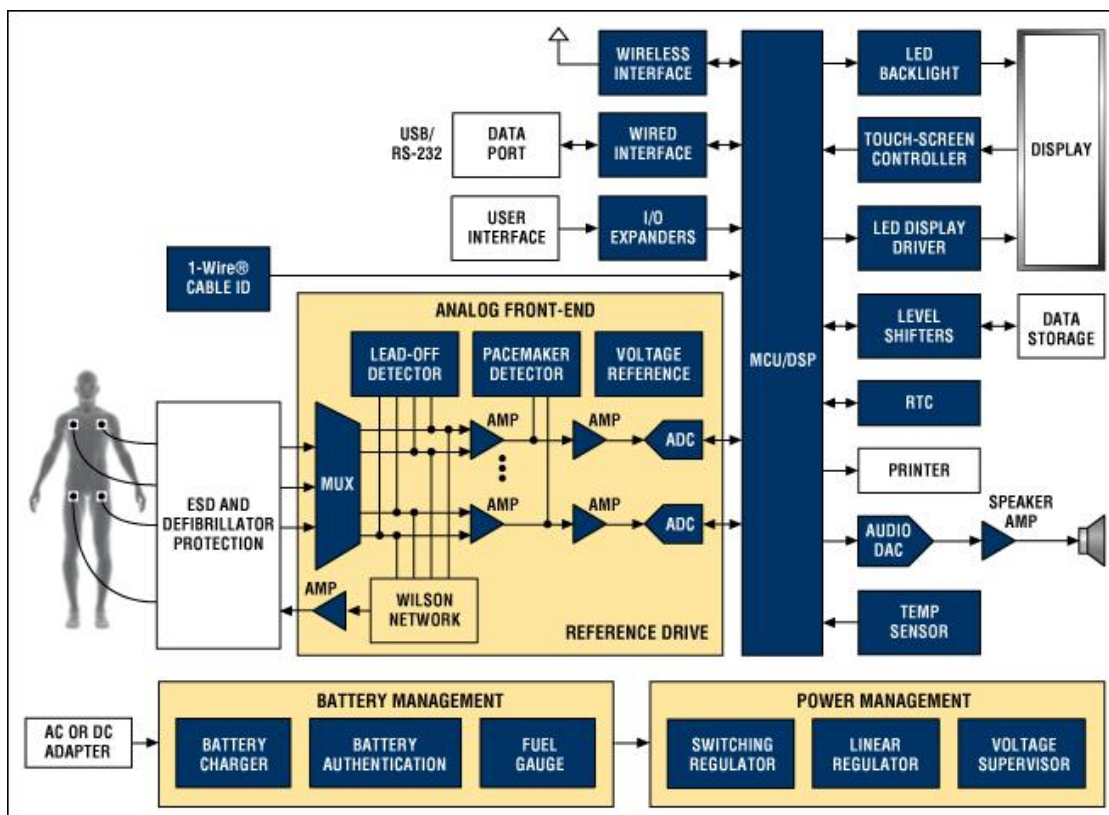
The MRI transmitter generates the RF pulses necessary to resonate the hydrogen nuclei. The range of frequencies in the transmit excitation pulse and the magnitude of the gradient field determine the width of the image slice. A typical transmit pulse will produce an output signal with a relatively narrow ± 1 kHz bandwidth. The time-domain waveform required to produce this narrow frequency band typically resembles a traditional sinc function. This waveform is usually generated digitally at baseband and then up converted by a mixer to the appropriate centre frequency. Traditional transmit implementations require relatively low-speed digital-to-analog converters (DACs) to generate the baseband waveform, as the bandwidth of this signal is relatively small.

Image Signal Processing

Both frequency and phase data are collected in what is commonly referred to as the k-space. A two-dimensional Fourier transform of this k-space is computed by a display processor/computer to produce a grey-scale image.

ECG

All ECGs pick up heart signals through electrodes connected externally to specific locations on the body. The heart signals are generated by the body and have amplitudes of a few millivolts. The specific locations of the electrodes allow the heart's electrical activity to be viewed from different angles, each of which is displayed as a channel on the ECG printout. Each channel represents the differential voltage between two of the electrodes, or the differential voltage between one electrode and the average voltage from several electrodes. The different combinations of electrodes allow more channels to be displayed than there are electrodes. The channels are commonly referred to as "leads," so a 12-lead ECG device has 12 separate channels displayed graphically. The number of leads varies from 1 to 12 depending on the application. Unfortunately, the wires running to the electrodes are occasionally referred to as leads as well. This can create confusion, as a 12-lead (12-channel) ECG device only requires 10 electrodes (10 wires), so be careful of the context in which "lead" is used. In addition to the biological signals, most ECGs also detect two manmade signals. The most important of these signals comes from implanted pacemakers and is referred to simply as "pace." The pace signal is relatively short, tens of microseconds to a couple of milliseconds, with an amplitude ranging from a few millivolts to nearly a volt. Often, the ECG must detect the presence of a pace signal while simultaneously preventing it from distorting the signals from the heart.



The second manmade signal is for detecting "lead-off," which is when an electrode is making poor electrical contact. Many ECG devices must provide an alert when this poor contact occurs. Therefore, the ECG device generates a signal to measure the impedance between the electrode and the body for detecting a lead-off occurrence. The measurement may be AC, DC, or both. In some ECG devices, respiration rate is also detected by analysing the impedance from the lead-off measurement. Lead-off detection is continuous and should not interfere with accurate measurement of the heart signals.

Modern heart rate monitors usually comprise two elements: a chest strap transmitter [needs update] and a wrist receiver (which usually is a smartwatch). In early plastic straps, water or liquid was required to get good performance. Early units have used conductive smart fabric with built-in microprocessors that analyse the electrical activity to determine the heart rate similar to an EKG. More recent devices use optics to measure heart rate by which measures changes in blood flow by shining a light from an LED through the skin and measuring how it scatters off blood vessels.

PULSE RATE MONITOR

Strapless heart rate monitors (often referred to as "wearables") now allow the user to just touch two sensors on a smartwatch display for a few seconds to view heart rate data. These are popular for comfort and ease of use, though they don't give as much detail as monitors that use a chest strap. Some models of these variations of heart rate monitors use either infrared light or red visible light to measure the heart rate, as opposed to two or more electrodes. In addition to measuring the heart rate, devices using this technology are able to measure blood oxygen saturation (SpO₂)

More advanced models offer measurements of heart rate variability, activity, and breathing rate to assess parameters relating to a subject's fitness. Sensor fusion algorithms allow these monitors to detect core temperature and dehydration.

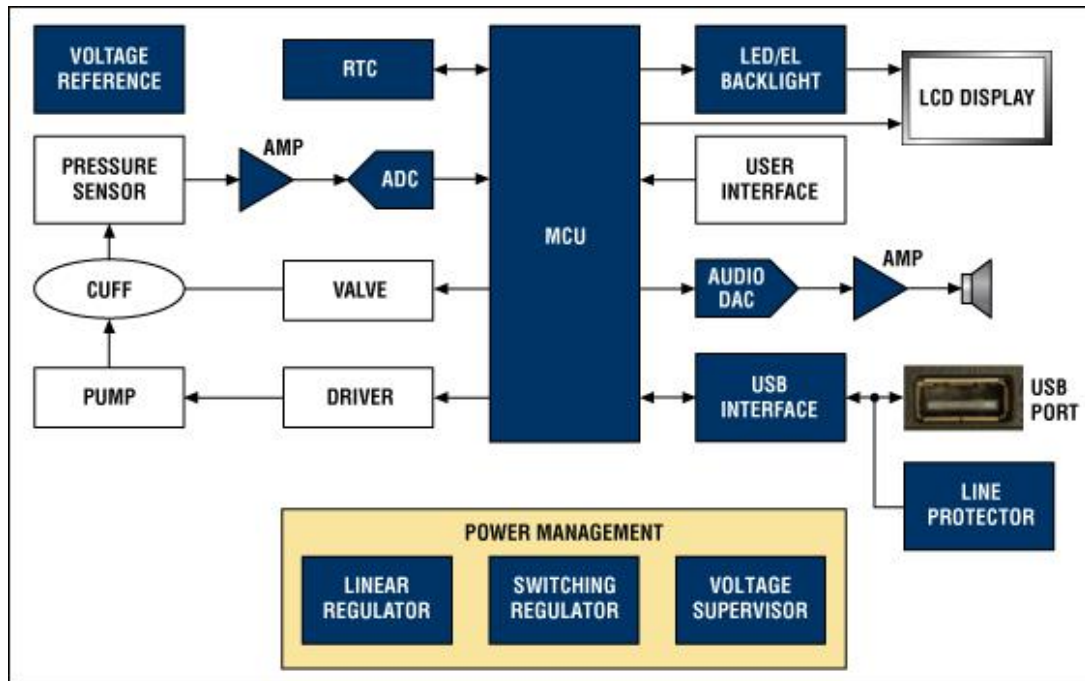
Another style of heart rate monitor replaces the plastic around-the-chest strap with fabric sensors - the most common of these is a sports bra that includes sensors in the fabric.

In old versions, when a heartbeat is detected a radio signal is transmitted, which the receiver uses to determine the current heart rate. This signal can be a simple radio pulse or a unique coded signal from the chest strap (such as Bluetooth, ANT, or other low-power radio link); the latter prevents one user's receiver from using signals from other nearby transmitters (known as cross-talk interference).



Newer versions include a microprocessor, which simultaneously monitors heart rate, SpO₂, and other parameters. These may include sensors such as accelerometers, gyroscopes, and GPS to detect speed, location and distance eliminating the need for ankle worn devices.

There are a wide number of receiver designs, with various features. These include average heart rate over exercise period, time in a specific heart rate zone, calories burned, breathing rate, built-in speed and distance, and detailed logging that can be downloaded to a computer. The receiver can be built into a smartwatch or smartphone. Bracelets with integrated sensors work optically, and have poor accuracy.



BLOOD PRESSURE MONITOR

A blood pressure monitor, or sphygmomanometer, uses an inflatable air-bladder cuff and a listening device or pressure sensor to measure blood pressure in an artery. This monitoring can be performed by using either of two methods: a manually inflated cuff with a stethoscope for listening to arterial wall sounds (the auscultatory method), or a blood pressure monitor that contains a pressure sensor for sensing arterial wall vibrations (the oscillometric method).

Automatic Monitor Types

The two main types of automatic blood pressure monitors are upper-arm and wrist models. The upper-arm model has a cuff that is placed on the upper arm; the cuff is connected by a tube to the monitor that rests on a surface near the arm. The wrist model is smaller and the entire unit wraps around the wrist—this is a much more space-critical design. Some upper-arm models require manual inflation of the cuff, but most upper-arm and all wrist models are fully automatic.

Measurement Techniques

An automatic blood pressure monitor inflates a cuff surrounding an arm with sufficient pressure to prevent blood flow in the local main artery. This pressure is gradually released until the moment that the blood begins to flow through the artery, the measurement of which determines the systolic pressure. Pulse rate is also sensed at this time. The measurement taken when the blood flow is no longer restricted determines the diastolic pressure. This complete measurement cycle is performed automatically with a pump, cuff, valve, and pressure sensor.

The signal from the pressure sensor is conditioned with an op-amp circuit or by an instrumentation amplifier before data conversion by an analog-to-digital converter (ADC). The systolic pressure, diastolic pressure, and pulse rate are then calculated in the digital domain using a method appropriate for the type of monitor and sensor utilized. The resulting systolic, diastolic, and pulse-rate measurements are displayed on a liquid-crystal display (LCD), time/date-stamped, and stored in non-volatile memory.

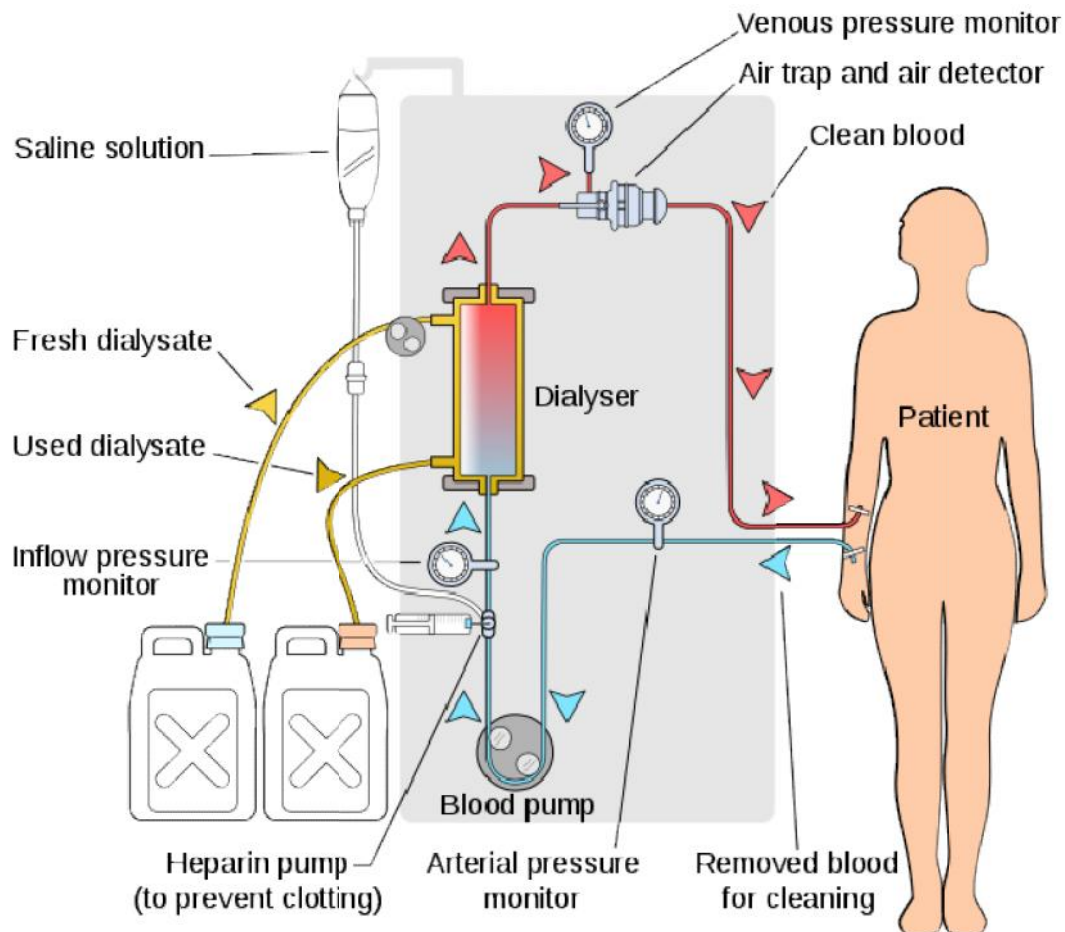
HAEMODIALYSIS

Haemodialysis, commonly called kidney dialysis or simply dialysis, is a process of purifying the blood of a person whose kidneys are not working normally. This type of dialysis achieves the extracorporeal removal of waste products such as creatinine and urea and free water from the blood when the kidneys are in a state of kidney failure.

The principle of haemodialysis is the same as other methods of dialysis; it involves diffusion of solutes across a semipermeable membrane. Haemodialysis utilizes counter current flow, where the dialysate is flowing in the opposite direction to blood flow in the extracorporeal circuit. Counter-current flow maintains the concentration gradient across the membrane at a maximum and increases the efficiency of the dialysis.

Fluid removal (ultrafiltration) is achieved by altering the hydrostatic pressure of the dialysate compartment, causing free water and some dissolved solutes to move across the membrane along a created pressure gradient.

The dialysis solution that is used may be a sterilized solution of mineral ions. Urea and other waste products, potassium, and phosphate diffuse into the dialysis solution. However, concentrations of sodium and chloride are similar to those of normal plasma to prevent loss. Sodium bicarbonate is added in a higher concentration than plasma to correct blood acidity. A small amount of glucose is also commonly used.



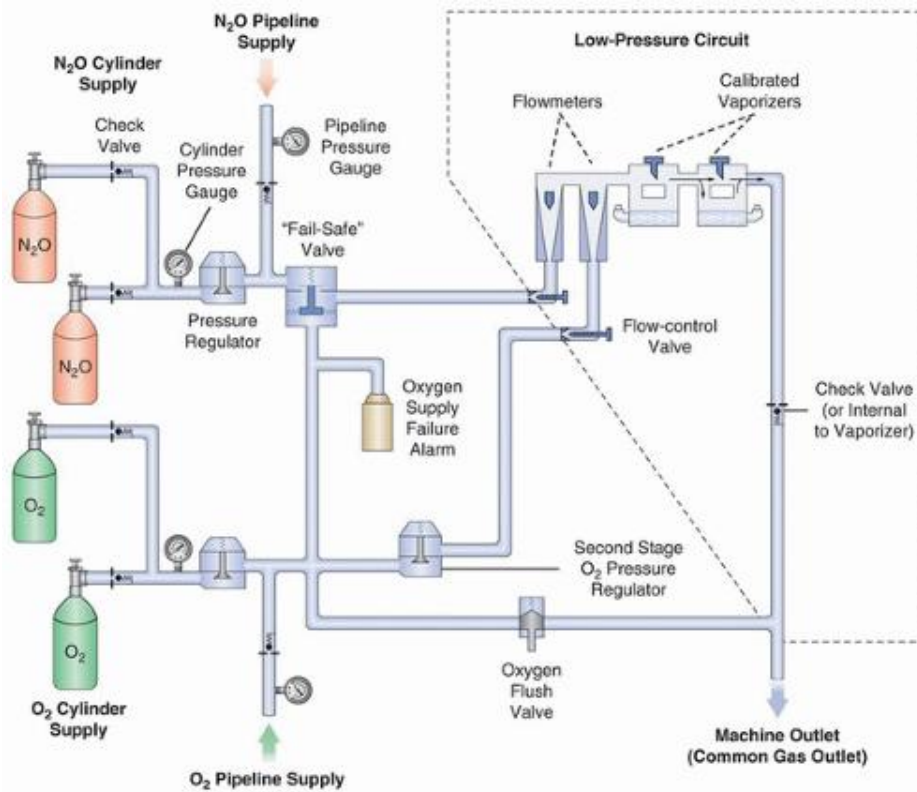
DIALYZER

The dialyzer is the piece of equipment that actually filters the blood. Almost all dialyzers in use today are of the hollow-fibre variety. A cylindrical bundle of hollow fibres, whose walls are composed of semi-permeable membrane, is anchored at each end into potting compound (a sort of glue). This assembly is then put into a clear plastic cylindrical shell with four openings. One opening or blood port at each end of the cylinder communicates with each end of the bundle of hollow fibres. This forms the "blood compartment" of the dialyzer.

Two other ports are cut into the side of the cylinder. These communicate with the space around the hollow fibres, the "dialysate compartment." Blood is pumped via the blood ports through this bundle of very thin capillary-like tubes, and the dialysate is pumped through the space surrounding the fibres. Pressure gradients are applied when necessary to move fluid from the blood to the dialysate compartment.

ANAESTHESIA MACHINE

Anaesthesia machine (US English) or Boyle's machine is used independently by physician anaesthesiologists and nurse anaesthetists. Anaesthesiologist assistants also use anaesthesia machines under the direct supervision of physician anaesthesiologists. Anaesthesia machines are used to support the administration of anaesthesia. The most common type of anaesthetic machine in use in the developed world is the continuous-flow anaesthetic machine, which is designed to provide an accurate and continuous supply of medical gases (such as oxygen and nitrous oxide), mixed with an accurate concentration of anaesthetic vapour (such as isoflurane), and deliver this to the patient at a safe pressure and flow. Modern machines incorporate a ventilator, suction unit, and patient monitoring devices.



A modern anaesthesia machine includes the following components:

- Connections to piped hospital oxygen, medical air, and nitrous oxide.
- Reserve gas cylinders of oxygen, air, and nitrous oxide attached via a specific yoke with a Bodok seal.
- A high-flow oxygen flush which provides pure oxygen at 30-75 litres/minute
- Pressure gauges, regulators and 'pop-off' valves, to protect the machine components and patient from high-pressure gases
- Flow meters (rotameters) for oxygen, air, and nitrous oxide, low Flow meters' oxygen nitrous oxide
- Updated vaporizers to provide accurate dosage control when using volatile anaesthetics such as isoflurane and sevoflurane
- An integrated ventilator to properly ventilate the patient during administration of anaesthesia
- A manual ventilation bag in combination with an Adjustable Pressure Limiting (APL) valve
- Systems for monitoring the gases being administered to, and exhaled by the patient
- Systems for monitoring the patient's heart rate, ECG, blood pressure and oxygen saturation, in some cases with additional options for monitoring end-tidal carbon dioxide and temperature
- Breathing circuits, circle attachment, or a Bain's breathing system

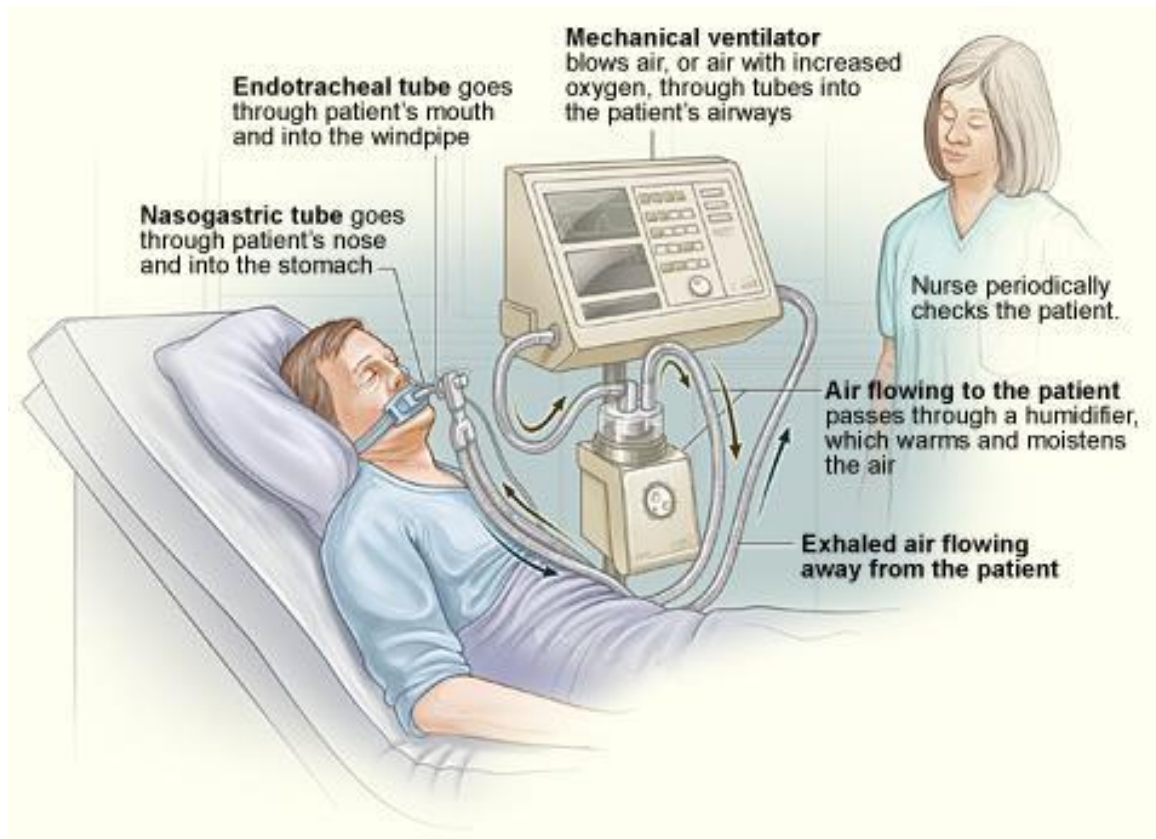
VENTILATOR

A medical ventilator (or simply ventilator in context) is a mechanical ventilator, a machine designed to move breathable air into and out of the lungs, to provide breathing for a patient who is physically unable to breathe, or breathing insufficiently. While modern ventilators are computerized machines, patients can be ventilated with a simple, hand-operated bag valve mask. Ventilators are chiefly used in intensive care medicine, home care, and emergency medicine (as standalone units) and in anaesthesia (as a component of an anaesthesia machine).

Function: - In its simplest form, a modern positive pressure ventilator consists of a compressible air reservoir or turbine, air and oxygen supplies, a set of valves and tubes, and a disposable or reusable "patient circuit". The air reservoir is pneumatically compressed several times a minute to deliver room-air, or in most cases, an air/oxygen mixture to the patient. If a turbine is used, the turbine pushes air through the ventilator, with a flow valve adjusting

pressure to meet patient-specific parameters. When over pressure is released, the patient will exhale passively due to the lungs' elasticity, the exhaled air being released usually through a one-way valve within the patient circuit called the patient manifold. Ventilators may also be equipped with monitoring and alarm systems for patient-related parameters (e.g. pressure, volume, and flow) and ventilator function (e.g. air leakage, power failure, mechanical failure), backup batteries, oxygen tanks, and remote control. The pneumatic system is nowadays often replaced by a computer-controlled turbo pump. Modern ventilators are electronically controlled by a small embedded system to allow exact adaptation of pressure and flow characteristics to an individual patient's needs. Fine-tuned ventilator settings also serve to make ventilation more tolerable and comfortable for the patient. In Canada and the United States, respiratory therapists are responsible for tuning these settings, while biomedical technologists are responsible for the maintenance. The patient circuit usually consists of a set of three durables, yet lightweight plastic tubes, separated by function (e.g. inhaled air, patient pressure, exhaled air). Determined by the type of ventilation needed, the patient-end of the circuit may be either non-invasive or invasive. Non-invasive methods, which are adequate for patients who require a ventilator only while sleeping and resting, mainly employ a nasal mask. Invasive methods require intubation, which for long-term ventilator dependence will normally be a tracheotomy cannula, as this is much more comfortable and practical for long-term care than is larynx or nasal intubation.

Life-critical system: -Because failure may result in death, mechanical ventilation systems are classified as a life-critical system, and precautions must be taken to ensure that they are highly reliable, including their power-supply. Mechanical ventilators are therefore carefully designed so that no single point of failure can endanger the patient. They may have manual backup mechanisms to enable hand-driven respiration in the absence of power (such as the mechanical ventilator integrated into an anaesthetic machine). They may also have safety valves, which open to atmosphere in the absence of power to act as an anti-suffocation valve for spontaneous breathing of the patient. Some systems are also equipped with compressed-gas tanks, air compressors, and/or backup batteries to provide ventilation in case of power failure or defective gas supplies, and methods to operate or call for help if their mechanisms or software fail.



HEART LUNG MACHINE

The heart–lung machine is a system which takes over the function of the heart and the lungs with sufficient safety to maintain life while the heart is stopped or opened to allow surgery on the coronary arteries or the heart valves, or to allow repair of congenital abnormalities.

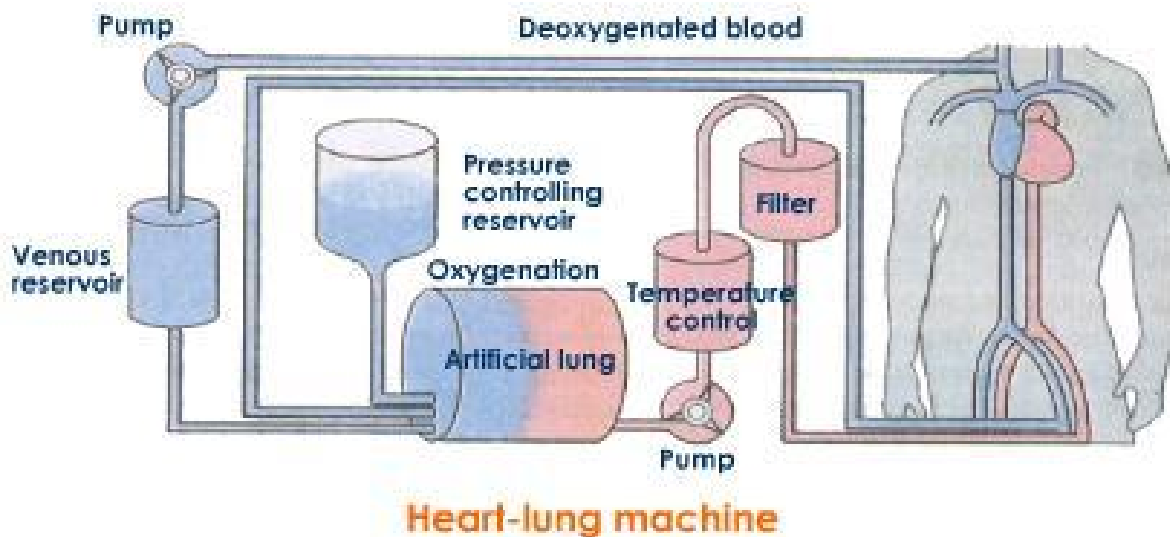
While in theory it is only necessary to bypass the function of the heart, it soon became apparent that in practice it is simpler to bypass the function of both the heart and the lungs. The main components of a heart–lung machine are a pump (to provide the driving force to the blood in the arterial system), an oxygenator (for exchange of oxygen and carbon dioxide), and a heat exchanger (to allow control of temperature of the body). The connecting tubing and filter are other components of the heart–lung bypass circuit.

Venous blood is siphoned from the body via a tube in the right atrium of the heart, or via two tubes in the major veins which converge on the heart. It is pumped through the oxygenator and heat exchanger, and returned via a plastic

tube into the arterial system of the body — usually at the upper portion of the ascending aorta.

The design of pump which is in most common use today is the roller pump — a simple rotating arm carrying rollers which compress a loop of polymeric tubing against a solid surface. Speed of rotation of the roller-bearing arm is controlled to allow a pumping rate similar to that of the normal heart at rest (about 2.4 litres/min/m² body surface — or typically about 5 litres/min in an adult).

There are two main types of oxygenator in use at present. ‘Bubble oxygenators’ expose the passing blood to a stream of gaseous bubbles composed of 95% oxygen and 5% carbon dioxide. Gas exchange with the blood occurs on the surface of the bubbles and results in reasonably normal levels of oxygenation of the blood and maintains carbon dioxide in the normal physiological range. The bubble oxygenator has a sponge-like filter and reservoir to enable gaseous bubbles to be removed from the oxygenated blood before it is pumped back to the body.



Membrane oxygenators consist of a series of fine tubes which allow diffusion of oxygen and carbon dioxide between the blood flowing through them and the ventilating gas surrounding them (or vice versa).

The oxygenator also combines with a heat exchanger — a system of tubes through which the blood passes, surrounded by circulating water at controlled temperature. This allows the blood temperature to be maintained (counteracting the heat loss during the passage of blood through the heart–lung machine). It also allows deliberate cooling and subsequent rewarming of

the blood, giving the surgeon the option of reducing, or even stopping, the circulation of the blood around the body for a period of time with safety, because the oxygen requirement of the body is reduced by hypothermia.

The connecting tubes, the oxygenator, and the pump tubing are all filled with a physiologically compatible fluid (priming fluid) prior to final connection with the circulation of the body. Avoidance of air bubbles in the heart–lung circuit is of vital importance. Exposure of blood to the foreign surfaces of the heart–lung machine initiates the natural clotting mechanisms of the body, and this must be inhibited by giving the drug heparin to the patient before allowing the circulation to be taken over by the heart–lung machine. Normal blood clotting is restored after the operation by the administration of protamine, which neutralizes the heparin.

MUSCLE SIMULATOR

Electrical muscle stimulation (EMS), also known as neuromuscular electrical stimulation (NMES) or electromyostimulation, is the elicitation of muscle contraction using electric impulses. EMS has received an increasing amount of attention in the last few years for many reasons: it can be utilized as a strength training tool for healthy subjects and athletes; it could be used as a rehabilitation and preventive tool for partially or totally immobilized patients; it could be utilized as a testing tool for evaluating the neural and/or muscular function in vivo; it could be used as a post-exercise recovery tool for athletes.[1] The impulses are generated by a device and are delivered through electrodes on the skin near to the muscles being stimulated. The electrodes are generally pads that adhere to the skin. The impulses mimic the action potential that comes from the central nervous system, causing the muscles to contract.

Electronic muscle stimulation (EMS) may help you to strengthen weak muscles. There are several theories on how EMS may assist muscle strengthening.

One potential reason is that when you maximally contract a muscle, at best, only 30% of all your muscle fibres are in a state of contraction. The remaining 70% are dormant and awaiting recruitment when the contracting fibres fatigue. With EMS you can potentially electrically stimulate these resting muscle fibres to improve their strength. Clinically, EMS appears to be more effective when the muscles are very weak and you have difficulty performing normal anti-gravity exercises.

Another reason that EMS potentially works is via an improvement in the recruitment of nerve conduction rates. Explained simply, it takes approximately 10000 repetitions for your brain to learn how to quickly send a message to your muscles via the quickest nerve pathways. This contraction pattern becomes your "memory engram". The more frequent your muscle is recruited the better your body becomes at finding the quickest way to recruit that muscle. EMS can potentially provide you with repeated contractions to accelerate this learning process.

To achieve your best outcome, we recommend that you seek professional advice on how to best utilise your EMS machine from your local physiotherapist who specialises in EMS muscle retraining.

HEARING AIDS

A hearing aid is a device designed to improve hearing by making sound audible to a person with hearing loss. Hearing aids are classified as medical devices in most countries, and regulated by the respective regulations. Small audio amplifiers such as PSAPs or other plain sound reinforcing systems cannot be sold as "hearing aids".

Early devices, such as ear trumpets or ear horns, were passive amplification cones designed to gather sound energy and direct it into the ear canal. Modern devices are computerised electroacoustic systems that transform environmental sound to make it audible, according to audio metrical and cognitive rules. Modern devices also utilize sophisticated digital signal processing to try and improve speech intelligibility and comfort for the user. Such signal processing includes feedback management, wide dynamic range compression, directionality, frequency lowering, and noise reduction.

Modern hearing aids require configuration to match the hearing loss, physical features, and lifestyle of the wearer. This process is called "fitting" and is performed by audiologists. The amount of benefit a hearing aid delivers depends in large part on the quality of its fitting. Almost all hearing aids in use in the US are digital hearing aids. Devices similar to hearing aids include the Osseo integrated auditory prosthesis (formerly called the bone anchored hearing aid) and cochlear implant.

Hearing aids are used for a variety of pathologies including sensorineural hearing loss, conductive hearing loss, and single-sided deafness. Hearing aid

candidacy is typically determined by an audiologist, who will also fit the device based on the nature and degree of the hearing loss being treated.

The amount of benefit experienced by the user of the hearing aid is multi-factorial, depending on the type, severity, and aetiology of the hearing loss, the technology and fitting of the device, and on the motivation, personality, lifestyle, and overall health of the user.

NEBULIZER

In medicine, a nebulizer is a drug delivery device used to administer medication in the form of a mist inhaled into the lungs. Nebulizers are commonly used for the treatment of cystic fibrosis, asthma, COPD and other respiratory diseases or disorders.

Analytical nebulizers are another form of nebulizer and are used primarily in laboratory settings for elemental analysis.

Nebulizers use oxygen, compressed air or ultrasonic power to break up solutions and suspensions into small aerosol droplets that can be directly inhaled from the mouthpiece of the device. An aerosol is a mixture of gas and solid or liquid particles.

Soft mist inhaler The medical company Boehringer Ingelheim also invented a new device named Respimat Soft Mist Inhaler in 1997. This new technology provides a metered dose to the user, as the liquid bottom of the inhaler is rotated clockwise 180 degrees by hand, adding a build-up tension into a spring around the flexible liquid container. When the user activates the bottom of the inhaler, the energy from the spring is released and imposes pressure on the flexible liquid container, causing liquid to spray out of 2 nozzles, thus forming a soft mist to be inhaled.

Jet nebulizer The most commonly used nebulizers are jet nebulizers, which are also called "atomizers". Jet nebulizers are connected by tubing to a compressor, that causes compressed air or oxygen to flow at high velocity through a liquid medicine to turn it into an aerosol, which is then inhaled by the patient. Currently there seems to be a tendency among physicians to prefer prescription of a pressurized Metered Dose Inhaler (pMDI) for their patients, instead of a jet nebulizer that generates a lot more noise (often 60 dB during use) and is less portable due to a heavier weight. However, jet nebulizers are commonly used for patients in hospitals who have difficulty using inhalers,

such as in serious cases of respiratory disease, or severe asthma attacks. The main advantage of the jet nebulizer is related to its low operational cost.

Ultrasonic wave nebulizer Ultrasonic wave nebulizers were invented in 1964[citation needed] as a new type of portable nebulizer. The technology inside an ultrasonic wave nebulizer is to have an electronic oscillator generate a high frequency ultrasonic wave, which causes the mechanical vibration of a piezoelectric element. This vibrating element is in contact with a liquid reservoir and its high frequency vibration is sufficient to produce a vapour mist. As they create aerosols from ultrasonic vibration instead of using a heavy air compressor, they only have a weight around 170 grams (6.0 oz.). Another advantage is that the ultrasonic vibration is almost silent.

Vibrating mesh technology, a new significant innovation was made in the nebulizer market around 2005, with creation of the ultrasonic Vibrating Mesh Technology (VMT). With this technology a mesh/membrane with 1000-7000 laser drilled holes vibrates at the top of the liquid reservoir, and thereby pressures out a mist of very fine droplets through the holes. This technology is more efficient than having a vibrating piezoelectric element at the bottom of the liquid reservoir, and thereby shorter treatment times are also achieved. The old problems found with the ultrasonic wave nebulizer, having too much liquid waste and undesired heating of the medical liquid, have also been solved by the new vibrating mesh nebulizers.



CHAPTER-3

BIO SIGNALS

A bio signal is any signal in living beings that can be continually measured and monitored. The term bio signal is often used to refer to bioelectrical signals, but it may refer to both electrical and non-electrical signals. The usual understanding is to refer only to time-varying signals, although spatial parameter variations (e.g. the nucleotide sequence determining the genetic code) are sometimes subsumed as well.

Electrical biosignals[edit]

Electrical biosignals, or bioelectrical time signals, usually refers to the change in electric current produced by the sum of an electrical potential difference across a specialized tissue, organ or cell system like the nervous system. Thus, among the best-known bioelectrical signals are:

- Electroencephalogram (EEG)
- Electrocardiogram (ECG)
- Electromyogram (EMG)
- Mechanomyogram (MMG)
- Electrooculography (EOG)
- Galvanic skin response (GSR)
- Magneto encephalogram (MEG)

EEG, ECG, EOG and EMG are measured with a differential amplifier which registers the difference between two electrodes attached to the skin. However, the galvanic skin response measures electrical resistance and the MEG measures the magnetic field induced by electrical currents (electroencephalogram) of the brain.

With the development of methods for remote measurement of electric fields using new sensor technology, electric biosignals such as EEG and ECG can be measured without electric contact with the skin. This can be applied for example for remote monitoring of brain waves and heartbeat of patients who must not be touched, in particular patients with serious burns.

Electrical currents and changes in electrical resistances across tissues can also be measured from plants.

Biosignals may also refer to any non-electrical signal that is capable of being monitored from biological beings, such as mechanical signals (e.g. the mechanomyogram or MMG), acoustic signals (e.g. phonetic and non-phonetic utterances, breathing), chemical signals (e.g. pH, oxygenation) and optical signals (e.g. movements).

BIO ELECTRODES

Bio electrodes function as an interface between biological structures and electronic systems. Electrical activity within the biological structure is either sensed or stimulated. The electrical systems are either passively sensing (measuring) or actively stimulating (inducing) electrical potentials within the biological structure or unit.

Electrical currents are generated by many biological structures. Currents give rise to potential differences that can be measured using electrodes and can be interpreted to gain insight in the functioning of the source structure. Conversely, current can be applied to the biological structure through electrodes to affect the target.

The same electrode may function either passively or actively, depending on the purpose and the electronic system controls. An example seen on TV is the large defibrillation paddles used by paramedics to resuscitate people in cardiac distress. When the paddles are applied to a patient, the electrical system is programmed to first passively sense the electrical activity (or lack of) within the heart. Then the electrical system uses algorithms to determine if a stimulation (shock) is required, and finally to provide the appropriate electrical stimulation.

The size of bio electrodes ranges from microscopic intra-cellular research electrodes to large (3 x 5-inch) defibrillation paddles.

Most bio electrodes are made of metal, but the microscopic intra-cellular research electrodes are glass capillary tubes filled with a conductive saline solution.

CONTACT IMPEDANCE

Electrical Impedance Tomography (EIT) applies current and measures the resulting voltage on the surface of a target. In biomedical applications, this current is applied, and voltage is measured, through electrodes attached to the body. Models are used to represent these electrode connections in the reconstruction of the conductivity image, tying circuit models to Finite Element

Method (FEM) simulations. Changes in the contact impedance or boundary shape relative to the electrode's surface area can introduce artifacts in the reconstructed image. The quantity and quality of these artifacts is dependent upon the electrode model and the properties assigned to that model. The electrode models were originally formulated in the context of mathematical proofs of solution existence and uniqueness for EIT (Calderón 2006, Nachman 1996). The Complete Electrode Model (CEM) allows a complex impedance for each electrode that models the metal electrode, conductive gel and chemical interaction at the skin electrode interface (Cheng et al. 1989, Somersalo et al. 1992). The FEM is used in the numerical solution of EIT images. The simplest electrode model to implement in the FEM is the Point Electrode Model (PEM) which applies current and measures voltage at single nodes on the boundary and requires no further equations to implement. The PEM does not consider the geometry or contact impedance of an electrode. To reconstruct accurate images from in vivo data, an accurate electrode model is frequently required, and thus, the CEM is generally preferred (Cheng et al. 1989). (Figure 1)

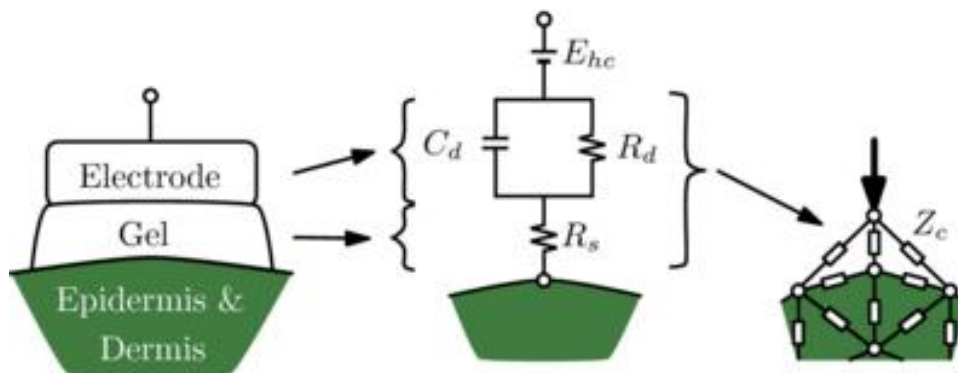


Figure 1 Generalized electrode model

Electrodes in Biomedical Instrumentation

Electrodes are devices that convert ionic potentials into electronic potentials. The type of electrode used for the measurements depends on the anatomical location of the bioelectric event to be measured. In order to process the signal in electronic circuits, it will be better to convert ionic conduction into electronic conduction. So simply bio-electrodes are a class of sensors that transduces ionic conduction into electronic conduction. The purpose of bio-electrodes is to acquire bioelectrical signals such as ECG, EMG, EEG etc. Electrodes are mainly classified into two. They are perfectly polarized electrodes and perfectly non-polarized electrodes. There are a wide variety of electrodes which can be used to measure bioelectric events. The three main classes of electrodes are Microelectrodes, Body Surface electrodes and Needle electrodes.

A. **Microelectrodes** are electrodes with tips having tips sufficiently small enough to penetrate a single cell in order to obtain readings from within the cell. The tips must be small enough to permit penetration without damaging the minute cell. The main functions of microelectrodes are potential recording and current injection. Microelectrodes are having high impedances in mega ohm range because of their smaller size. Microelectrodes are generally of two types. With the use of a microelectrode or an array of microelectrodes, researchers can gather all sort of information regarding living organism.

- Metal type
- Micropipette type

a. **Metal microelectrode:** Metal microelectrodes are formed by electrolytic ally etching the tip of fine tungsten to the desired size and dimension. Then the wire is coated almost to the tip with any type of insulating material. The metal-ion interface takes place where the metal tip contacts the electrolyte. The main features of metal microelectrodes are

1. Very good S/N ratio
2. Strong enough to penetrate
3. High biocompatibility



b. **Micropipette:** The micropipette type of microelectrode is a glass micropipette with its tip drawn out to the desired size. The micropipette is filled with an electrolyte which should be compatible with the cellular fluids. A micropipette is a small and extremely fine pointed pipette used in making microinjections. A commercial type of micropipette is shown in figure below.

B. **Body Surface Electrodes:**

Surface electrodes are those which are placed in contact with the skin of the subject in order to obtain bioelectric potentials from the surface. Body surface electrodes are of many sizes and types. In spite of the type, any surface electrode can be used to sense ECG, EEG, EMG etc. The various types of body surface electrodes are discussed below. Major body surface electrodes are

1. **Immersion electrodes:** They are one of the first type of bioelectric

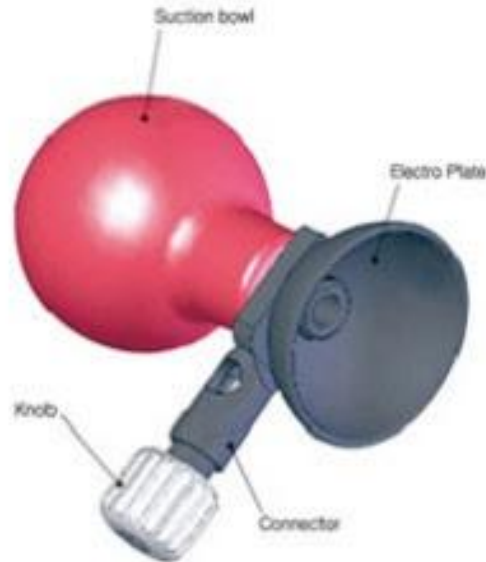
measuring electrodes. Immersion electrodes were simply buckets of saline solution in which the subject placed his hands and feet. So it was not a comfortable type of measurement and hence it was replaced with plate electrodes.

2. **Plate electrodes:** These electrodes were separated from subject's skin by cotton pads soaked in a strong saline solution. The plate electrodes have generally smaller contact area and they do not totally seal on the patient. The electrode slippage and displacement of plates were the major difficulties faced by these type of electrodes because they have a tendency to lose their adhesive ability as a result of contact with fluids on or near the patient. Since these types of electrodes were very sensitive, it led to measurement errors.

3. **Floating electrodes:** These types of electrodes can eliminate the movement errors (called artifacts) which is a main problem with plate electrodes. This is done by avoiding any direct contact of the metal with the skin. So the main advantage of floating electrodes is mechanical reliability. Here the conductive path between the metal and the skin is the electrolyte paste or jelly.

4. **Disposable electrodes:** Normally plate electrodes, floating electrodes etc. can be used more than one time. This requires the cleaning and cares after each use. We can use disposable electrodes which can be used only once and be disposed after the use. These types of electrodes are now widely used.

5. **Suction electrodes:** These type of electrodes are well suited for the attachment to flat surfaces of body and to regions where the underlying tissue is soft, due to the presence of contact surface. An advantage of these type of electrodes is that it has a small surface area. These types of electrodes are mainly used for the measurement of ECG. Suction electrodes used a plastic syringe barrel to house suction tubing and input cables to an AC amplifier.



6. **Ear clip & Scalp electrodes:** These type of electrodes is widely used in the measurement of EEG exclusively. Scalp electrodes can provide EEG easily by placing it over bare head. A typical ear clip electrode is shown in figure below. The most common method for EEG measurement is 10 – 20 electrode placement system and here we use scalp electrode usually. They can avoid measurement errors and movement errors. During labour internal monitoring may be needed and is usually in the form of an electrode placed under the baby's scalp. It is called fetal scalp electrode which is used to monitor baby's heartbeat while still in uterus.



C. Needle Electrodes:

To reduce the interface and noise (artifact) caused due to electrode movement, during the measurement of EEG, EMG etc. we can use small sub-dermal needle electrodes which penetrate the scalp. Actually the needle electrodes are not inserted into the brain. They nearly penetrate the skin. Generally they are simply inserted through a small section of the skin just beneath the skin parallel to it.



The needle electrodes for EMG measurement consist of fine insulated wires placed in such a way that their tips are in contact with the muscle, nerve or other tissues from which the measurement is made. The needle creates the hole necessary for insertion and the wires forming the electrodes are carried inside it. A typical EEG needle electrode is shown in figure.

One of the main advantage of needle electrodes is that they are less susceptible to movement errors than surface electrodes. Also the needle electrodes have lower impedances when compared to surface electrodes as it makes direct contact with the sub-dermal tissues or intracellular fluid.

CHAPTER-4

TELEMETRY BIO POTENTIAL (ECG, EMG, EEG) DATA

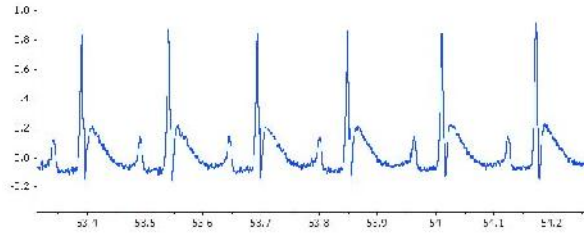
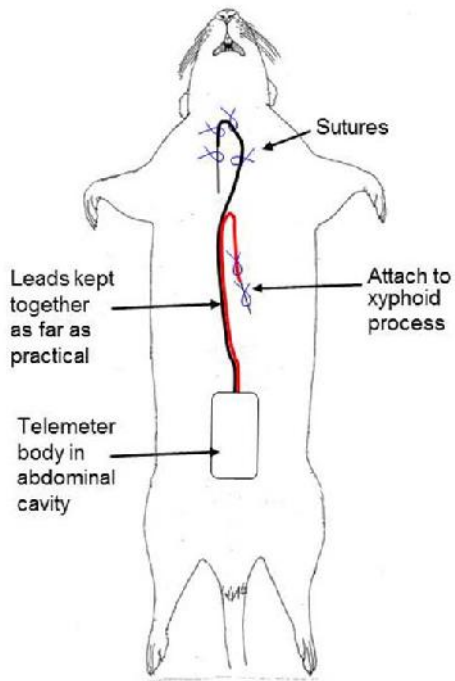
Bio potential telemetry measures the electrical potential between two electrodes/leads. Depending on where the leads are placed, bio potential telemetry can be used to measure long-term electrocardiogram (ECG), electroencephalogram (EEG) and electromyogram (EMG) in rats and mice. The [Rat Telemetry System](#) offers solutions for the long term recording of a single bio potential signal using our [TR50B](#) or simultaneous recording of two bio potential signals (e.g. EEG+EMG) with our [TR50BB](#) telemeters. For mice, Mouse Telemetry offers the [MT10B](#) telemeter for the long term recording of a single bio potential signal.

ELECTROCARDIOGRAPHY – ECG OR EKG

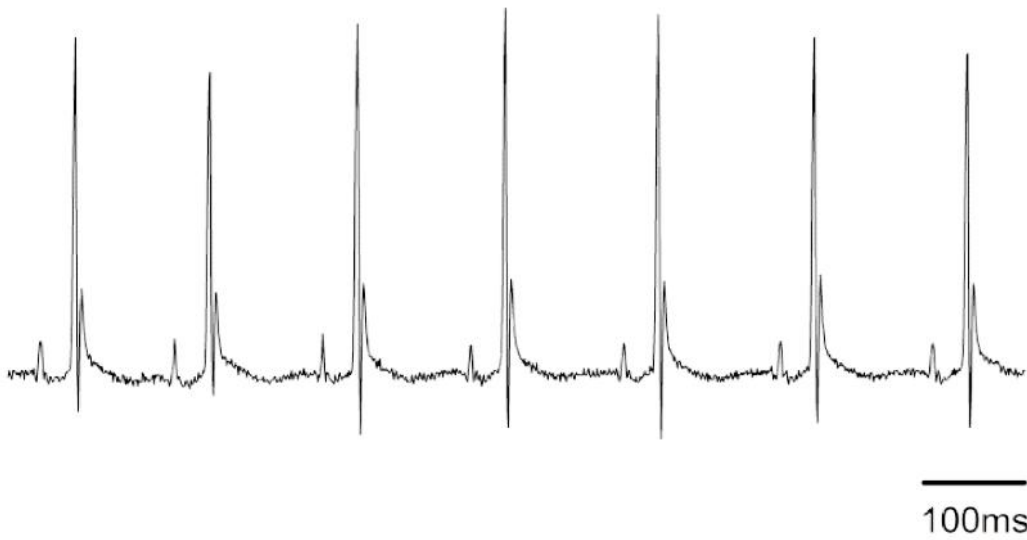
ECG records the net change in electrical activity across the heart with each heartbeat over time. Under normal conditions, the mechanical activity is temporally linked with the electrical activity. Changes in the electrical potential from the depolarization of the myocardium result in muscular contraction in the region of depolarization while repolarization results in the relaxation. The wave of depolarization in each heart beat originates from the sinoatrial node, travels through the atria to the atrial-ventricular node, then travels down the ventricular septum and up walls of the ventricles.

The P, QRS and T waves recorded in an ECG represent the change in electrical potential during the depolarization of the atria, the depolarization of the ventricles (and the simultaneous repolarization of the atria), and the repolarization of the ventricles respectively.

Clinically, ECG is recorded using 12 lead positions to generate information about how the electrical activity propagates in 3 dimensions. In rats and mice, telemetry ECG is often recorded using two electrodes recording a single lead configuration. Depending on the position of the electrodes and lead configuration, different ECG profiles are seen. The modified lead II position of an ECG in a rat is shown in the figure below. The lead wire positions have been adjusted slightly from the standard lead II position, which is most in line with the ventricles, to improve signal quality when the rat or mouse is moving around.



Example placement of electrode leads for recording of high quality ECG in the modified lead II configuration (left) and signal recorded (above).



Adjusting the position of the electrodes to record from different ECG lead configurations changes the relative size of the P, QRS and T waves, which allows detailed focus on one event. Good muscle contact will be required for large clean telemetry ECG signals as electrical conductance through connective tissue is poor. It is also

important to keep the lead wires together as far as practical and avoid curling the leads into a loop to minimize interference from ambient electrical noise.

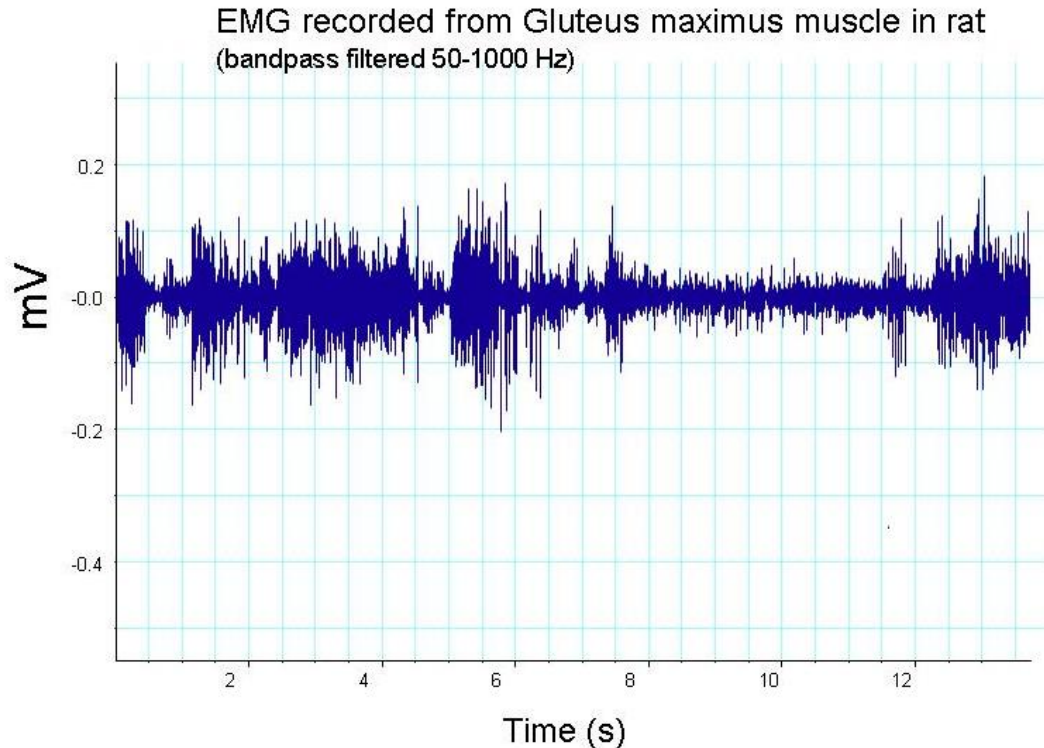
The most common use for ECG is the measurement of heart rate, which can be calculated by the number of R waves in a given period of time. In addition to the detection of the heart rate, the ECG can be used to record:

- heart rate variability (R-R intervals)
- duration of depolarization of the atria (P wave duration) or ventricles (QRS duration)
- arrhythmias and counts of P, QRS, T waves
- electrical conductance across the heart and waveform abnormalities
- relative amplitudes of the waveforms can also be calculated
- These measurements can be useful in basic cardiovascular physiology, behavioural or pharmacological/toxicology studies.

ELECTROMYOGRAPHY - EMG

EMG records the electrical potential and the change in potential (electrical activity) across the skeletal muscle. The electrical potential changes during contraction and relaxation of the skeletal muscle as the muscle depolarizes and then repolarizes. EMG can be used to assess the muscle contraction, mechanics or inferring movement rates across the muscle. For example, attaching the lead wires to the diaphragm allows for the measurement of respiration rate, while attachment of the lead wires to the gluteus Maximus muscle can be used to assess walking or movement. Other potential applications include measurement of gastrointestinal peristaltic movements and movement of specific muscles such as nuchal EMG.

Below is an example of the EMG signal recorded from the gluteus Maximus muscle in a walking rat.



EMG can be recorded from a muscle or muscle groups, provided that the size of the muscle is large enough for the attachment of the two electrodes with a gap to prevent contact between the electrodes. It is important that the electrodes do not contact as this results in electrical shortening, and a signal will not be detected. It is also important that the electrodes are tied securely to the muscle that is being recorded from to minimize movement artifacts.

Telemetry is advantageous over tethered systems for measuring EMG as the rats and mice are allowed to move freely in their home cage eliminating behavioural adaptations to tethering. The battery of the rat telemeters also allows recording of EMG away from the home cage and tethers, opening up opportunities such as EMG recordings during behavioural tests. Rat bio potential telemeters provide up to 4 hours of continuous data transmission powered by a rechargeable battery when the rat telemeter is not actively being powered by the Smart Pad.

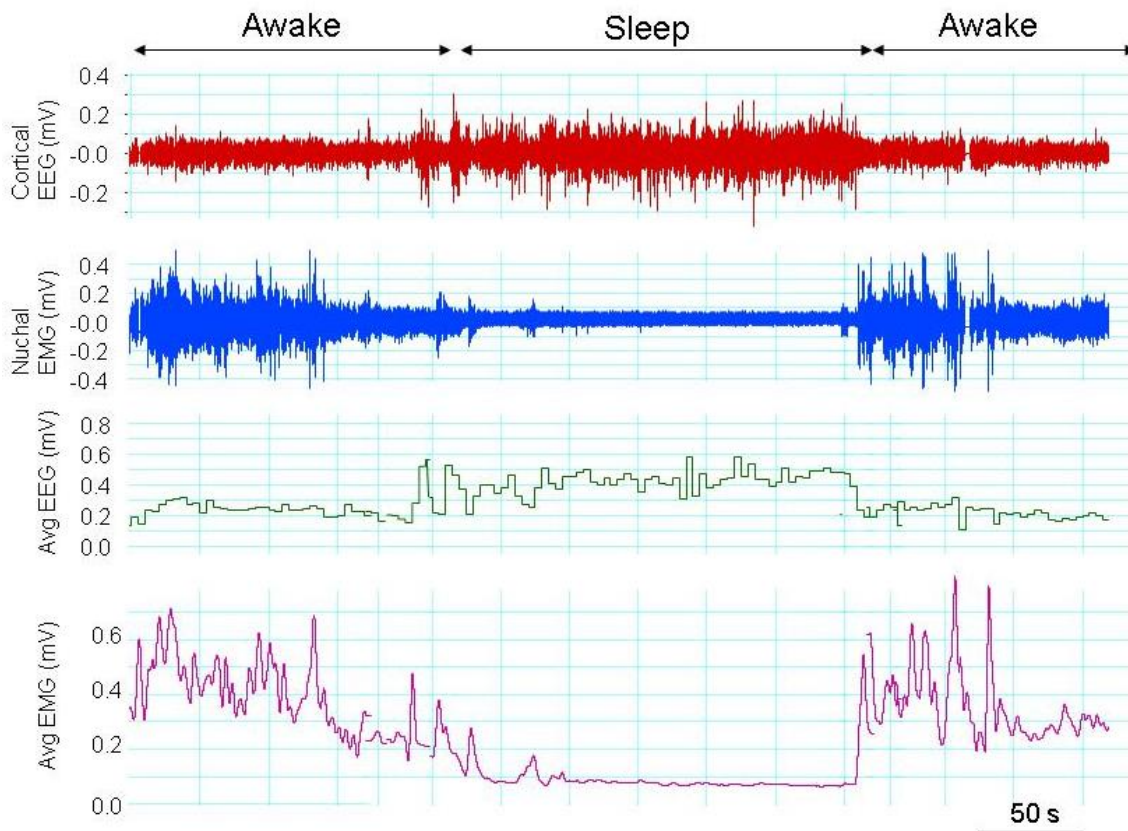
ELECTROENCEPHALOGRAPHY - EEG

EEG records the electrical activity over an area of brain tissue. Electrical activity in the brain is generated by depolarization of neurons. As the electrical activity provided by a single neuron is too small to be detected, recorded

telemetry EEG represents the summation of electrical activity from a large number of neurons in an area.

Electrodes can be placed on the surface of the brain for cortical surface EEG, or deeper into the tissue to measure from a particular area of interest. EEG can be applied to the study of neurological disorders, such as seizure detection or epilepsy studies and pharmacological studies into neurostimulating drugs. EEG can also be used in behavioural research to study brain activity patterns in response to stimuli or in studies of sleep-wake cycles. Both the Rat and Mouse Telemetry Systems allow recording of EEG from animals living in their home cages free from the stress and restriction of using tethers.

Below is an example of EEG recorded in a rat using the [TR50BB](#) telemeter with simultaneous nuchal EMG recordings in a study of the sleep-wake cycle.



In addition to EMG, it is possible to record EEG in conjunction with brain oxygen ([TR50B](#) + [TR57Y](#)) or intracranial pressure ([TRM54PB](#)) using the Rat Telemetry System.