CHAPTER ONE

Terminology, Modeling and Measurement

In this chapter we present three broad topics .First we examine what we mean by medical physics and describe some related and overlapping disciplines. In the next section we discuss modeling, a concept that is essential in science, engineering, and medicine. We discuss and give examples of feedback, an important feature of many models. In the last section we discuss measurement. Most of this last section is a review of material taught in an elementary physics course. As part of this last section we discuss the problem of accurately measuring a person is weight. As you will see, this measurement is far from simple.

1.1. Terminology:

The field of medical physics overlaps the two very large fields of medicine and physics .In this book the term medical physics refers to two major areas: the applications of physics to the function of the human body in health and disease and the application of physics in the practice of medicine. The first of these could be called the physics in physiology; the second includes such things as the physics of the stethoscope, the tapping of the chest (percussion), and the medical application of lasers, ultrasound, radiation, and so forth.

The word physics appears in a number of medical contexts. Only a generation ago in England a professor of physics was actually a professor of medicine. The words physicist and physician have root in the Greek word physike (science of nature). Today the first thing a physician dose after taking a medical history of a patient is to give him a physical examination.

During this examination he uses the stethoscope, taps the chest, measured the pulse rate, and in other ways applies physics. The branch of medicine referred to as physical medicine deals with the diagnosis and treatment of disease and injury by means of physical agent's therapy is the treatment of disease or bodily weakness by physical means such as massage and gymnastics rather than by drugs.

In principle, the field of biophysics should include medical physics as an important subspecialty. In fact, biophysics is a relatively well-defined field that has very little to do with medicine. It is primarily involved with the physics of large biomolecules, viruses, and so forth, although it does approach medical physics in the area of transport of materials across cell membranes. Biophysicist conduct basic research that may improve the practice of medicine in the next generation, while medical physicists generally energy in the applied research that they hope will improve the practice of medical in the current generation.

The field of medical physics has several subdivisions: 1- Most medical physicists in the United States work in the field of radiological physics. This involves the applications of physics to radiological problems and includes the use of radiation in the diagnosis and treatment of disease as well as the use of radionuclides in medicine (nuclear medicine). 2- Another major subdivision of medical physics involves radiation protection of patients, workers, and the general public. In the United States this field is often called health physics; Health physics also includes radiation protection outside of the hospital such as around nuclear power plants and in industry.

3-Very often an applied field of physics called engineering. Thus, medical physics could be called medical engineering. However, for practical

purposes if you meet an individual who refers to himself as a medical physicist it is highly probable that he is working in the area of radiological physics; a person who refers to himself as a medical engineer or biomedical engineer is likely to be working on medical instrumentation, usually of an electronic nature. 4- The word medical is sometimes replaced with the word clinical if the job is closely connected with patient problems in hospital, i.e., clinical engineering or clinical physics.

In the United states relatively few hospital or medical school have department of medical physics or medical engineering, although they are quit common in medical school in the United Kingdom and in the Scandinavian countries.

1.1. Modeling

Even though physicists believe that the physical world obeys the laws of physics, they are also aware that the mathematical descriptions of some physical situations are too complex to permit solution for example:

If you tore a small corner off this page and let it fall to the floor, it would go through various gyrations. Its path would be determined by the laws of physics, but it would almost impossible to write the equation describing this path. Physicists would agree that the force of gravity would cause it to go in the general direction of the floor if some other force did not interfere. Air currents and static electricity would affect its path.

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

In many ways the eye is analogous to a camera; however, the analogy is poor when the film, which must be developed and replaced, is compared to the retina, the light detector of the eye. In this chapter we often use analogies to help explain some aspect of the physics of the body. The real situation is always more complex than the one we describe.

Many of the analogies used by physicists employ models. A famous nineteenth century physical, lord kelvin, said, "I never satisfy myself until I can make a mechanical model of a thing. If I can make a mechanical model I can understand it"

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

A model in which the flow of blood is represented by the flow of electricity is often used in the study of the body's circulatory system. Also, all analogies have their limitation.

Blood is made up of red blood cells and plasma, and the percentage of the blood occupied by the red blood cells (the hematocrit) changes as the blood flows toward the extremities. This phenomenon is difficult to simulate with the electrical model. Other models are mathematical; equations are mathematical models that can be used to describe and predict the physical behavior of some system. In the everyday would physics we have many such equation. Some are of such general use that they are referred to as laws.

1.3. Measurement

One of the main characteristics of science is it's to reproducibly measure quantities of interest. The growth of science is closely related to the growth of the ability to measure. In the practice of medicine, early efforts to measure quantities of clinical interest were often second as detracting from the skill the physician.

For example:

Even though body temperature and pulse rate could be measured during the seventeenth century, these measurements were not routinely made until the nineteenth century. In this century there has been a steady growth

of science in medicine as the number and accuracy of quantitative measurements used in clinical practice have increased.

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

For Example:

An x-ray gives only qualitative information about the inside of the body; a repeat x-ray taken with a different machine may look quite different to the ordinary observer.

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

1- Measurements of the repetitive processes usually involve the number of repetitions per second, minute, hour, and so forth, such as the pulse rate which is about 70/min and the breathing rate which is about 15/min.

2- Measurements of no repetitive processes, such as how long it takes the kidneys to remove a foreign substance from the blood. No repetitive time processes in the body range from the action potential of a nerve cell (msec) to more time.

In science accuracy and precision have different meanings:

Accuracy

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

For example: a person is height measured as 1.765m may be accurate to 0.003m (3mm) compared to the standard meter.

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

For example: An ill person measured her temperature ten times in a row and got the following values in degrees Celsius 36.1, 36.0, 36.1, 36.2, 36.4, 36.0, 36.3, 36.4, and 36.2.The precision was fairly good, with a variation of 0.2c from the average value of 36.2c.

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

The process of measuring the blood pressure may introduce errors (uncertainties).Although the date are scarce, it is general believed that when an attractive woman is performing the measurement, the blood pressure of a young man will increase. Similarly, a handsome man may affect the blood pressure measurement of a female patient.

When the physician decides if the patient is ill or not?

After he has reviewed a patients'

1-Medical history.

2-The findings of the physical examination.
3-The results of clinical laboratory measurements.
It is not surprising that sometime wrong decisions are made. These wrong decisions are of two types:

1-False positives.
2-false negatives.

A false positive error occurs when a patient is diagnosed to have a particular disease when he does not have it.

A false negative error occurs when a patient is diagnosed to be free of a particular disease when he does have it. For example:

A young woman was thought to have a rheumatic heart condition and spent several years in complete bed rest before it was discovered that a false positive diagnosis had been made she really had arthritis.

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

Diagnostic error (false positive and false negative) can be reduced by:
1- Research into the causes of misleading laboratory test values.

2- Development of new clinical tests and better instrumentation.

Errors or uncertainties from measurements can be reduced by:
1-Using care in taking the measurement.
2-Rrpeating measurements.
3-Using reliable instruments.

4-Properly calibrating the instruments.

The END

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Lecture tow: forces on and in the body

1- Type of the forces

2- Types of Levers in the Body:

3- Some Effects of Gravity on the Body

4- Frictional forces

5- DYNAMICS

6- Effects of accelerations

7- Pain symptoms of human subjected to vibrations from 1 to 20Hz

8- Example

1- Type of the forces:

Physicists recognize four fundamental forces. In order of their relative strength from weakest to strongest. They are:

- 1- Gravitational force
- 2- Electrical force
- 3- Weak nuclear force
- 4- Strong nuclear force.

The **first** fundamental force described was gravitational force. Newton formulated the law of universal gravitation. This law states that there is a force of attraction between any two objects. The gravitational force is much smaller on the moon. **One** of the important medical effects of gravitational force is the formation of varicose veins in the legs, **another** medical effect of gravity is on the bones. Gravitational force on the skeleton in some way contributes to healthy bones. The **second** fundamental force described by physicists was electrical force. This force is more complicated than gravity since it involves attractive and repulsive forces between static electrical charges as well as magnetic forces produced by moving electrical charges. Our bodies are basically electrical machines. The forces produced by the muscles are caused by electrical charges attracting or repelling other electrical charges. Each of the billions of living cells in the body has an electrical potential difference across the cell membrane because of a difference in charge between the inside and outside of the cell, this amounts to less than 0.1 v. **Only** the gravitational and electrical forces are importance in our study of the forces affecting the human body. Gravitational force, though very much weaker than the electrical force by a factor 10^{39}.

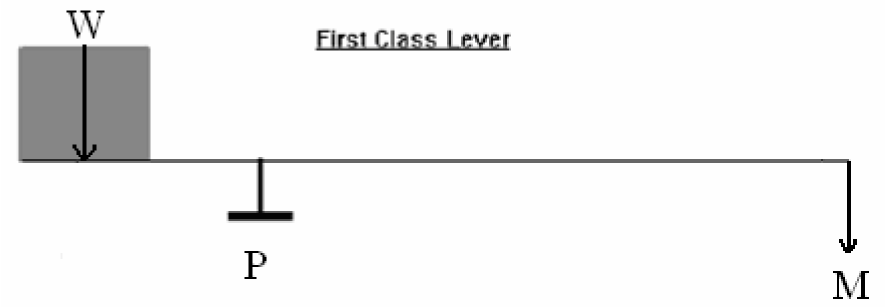
2- Types of Levers in the Body:

Many of the muscle and the bone system of the body acts as levers. Levers are classified according to the positions of the fulcrum, effort and load or resistance. There are three classes of levers, identified as **first**, **second**, and **third class** levers.

Bones as Levers:

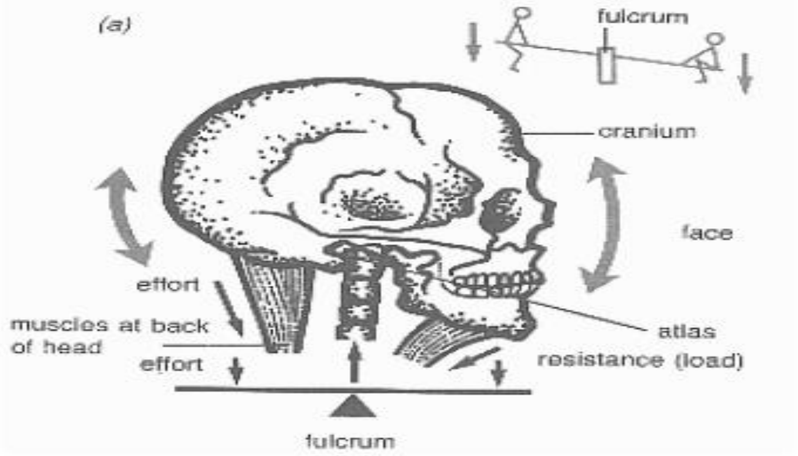
Each of the three types of levers can be found in the human body. In each type of lever, notice where the fulcrum is located compared to the effort and the load. In your body, the **effort** is the **force** that your muscles apply to the lever. The **load** is the weight that resists the pull of your muscles.

1- First Class Lever



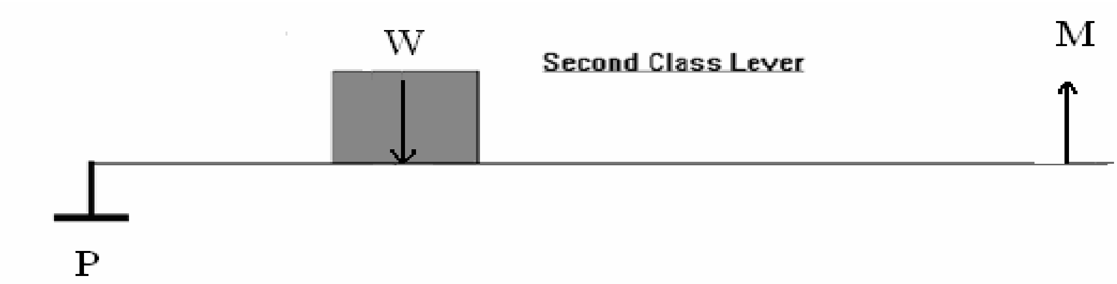
In a first class lever, the weight and force are on opposite sides of the fulcrum: An Examples of a **first-class lever** is the joint between the **skull**

and the atlas vertebrae of the spine: the spine is the fulcrum across which muscles lift the head.

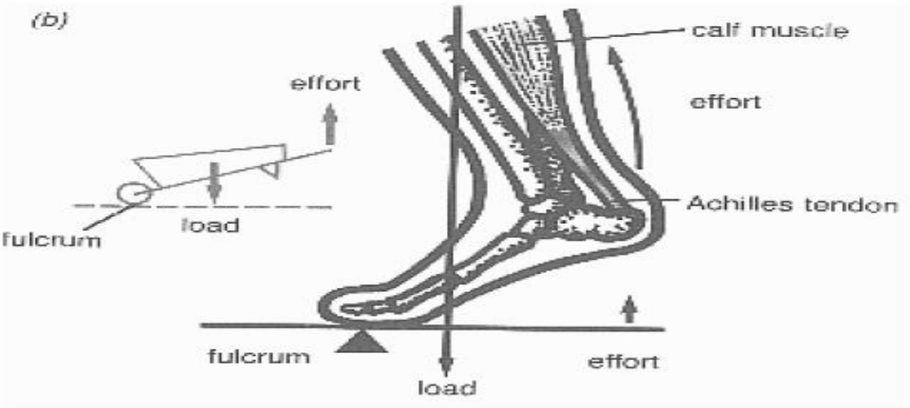


2- Second Class Lever

In the second class lever, the load is between the fulcrum and the force:

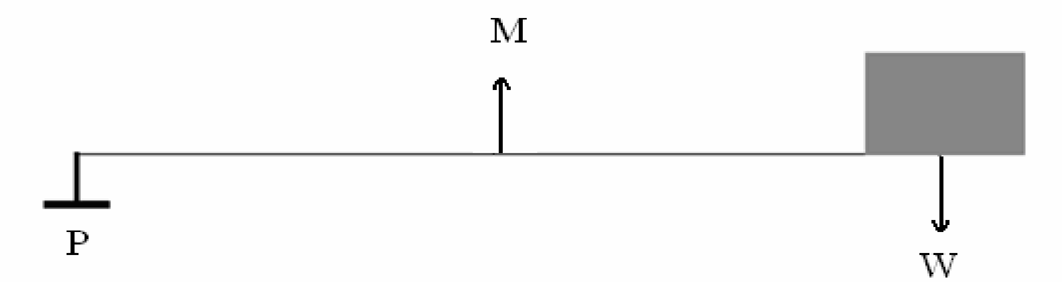


An example in the human body of a **second-class lever** is the **Achilles tendon**, pushing or pulling across the heel of the foot.

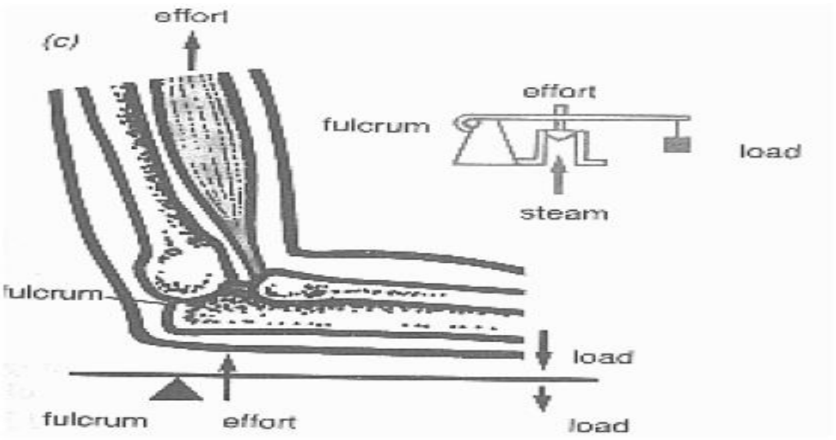


3- Third Class Lever

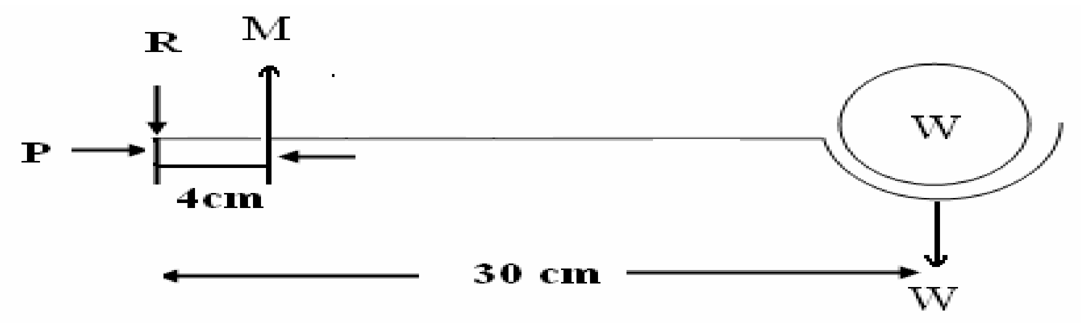
In the third class lever, the force is between the fulcrum and load:



An example of a **third-class** lever in the human body is the **elbow joint**: when lifting a book, the elbow joint is the fulcrum across which the biceps muscle performs the work.



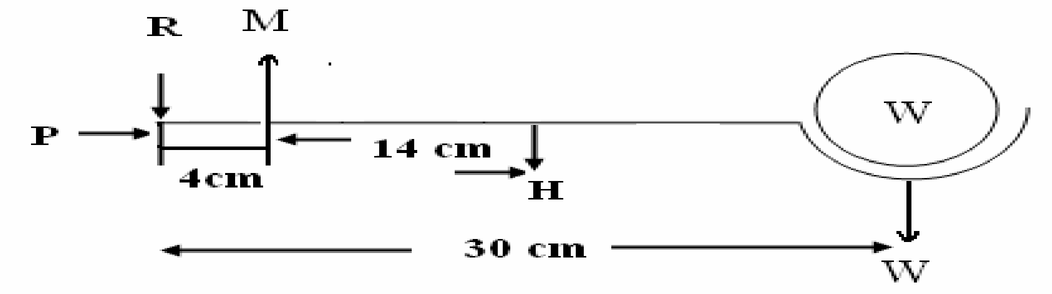
Example: - The lever system in the body is the case of the biceps muscle and the radius bone acting to support a weight in the hand.



R: - The reaction force of the human on the ulna.

M: - The Muscle force supplies by the biceps.

W: - the weight in the hand



The force and dimension where the weight of the tissue and bones of the hand and arm (H) at their center of gravity. From this example:

Find value of (M) when **W = 100N?**

Sol:

Tow torques:

1. due to the weight W
2. due to muscle M

Sum of clockwise torque = sum of counter clockwise torque

$\tau = r \times F = 30\times10^{-2} \times100 = 4\times10^{-2} \times M$

$\therefore$ M=750N [If neglected the weight of the forearm and hand (H)]

If H=15N; W=5N

$\tau w= \tau M \qquad (W\times L+H\times L) = M\times L$

$5\times30\times10^{-2} +15\times14\times10^{-2} = M\times4\times10^{-2}$

150 + 210 = 4M

M= 90N

3- Some Effects of Gravity on the Body:

The forces produced by muscles are caused by electrical charges attracting opposite electrical charges.

Cells in the body has an electrical potential difference across the cell membrane.

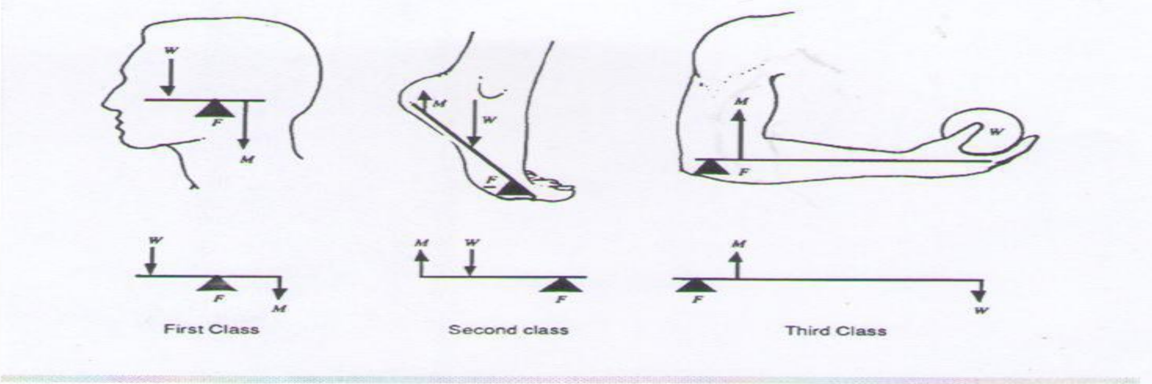
4- Frictional forces:

Friction and energy loss resulting from friction appear everywhere in our everyday life.

Some diseases of the body, such as arthritis, increase the friction in bone joint.

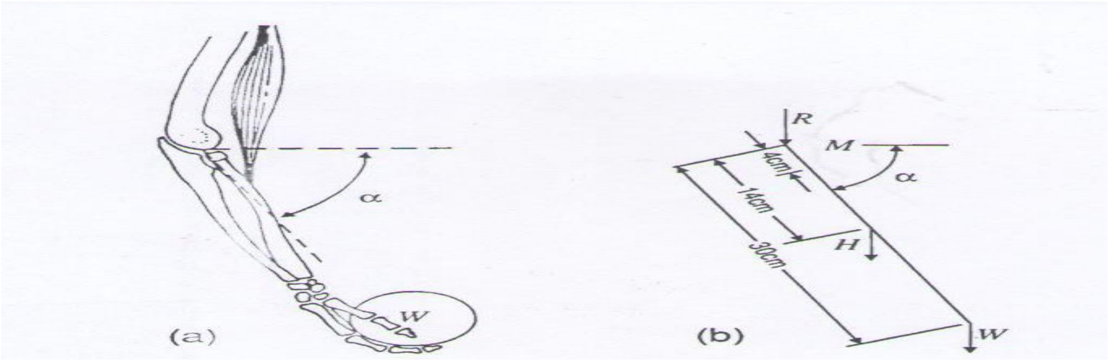
- Force of friction (F_f) is described by
- $\mathbf{F_f = \mu N}$
- N: is normal force
- μ: is coefficient of friction between two surfaces
- F - friction must be overcome when joints move, but for normal joints it is very small.
- Synovial fluid in the joint is involved in lubrication.

Second, and third class systems

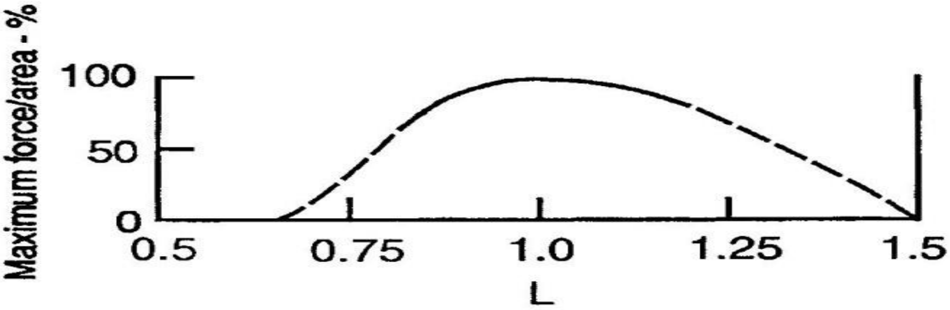


Third class levers are most common in the body

(Fig.)The forearm at the angle α to the horizontal. (a) The muscle and the bone system. (b) The forces and dimensions



The torques about the joint we find that M remains constant as α change •length of the biceps muscle changes with the angle. In general, each muscle has **a minimum** length to which it can be contracted and **maximum** length to which it stretched and still faction. At these two extremes the force the muscle can exert is essentially zero. At some point in between, the muscle can produce its maximum force.



(Fig.) At its resting length L a muscle is close to its optimum length for producing force.

5- DYNAMICS

- Forces on the body where acceleration, the Newton's second low, force equals mass times acceleration. •F = ma

- The force equals the change of momentum Δ (mv) over a short internal of time Δt or • F = (Δ (mv))/Δt

6- Accelerations can produce a number of effects such as

1- An apparent increase or decrease in body weight.

2- Changes in internal hydrostatic pressure.

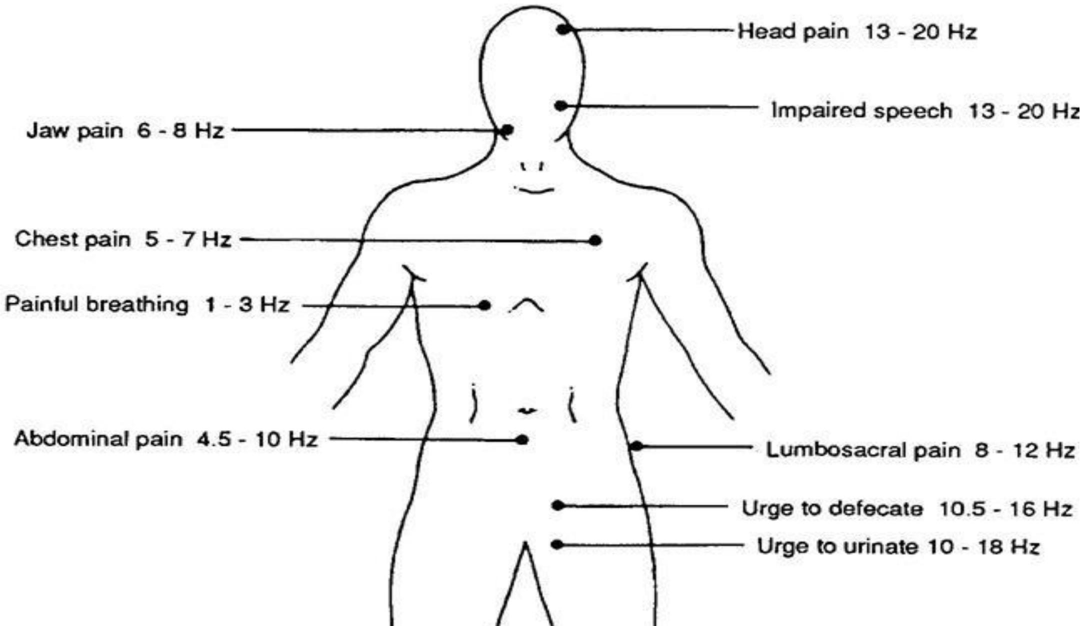
3- Distortion of the elastic tissues of the body.

4- If the acceleration become large may pool in various regions of the body, the location of the pooling depends upon the direction of acceleration. If a person is accelerated head first the lack of blood flow to the brain can cause blackout.

5-Tissue can be distorted by acceleration, if the forces are large, tearing or rupture can take place.

7- Pain symptoms of human subjected to vibrations from 1 to 20Hz

Each of our major organs has its own resonant frequency (or natural period) which depends on its mass and elastic forces that act on it. Pain or discomfort occurs if particular organ is vibrated strongly and its resonant frequency



•The speed at which small objects fall through a liquid **depends on** their size, viscosity, acceleration due to gravity g, we can artificially increase g by centrifuge. Let us consider sedimentation of the small spherical objects of density ρ in the solution of the density ρ_o in the gravitational field g. Stokes has shown that for a spherical object or radius a, the retarding force fed and terminal velocity V are related by **($F_D = 6\pi\eta aV$)**

η: is the viscosity of the liquid :

The force of gravity **$F_g = 4/3\ \pi\ a3\rho g$**

In some forms of disease such **as rheumatism, heart disease**, the red blood cells clump together and the effective radius increases; thus an increased sedimentation velocity occurs. In other disease **such as hemolytic jaundice and sickle cell anemia**, the red blood cells changes shape and break. The radius decreases; thus the rate of sedimentation of these cells in slower than normal.

Where f is rotation rate in revolution per second and r is the position on the radius of the centrifuge. A related medical test that also depends on the equation of sedimentation velocity, is the determination of the hematocrit, the percent of red blood cells, since the sedimentation velocity is proportional to the gravitational acceleration, it can be greatly enhanced if the acceleration is increased. We can increase g by means of A centrifuge, since the packing of the red blood cells takes place in the centrifuge, the hematocrit obviously depends upon the radius of the centrifuge and the speed and duration of centrifugation. The increase of any these leads to more dense packing of the red blood cells or a smaller hematocrit. A normal hematocrit is 40 – 60; a value **lower** than 40 indicates anima, and **a high** value may indicate polycythemia. In the body, friction effects are often important.

8- Example:-

A 60 Kg person walking at 1 m/sec bumps into a wall and stops

In a distance of 2.5 cm in about 0.05sec what is he force developed on impact?

Example:-

A person walking at 1 m/sec hits his head on a steel beam. Assume his head stops in 0.5 cm in about 0.01 sec. If the mass of his head is 4kg, what is the force developed**?**

College of dentistry / first stage / medical physics

Physics of the skeleton

1- Functions of the bone.

2- What is Bone Made of?

3- Composition of Bone.

4- HOW STRONG ARE YOUR BONES?

5- Young's modulus of elasticity.

6- LUBRICATION OF BONE JOINTS.

7- Example.

1- Functions of the bone

Bone is of interest to medical physics and engineers. Perhaps this organ system of the body appeals most to physical scientists because engineering type problems dealing with static and dynamic leading forces that occur during standing , walking , running , lifting , and forth. **Bone has at least six functions in the body:**

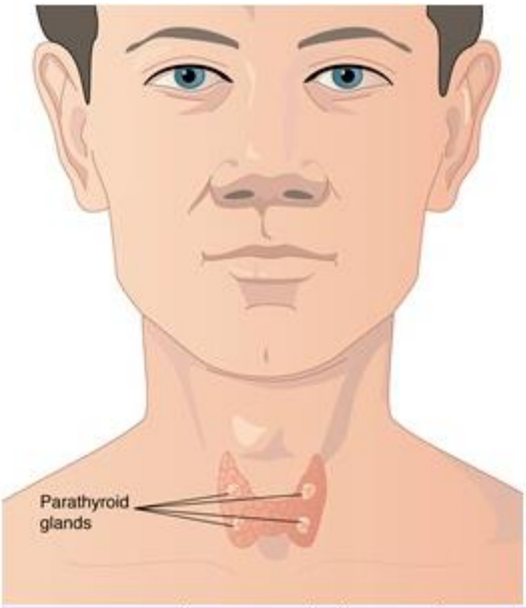
1- support, 2- locomotion, 3- protection of various organs, 4- storage of chemicals, 5- nourishment, and 6- sound transmission .(in the middle ear)

1- The support function of bone is most obvious in the legs. The body's muscles are attached to the bones through tendons and ligaments and the system of bones plus muscles supports the body.

2- Bone joints permit movement of one bone with respect to another. But the destruction of joints by arthritis can limit locomotion.

3- For protection, the skull, which protects the brain and several of the most important sensory organs like eyes and ears .Also ribs form a protective cage for the heart and lungs.

4- The bones act as chemical "bank" for storing elements for future use by the body. The body can withdraw these chemical as needed. For example, a minimum level of calcium is needed in the blood.



The parathyroid glands lie just behind the thyroid glands in the neck. The parathyroid glands (light pink) produce parathyroid hormone, which increases levels of calcium in the blood.

5- For nourishment the teeth are specialized bones that can cut food, tear it and grind it and thus serve in providing nourishment for the body.

6- For sound transmission the smallest bones of the body are the ossicles in the middle ear. These three small bones act as levers and use for converting sound vibrations in air to sound vibrations in the fluid in the cochlea.

2- Made of Bone

Note the large percentage of calcium (Ca) in bone, since calcium has a much heavier nucleus than most elements of the body, it absorbs x-rays much better than the surrounding soft tissue. This is the reason x-ray show bones so well. Bone consists of two quite different materials plus **water: collagen,** the major organic fraction, which is about 40 % of the weight of solid bone and 60 % of its volume, and bone mineral, the so-called "inorganic" component of bone, which is about 60 % of the weight of the bone and 40 % of its volume. Collagen is apparently produced by the osteoplastic cells. Because of the small size of the crystals, bone mineral has a very large surface area. Bone mineral is believed to be made up of calcium hydroxyapatite Ca10 (po4)6(OH) ^{2}.

Bone = collagen + bone mineral + water

Either of these components may be removed from bone, and in each case the remainder, composed of only collagen or bone mineral, will look like the original bone. The collagen remainder is quit flexible, some what a chunk of rubber, it bends easily if it is compressed. When the collagen is removed from the bone, the bone mineral remainder is very fragile and can be crushed with fingers.

Studies using x-ray scattering have indicated that bone mineral crystals are rod shape with diameters of 20 to 70, and lengths of from 50 t0 100. Because of small size of the crystals, bone mineral has a very large surface area. The large area of exposed bone mineral crystal permits the bones to interact rapidly with chemicals in the blood and other body fluids.

Within a few minutes after small quantity of radioactive fluorine (^{14}F) is injected into a patient, it will be distributed throughout bones of his body

Bone tumors not yet visible on an x-ray can be identified by this method. Bone in bone tumor is being destroyed somewhat like a brick house being torn down a brick at a time. When the radioactive fluorine atoms come in contact with this partially destroyed bone, the find many places they can fit in more so than in normal bone.

3- Composition of Bone:

Collagen, Mineral $Ca_{10}(PO_4)_6(OH)_2$, Water

- Collagen makes bones flexible (elastic).
- Mineral makes bones rigid.
- Water in interstitial spaces stores nutrients.

4- HOW STRONG ARE YOUR BONES

Two Quite Different Types of Bone. Solid or Compact, Spongy, Bone Made Up of Thin Thread – Like Trabecular- Trabecular Bone is Found In The Ends of The Long Bones, While Most of Compact Bone Is In The Central Shaft. Trabecular Is Weaker Than Compact Bone Due To The Reduced Amount of Bone In A Given Volume. What are the advantages of trabecular bone over compact bone, There are at least **two**, where a bone is subjected primarily to compressive forces, such as at the ends of the bones, trabecular bone gives the **strength** necessary with less material than compact bone, also because the trabecular are relatively flexible, trabecular bone can **absorb** more energy when large forces are involved such as in walking, running and jumping, on other hand, trabecular bone cannot withstand very well the bending stresses that occur mostly in the central portions of long bones.

All materials change in length when placed under tension or compression. When a sample of fresh bone placed in a special instrument for measuring the elongation under tension, a curve similar to that in (fig 1) is obtained. The strain $\Delta L/L$ increases linearly at first, indicating that is proportional to the stress (F/A) Hooks law. As the force increases the length increases more rapidly, and the bone breaks at stress of about 120 N/mm^2.The ratio of stress to strain in the initial linear portion is Young's modulus Y. That is: $Y = (L\ F) / (A\ \Delta L)$

Stress: force per unit area, $\sigma = F / A$

Strain: fractional change in length due to stress, $\varepsilon = \Delta L / L$

Hooke’s law: $\sigma = Y\varepsilon$, stress-strain diagram

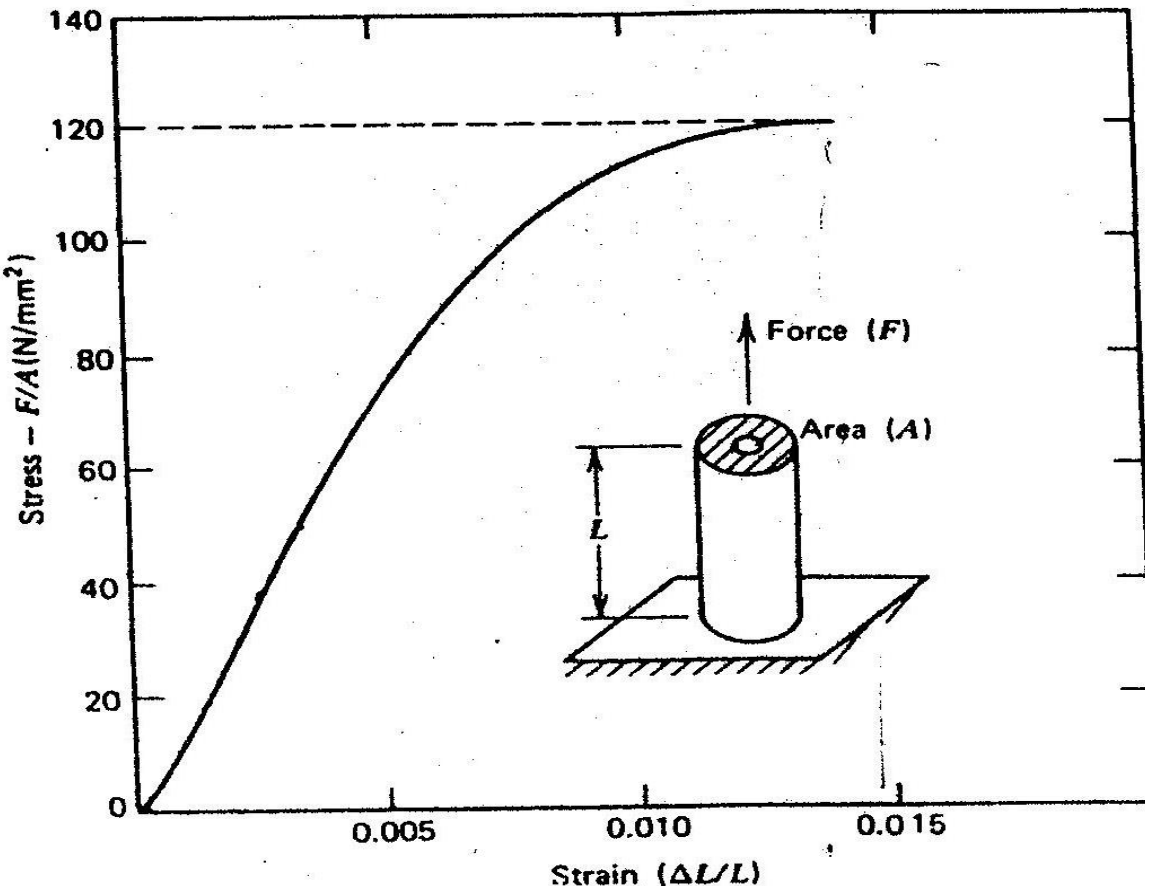


Figure. When A Piece of Bone Placed Under Increasing Tension, Its Strain ΔL/L Increases Linearly At First (Hooks Law) and Then More Rapidly Just Before It Breaks In Two At120 N/Mm^2

5- Young's modulus of elasticity:-

How much forces is needed to break the bone by compression , tension and twisting .When the bone placed under tension or compression there is change in its length from the stress – strain curve in fig.

Stress = $\frac{F}{A}$ = N/mm^2

Strain = $\frac{\Delta L}{L}$

Stress = 120 N/m^2

$\frac{\Delta L}{L} \Rightarrow 0.015$ At fracture

The strain $\frac{\Delta L}{L}$ increase linearly at first with the stress $\frac{F}{A}$ (hook's law)

If F increases the L increase more rapidly and the bone breaks at stress of 120 N mm^{-2}.

$\therefore$The ratio of stress to strain in the initial linear portion is called young's modulus Y

$Y = \frac{LF}{A\Delta L}$, **Y_{bone} = 1.8 x 10^{10} N/m^2**.

Example: Man with mass of (100 Kg) standing on the one leg has a (1 M) shaft of bone with average cross-sectional area of (3 cm^2) find:-

1-The pressure in Pa.

2-The amount of shortening in this bone.

$P = \frac{F}{A}$. F = M * g = 100 x 10 = 10^3 N

$\therefore P = 10^3 N / 3 \times 10^{-4} m^2$

$= \frac{1}{3} \times 10^7$ Pa

$= 3 \times 10^6$ Pa

$$\Delta L = \frac{LF}{AY} = \frac{1x10^3}{3x10^{-4}x1.8x10^{10}} \approx 10^{-4} \text{ m}$$

$Y = \frac{LF}{A\Delta L}$ tension elongate in L due to $\frac{F}{A}$ stress

$\Delta L = \frac{LF}{AY}$ compression

Shorting in the length of the bone of its length (L)

Young's modulus

$$Y = \frac{\sigma}{\varepsilon} = \frac{LF}{A\Delta L}$$

6 -LUBRICATION OF BONE JOINTS

There are **two** major diseases that affect the joint-rheumatoid, arthritis, which results in over production of the synovial fluid in the joint and commonly causes swollen joints, and osteoarthritis, a disease of the joint itself. The synovial membrane encases the joint and retains the lubricating synovial fluid. The lubricating properties of a fluid depend on its viscosity. The viscosity of synovial fluid decreases under the large shear stresses found in the joint.

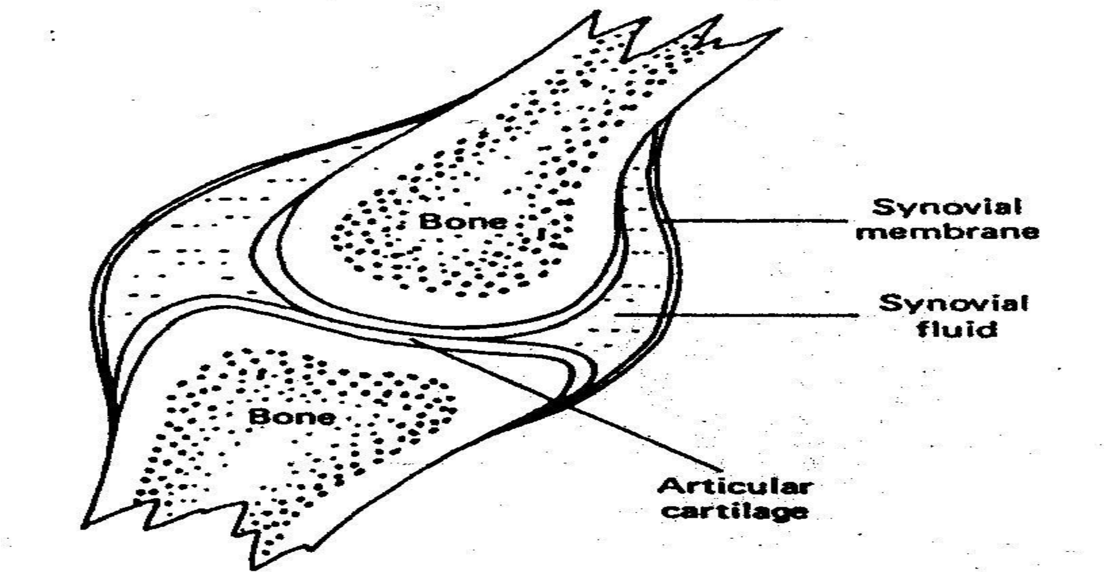


Figure. The main components of a joint.

7- Example: Assume a leg has a (1.2 m) shaft of bone with an average cross- sectional area of (3 cm^2). What is the amount of shortening when all of the body weight of (700 N) is supported on this Leg?

Lecture four

Chapter (4): The physics of the lungs and breathing

1-Function of the breathing system.

2- The Airways.

3- How Blood and Lungs Interact.

4- Physics of the Alveoli.

1-Function of the breathing system

The lungs (pulmonary system) serve as the supplier of O_2 .The blood takes the O_2 to the tissues, and removes the CO_2 from the tissues, it must come in close contact with the air in the lungs in order to exchange its load of CO_2 for a fresh load of O_2 .The air we inspire is about 80 % N2 and 20 % O_2. Expired air is about 80 % N2, 16% O_2 and 4% CO_2. The lungs perform other physiologic functions:

1- Exchange of O_2 and CO_2.

2- Keeping the PH (acidity) of the blood constant.

3- Play secondary roll in heat exchange and fluid balance of the body by warming the air we breathe in (inspire).

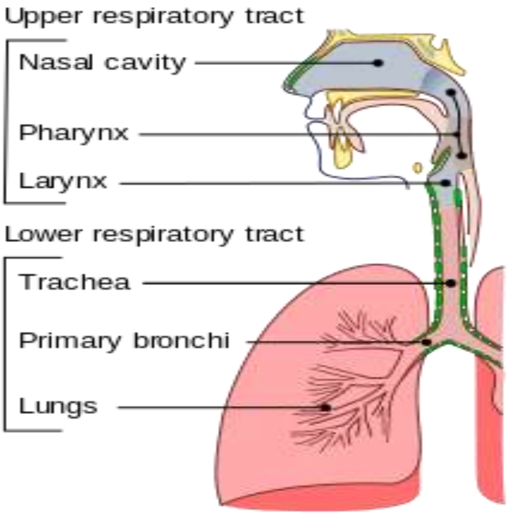
4- Controlling flow of air for talking, coughing, etc.

5- Voice production.

6- Removing the dust particles stuck to the moist lining of various airways.

2-The Airways:

The principal air passages into the lungs are shown in Fig. Air normally enters the body through the nose where it is warmed (if necessary), filtered, and moisturized .The moist surfaces and the hairs in the nose trap dust particles. During heavy exercise, such as jogging, air is breathed in through the mouth and by passes this filter system .The air then passes through the windpipe (trachea) .The trachea divides in two (bifurcate) to furnish air to each lung through the bronchi. Each bronchus divides and about 15 more times, the resulting terminal bronchioles supply air to millions of small sacs called alveoli. **The alveoli defined** , which are like small interconnected bubbles ,are about 0.2 mm in diameter (a sheet of paper is 0.1mm thick) and have walls only 0.4 µm thick .They expand and contract during breathing ,they are "where the action is " in the exchange of O_2 and CO_2. Each alveolus is surrounded by blood so that O_2 can diffuse from the alveolus into the red blood cells and CO_2 can diffuse from the blood into the air in the alveolus.



3- How Blood and Lungs Interact

The primary purposes of breathing are to bring a fresh supply of O_2 to the blood in the lungs and to dispose of the CO_2. Blood is pumped from the heart to the lungs under relatively low pressure. About (1 liter) of blood supply in the lungs but only 70 ml is in the capillaries of the lungs getting O_2.The transfer of O_2 and CO_2 into and out of blood is controlled by **law of diffusion**. Molecules diffuse from region of higher concentration to lower concentration until concentration uniform. A molecule of O_2 diffuses faster than CO_2 because of its smaller mass.

Two general processes are involved in gas exchange in the lungs:

1- Getting the blood to the pulmonary capillary (perfusion)

2- Getting the air to the alveolus surfaces (ventilation).

If either process fails the blood will not be properly oxygenated.

There are **three types** of ventilation perfusion areas in the lungs:

1- Area with good ventilation and good perfusion.
2- Area with good ventilation and poor perfusion.
3- Area with poor ventilation and good perfusion.

In a normal lung, the first type accounts for over 90 % of the total volume. The second occur if the blood flow to part of a lung is blocked by a clot.

That causes poor perfusion. In the third type the air passage in the lungs are obstructed.

4- Physics of the Alveoli:

The alveoli like millions of small interconnected bubbles they have tendency to get smaller due to surface tension of unique fluid lining. This **lining** called surfactant. The absence of surfactant in the lungs of some newborn infant is the cause of respiratory distress syndrome (RDS) called hyaline membrane disease causes death. To understand the physics of alveoli we have to understand the physics of bubbles. The pressure inside bubble is inversely proportional to radius and directly to surface tension.

This relation called (Laplace's Law).

P= $4\gamma/R$ where R radius, γ surface tension

Two forces keep lungs from collapsing:

1- Surface tension between lungs and chest wall.

2- Air pressure inside the lungs.

Chapter (5) : Application of electricity and magnetism in medicine

1- High- Frequency electricity In Medicine

2- Low-frequency electricity and magnetism in medicine

3- Electrocardiography.

4- Electricity Waves – Energy Travel Over a Long Distance

1-High- Frequency electricity In Medicine:

There are many method used in the thermal treatment include:

1- Short wave

2- Ultrasound wave

3- microwave

4- infrared wave

5- electrical stimulation

Microwave diathermy. Is different from **short- wave** diathermy, in short wave diathermy the tissue to be heated is part of resonance circuit where the tissue to be heated is placed between two capacitor plates that have an oscillating electric field across them. The changing electric field forces the ions in the tissue to move back and forth .they thus acquire kinetic energy, Part of kinetic energy dissipated when the ions collide with molecules in the tissues. **While** in microwave diathermy the tissue absorbs electromagnetic waves that are incident up on it. Microwave diathermy is **used** to heat joints, tendon sheaths, and muscles.

The use of frequencies near 30 MHz for heating is **called** short-wave diathermy. Long - wave diathermy, at frequencies near 10 KHz, is no longer used. In short-wave diathermy **two** methods are used to get the electromagnetic energy into the body: the capacitance method and the inductance method. Short-wave diathermy is **used** in the treatment of arthritis, traumatic injuries, strains, and sprains. However, it does have limitations. The amount of energy absorbed depends upon the frequency of the microwaves, the energy is absorbed best at frequencies near 20 GHz and poorly at lower frequencies near 100 MHz and at higher frequencies around 1000 GHz .**Because** the energy is deposited more effect. Actively in tissue with high water content, microwave energy is absorbed better in muscle tissue than in fatty tissues, which have less water. And **because** of the large amount of energy deposited in surface fatty layers. For this reason microwave diathermy is frequently used.

2- Low-frequency electricity and magnetism in medicine:

When electrical conductor is moved perpendicular to magnetic field, a voltage is induced in the conductor proportional to the product of the magnetic field and the velocity of the conductor (Faraday's Law). This Law also holds for conducting fluid moving perpendicular to the magnetic field. Blood acts as conducting fluid. If it passes with mean velocity (v) through magnetic field (B). A voltage (V) is induced between the electrodes such that.

$$\mathbf{V = B\ d\ v}$$

Where (d) is the diameter of the blood vessel. Since (V, B, d) can all be measured, the mean velocity can obtained. The volume flow of blood (Q) through the vessel can then be calculated, since (Q) is the product of the mean velocity times the area of the vessel (πd2/ 4) or

$$\mathbf{Q = \frac{\Pi\ d^2}{4} \times \frac{V}{B\ d}}$$

Example: A magnetic blood flow meter is positional across a blood vessel (5 * 10^{-3} m) in diameter. With a magnetic field of ($3*10^{-2}$ T) an induced voltage of ($15*10^{-6}$ v) is measured

A-Find the velocity in the vessel.

From $V = B d v$

$$v = \frac{V}{B d} = \frac{1.5*10^{-5}}{(3*10^{-2})\,(5*10^{-3})} = 0.1\ m/sec$$

b- Assuming all the blood travels at the mean velocity, what is the volume flow rate?

$$Q = \frac{\Pi d^2}{4} \times \frac{V}{B d} = 1.9\ cm^3/sec$$

3- Electrocardiography (ECG) is the process of recording the electrical activity of the heart over a period of time using electrodes placed on a patient's body. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle polarize during each heartbeat.

4- Electricity Waves - Energy Travel over a Long Distance

Electric force can transform into different types of energy waves, such as heat, radiation, radio and micro waves; and these energy waves can travel along distance. A changing magnetic field will induce a changing electric field and vice-versa, the two are linked. These changing fields form electromagnetic waves. Electromagnetic waves can travel not only through air and solid materials, but also through space. The human nervous system can create electric energy waves that can be measured with scientific instruments. The human body produces infra-red radiation that, with night vision equipment, can be seen from miles away.

CHAPTERC SIX

Energy, Work and power of the body

Energy, Work and power of the body

All body activities including thinking, doing work, or keeping the body temperature constant involve energy changes, for example under resting conditions the skeletal muscles and the heart using 25% of the body's energy ,another 19% is being used by the brain,10%is being used by the kidneys, and 27% is being used by the liver and the spleen. A small percent of about 5% of food energy being excreted in urine. Extra food energy will be stored mainly as fat. External heat energy from environment can help maintain the body temperature, but it has no use in body function.

Conservation of energy

Change in the stored energy (i.e. food energy, body fat and the body heat) =Heat lost from the body + Work done.

Assumes that no food or drink is taken during the interval of time considered.hg

●This is similar to the first law of thermodynamic: - $\Delta Q= \Delta u + \Delta w$

●Where ΔQ is the change of quantity of heat of the system.

● Δu is the change in the internal or stored energy.

● Δw is the work done.

This can be written as $\Delta u= \Delta Q - \Delta w$

A body doing no work ($\Delta w =0$) and at constant temp. Continues to lose heat to its surroundings, and ΔQ is negative. Therefore, Δu is also negative, indicating a decrease in stored energy.

The rate of change of their variables is just taken per unit time (by dividing on Δt). $\Delta u / \Delta t = \Delta Q/\Delta t - \Delta w/\Delta t$

The body's basic source of energy is the food energy; it must be chemically changed by the body to make molecules that can combine with oxygen in the body's cells.

Energy change in the body

The units are joule or calorie 1cal= 4.184J or 1Kcal=4184J

The power is defined as energy or work per unit time =J/s=watt.

In the oxidation process within the body, heat is produced as energy of metabolism. The rate of oxidation is called metabolic rate. For example the oxidation of one mole of glucose can be shown as:

$$\underset{\substack{1\ \text{mole}\\ 180\text{g}}}{C_6H_{12}O_6} + \underset{\substack{6\ \text{mole}\\ 192\text{g}}}{6O_2} \longrightarrow \underset{\substack{6\ \text{mole}\\ 108\text{g}}}{6H_2O} + \underset{\substack{6\ \text{mole}\\ 264\text{g}}}{6CO_2} + 686\text{Kcal}$$

Co_2 and O_2 are gases (1 mole of a gas at normal temp. and pressure has a volume 22.4 liters) from the above equation we can calculate useful quantities for glucose metabolism:

- Kcal of energy released / g of fuel (glucose) = 686/180 =3.8
- Kcal of energy released / L of O_2 used = 686/ (22.4×6) = 5.1
- Liters of O_2 used / g of fuel glucose = (22.4×6)/180 = 0.75
- Liters of Co_2 produced / g of fuel glucose = (22.4×6)/180 =0.75

So the ratio of moles of Co_2 produced to moles of O_2 used, called the (respiratory quotient) R=1 No. of moles of Co_2 / No. of moles of O_2 =1

Similar calculation can be done for fats, proteins, and other Carbohydrates. By measuring the energy released per liter of O_2 we can get a good estimation of the energy released. Table 5.1 shows the caloric values for different types of foods and fuels. It gives the maximum values expected because not all food energy is available, as part of it is lost in incomplete combustion (not metabolized).

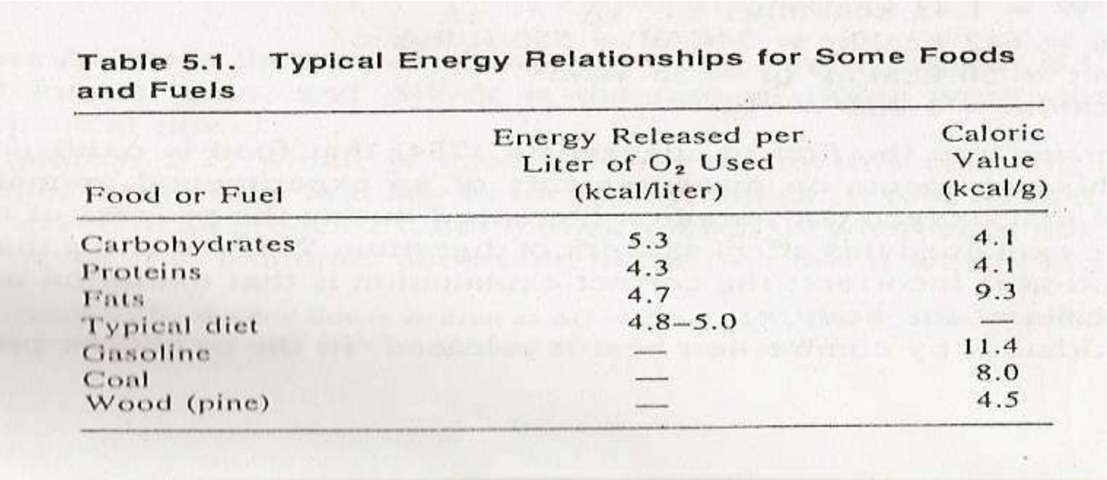
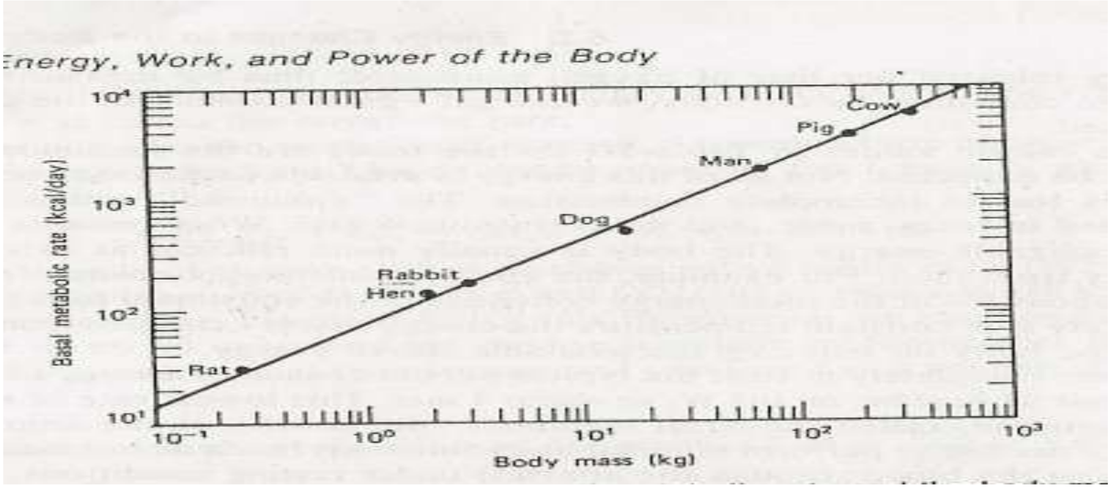


Table 5.1. Typical Energy Relationships for Some Foods and Fuels

Food or Fuel	Energy Released per Liter of O_2 Used (kcal/liter)	Caloric Value (kcal/g)
Carbohydrates	5.3	4.1
Proteins	4.3	4.1
Fats	4.7	9.3
Typical diet	4.8–5.0	—
Gasoline	—	11.4
Coal	—	8.0
Wood (pine)	—	4.5

When the body is completely at rest, it will have the lowest rate of energy consumption this is called the basal metabolic rate **(BMR),** which is the amount of energy needed to perform minimal body functions (such as breathing and pumping the blood through the arteries) under resting conditions, and for typical person 92 Kcal/ hr ≈ 10^7w or about 1 met (met is 50 Kcal/m^{2}hr). m ^{2}: body surface area

BMR depends on age, height, and weight; it depends primarily on thyroid function, overactive thyroid gives higher BMR. Since the energy used for basal metabolism becomes heat which is mainly dissipated from the skin, so the basal rate is related to the surface area or to the mass of the body. In figure 5.1 the graph represents the change between BMR (kcal/day) and the mass of different animals, the slope of the graph indicates that the BMR is proportional to mass.



When the animals gets larger the BMR increases faster than their increases in surface area but BMR increases even more faster with their mass(volume).

The **BMR** depends to large extent on the body temperature, for an increase of 1°C it will change by 10% in the metabolic rate, so for 3°C the change will be 30% greater than normal. Similarly, if the body temperature drops 3°C below normal, the metabolic rate decreases by about 30%. For this **reason** hibernating animals at low body temp. Will reduce the metabolic rate very much.

● a man who is taking food energy equivalent to his BMR plus his other physical activities will keep on constant weight.

● less food will cause weight lose and for longer time cause starvation.

● Excess food of body needs will cause food storage and increase in Weight.

● **BMR** is sometimes determined from oxygen consumption when resting, we can also estimate the food energy used in various physical activities by measuring the oxygen consumption, table (5.2) shows some typical values for various activities.

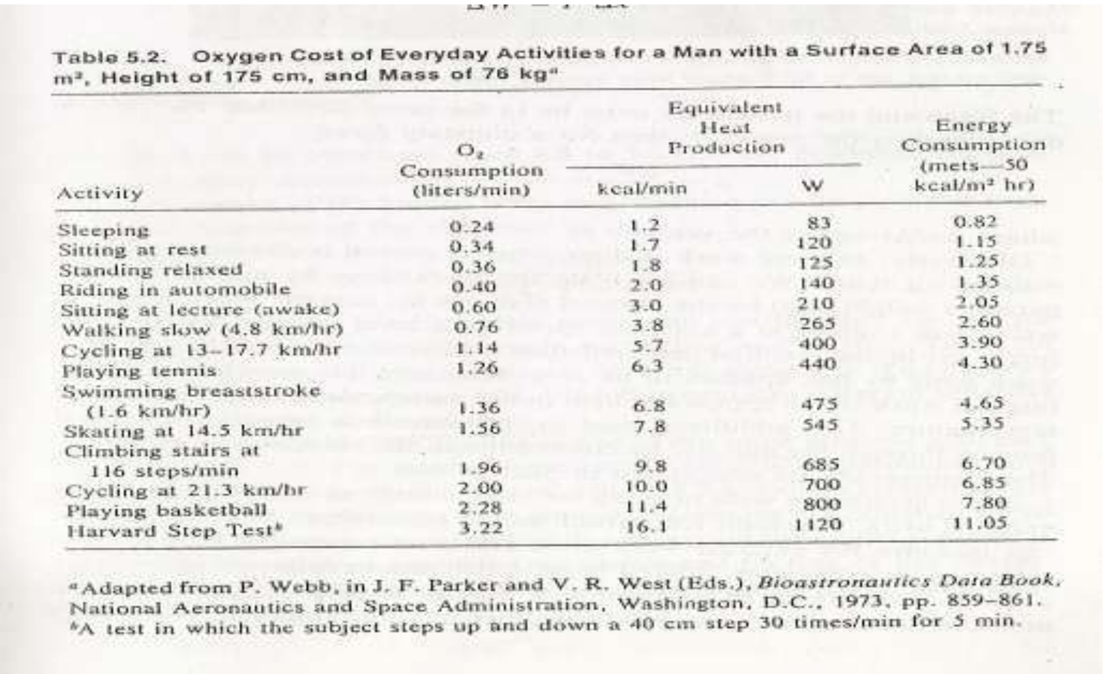


Table 5.2. Oxygen Cost of Everyday Activities for a Man with a Surface Area of 1.75 m², Height of 175 cm, and Mass of 76 kg[a]

Activity	O_2 Consumption (liters/min)	Equivalent Heat Production kcal/min	Equivalent Heat Production W	Energy Consumption (mets—50 kcal/m² hr)
Sleeping	0.24	1.2	83	0.82
Sitting at rest	0.34	1.7	120	1.15
Standing relaxed	0.36	1.8	125	1.25
Riding in automobile	0.40	2.0	140	1.35
Sitting at lecture (awake)	0.60	3.0	210	2.05
Walking slow (4.8 km/hr)	0.76	3.8	265	2.60
Cycling at 13–17.7 km/hr	1.14	5.7	400	3.90
Playing tennis	1.26	6.3	440	4.30
Swimming breaststroke (1.6 km/hr)	1.36	6.8	475	4.65
Skating at 14.5 km/hr	1.56	7.8	545	5.35
Climbing stairs at 116 steps/min	1.96	9.8	685	6.70
Cycling at 21.3 km/hr	2.00	10.0	700	6.85
Playing basketball	2.28	11.4	800	7.80
Harvard Step Test[b]	3.22	16.1	1120	11.05

[a] Adapted from P. Webb, in J. F. Parker and V. R. West (Eds.), *Bioastronautics Data Book*, National Aeronautics and Space Administration, Washington, D.C., 1973, pp. 859–861.

[b] A test in which the subject steps up and down a 40 cm step 30 times/min for 5 min.

Example: Suppose you wish to lose 4.5 kg either through physical Activity or by dieting.

1-How long would you have to work at an activity of 15 Kcal/min to lose 4.5 kg of fat?

From table 5.1 maximum of 9.3kcal/g of fat, if you worked for T minutes, then: T (15kcal/min) = (4.5x10^3g) (9.3kcal/g) = 4.2x10^4kcal

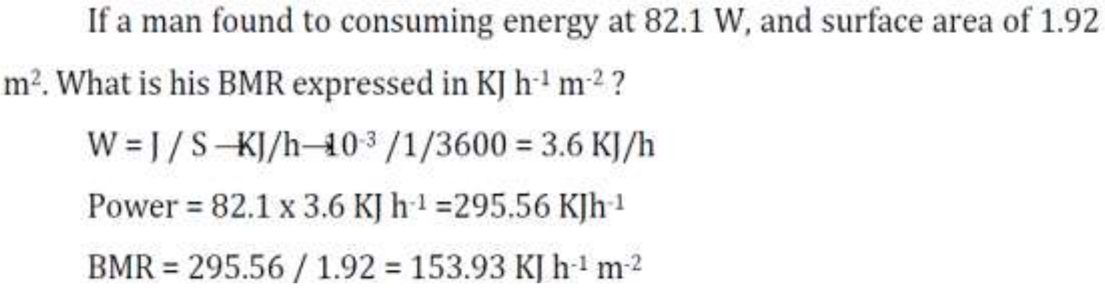
T=2810 min ≈ 47hr

2- It is much easier to lose weight by reducing your food intake. If you normally use 2500kcal/day, how long must you diet at 2000kcal/day to lose 4.5 kg of fat?

T= (energy of 4.5 kg fat/energy deficit per day)

= 4.2X10^4kcal / 5x10^2kcal/day ≈ 84 days

Example:



If a man found to consuming energy at 82.1 W, and surface area of 1.92 m^2. What is his BMR expressed in KJ h^{-1} m^{-2} ?

$W = J / S \rightarrow KJ/h \rightarrow 10^{-3} /1/3600 = 3.6\ KJ/h$

Power = 82.1 x 3.6 KJ h^{-1} =295.56 KJh^{-1}

BMR = 295.56 / 1.92 = 153.93 KJ h^{-1} m^{-2}

Work and power:

Chemical energy stored in the body is converted into external mechanical work as well as into life - preserving functions. Mechanical work is usually defined by **Δw =F. Δx** where **F** is the force on the same line of displacement **x**, or it can be also written as:

(**Δw = F Δx cos Ɵ**) where **Ɵ** is the angle between **F** and the direction of movement, the power is work per unit time.

P= Δw/Δt = F Δx / Δt = F v where **v** is the velocity

When the force is perpendicular to the displacement work will be **zero**, such as walking body, his weight is perpendicular to distance of movement but **practically** it will not be zero **because** the uses energy against friction and other movement of his body, but in the case of climbing person for distance (**h**) the weight is on the same line of displacement then the work = mgh, the efficiency of human body is

E = work done/ energy consumed

Efficiency is usually lowest at low power but can increase to 20% for trained individuals in activities such as cycling and rowing. The normal human temperature is 37°C which is obtained from taking the temperature of large of people. For a single individual the body temperature May vary about ≈0.5°C.The rectal temperature is about 0.5°C higher than the oral temperature **the** temperature **of the body depends on the:**

1-Time of the day (lower in the morning). **2-** Environment temp.

3-The amount of clothing. **4-**Health of the person.

5- On his recent physical activity.

● For example rectal temperature after hard exercise may be as high as 40°C, the body losses heat mainly by **radiation, convection, and evaporation**, all these processes can take place in the skin. The evaporation of perspiration from the skin can cool down the skin by absorbing the latent heat of evaporation from it. Evaporation takes place also in breathing causing cooling effect. If the air is cold it will also cool down the body. Eating and drinking cold or hot food can also decrease or increase the body temperature, the body temperature is kept constant for this **reason** the hypothalamus in the brain can control the body temperature (thermostat like).After heavy exercise the body is heated the hypothalamus initiate the sweating and vasodilation is the **first** causes heat loss by evaporation and the **second** increasing the blood supply to the skin for more loss of heat. On the other hand if the environment temperature drops the thermo receptors on the skin signals to the hypothalamus which in turn induce shivering to increase the body temperature The production of heat in the body for 2400 Kcal/day (assumeing no change in body weight)=1.7Kcal/min=120J/sec =120W. So the body must lose the same amount of heat to stay at constant temp.

The heat loses depends on many factors:

1- The temperature of the surroundings **2-**Humidity **3-**Motion of the air.

4-The physical activity of the body **5-**The amount of the body exposed

6-The amount of the insulation of the body (like clothes and fat)

We can calculate the work by: multiplying the person weight (mg) by the vertical distance (h) moved. **W =mg*h**

Example:

A man of mass 75 kg runs up a flight of 50 steps in 15 seconds. Calculate the power output of his leg muscles given that the vertical height of each step is 0.2 m?

Work done = **PE = mgh** = 75 x 10 x (50 x 0.2) = 7500 J

Power = work done / time taken = 7500 / 15 = 500W

We can also measure the oxygen consumed during any activity: The total food consumed can be calculated since 4.8 kcal are produced for each 1 liter of oxygen consumed. The efficiency of the human body as machine can be obtained from the following: **E = work done / energy consumed**

Question:

1. Suppose that the elevator is broken in the building in which you work and you have to climb 9 stories. -a height of 45m above ground level.

How many extra calories will this external work cost you if your mass is 70 kg and your body work at 15% efficiency?

2. A 70 kg hiker climbed a mountain 1000 m high. He reached the peak in 3 hr.

A. Calculate the external work done by the climber.

B. Assuming the work was done at a steady rate during the 3 hr period. Calculate the power generated during the climb.

C. Assuming the average O_2 consumption during he climb was 2 liters/min (corresponding to 9.6 kcal/min), find the efficiency of the hiker's body.

D. How much energy appeared as heat in the body?

Transfer of heat by radiation

All objects regardless on their temperature emit electromagnetic radiation, the amount of energy emitted by the body is proportional to the absolute temperature raised to the fourth power. The body also receives radiant energy from surrounding objects. The amount of heat difference between the energy radiated by the body and the energy absorbed from the surrounding can be calculated from the equation:

$$H_r = K_r\, A_r\, e\, (T_s - T_w)$$

Where

(H_r) is the rate of heat energy loss or gain

(K_r) is a constant depends upon various physical parameters and it's

About = **5Kcal/m^2 hr C° for man**

(A_r) effective body surface area emitting radiation

e is the emissivity of the surface which is **nearly=1**,independent on the color of the skin indicating that the skin at this wavelength is almost a perfect emitter and absorber of radiation. (T_s) is the skin temperature in C°.

(T_w) is the temp of the surrounding walls.

∆ Heat losses by radiation occur even the temp. Differences is not high.

Example: for a nude person have a skin temperature 34°C in a room of walls, temperature 25°C and his body area 1.2m^2 will lose 54 Kcal/hr which is 54% of the total losses. Most of the remaining heat will be by convection.

Transfer of heat by convection:

Heat losses by convection (H_c)

$$H_c = K_c\, A_c\, (T_s - T_a)$$

Where

H_c is the amount of heat gained or lost be convection

A_c is the effective surface area

T_s is the skin temp.

T_a is the environment temp. or air temp.

K_c is a constant that depends on the movement of the air, for a resting body and no apparent wind K_c is about **2.3kcal/ m^2 hr °C**. When the air is moving K_c increases according to the equation:-

$$K_c = 10.45 - v + 10\sqrt{v}$$

where v is the wind speed in m/sec

This equation is valid for speeds between 2.23m/sec (5mph) and 20m/sec (45mph) (1 mile=1.6 km). The equivalent temperature due to moving air is called the wind chill factor and is determined by the actual temperature and wind speed. For example for a windy day speed 10 m/sec an-20°C has the same cooling effect on the body as -40°C on a calm day.

Transfer of heat by evaporation

Under normal temp. Conditions and in the absence of hard work or exercise, heat loss mainly by radiation and convection, losses by evaporation become of less importance. Under extreme conditions of heat and exercise, a man may sweat more than **1** litter of liquid per hour. Since each gram of water that evaporate carries with it the heat of vaporization of 580 calories, the evaporation of **I** liter carries with it 580kcal. There is some heat losses by perspiration even if the body does not feel sweaty, it amount to about 7Kcal/hr, equivalent to 7% of the body losses. A similar loss of heat is due to the evaporation of moisture in the lungs, an additional amount of water will be evaporated during expiration. This will cool the body the same as the evaporation from the skin, also when we inspire cold air inside the lungs which also cool down the body. Under typical conditions the total respiratory heat losses is about 14% of the body's heat loss. Under extreme condition of heat and exercise the sweat Evaporation is very important, a man may sweat more than **1** lit/hr,

This is if all sweat is evaporated, the evaporated part (running down) does not contribute with cooling.

Counter current heat exchange

Since the radiation of heat from the body and the transfer of heat to the air depend upon the skin temp., any factors that affect the skin temp. Also affect the heat loss. The body has the ability to select the path returning blood from the hands and feet. In cold weather blood is returned to the heart through internal veins that are in contract to the arteries carrying blood to the extremities (hands and feet).In this way some of the heat from the blood going to the extremities is used to heat then returning blood. This counter current heat exchange lowers the temp. of the body to the environment. In warm weather the returning venous blood runs near the skin surface raising the skin temp. and thus increasing the heat loss from the body.

Most of the previous study involved heat losses from a nude person, if we consider the clothes, the calculation become more complicated, for this reason another unit of clothing is the (**clo**) is being introduced. One (**clo**) corresponds to the insulating value of clothing needed to maintain a room at 21°C and air movement of 0.1m/sec and humidity of less than 50%. One (**clo**) is equivalent to lightweight suit an individual in the arctic needs clothing of insulation of 4 clos. (A fox fur has an insulating value of 6 clos).

Q: How could the body maintains the balance between heat loss and heat production?

The body can do this by various means such as:

1- It may alter the metabolic rate.

2- Blood loses heat as it flows through the capillaries near the surface of the skin. The capillaries widen (vasodilatation) in warm condition , there by increasing the rate at which blood flows through them and so increasing the rate of loss of heat The opposite effect (vasoconstriction) occurs in cold condition .

3- Muscular activity generates heat. Most of the energy consumed by our muscles produces heat rather than useful work. The body makes use of this when we are cold by causing rapid contractions of the muscles (shivering).

4- The sweat glands become more when we are hot.

There is a limit to what the body can do for itself and we can do many thinks to keep our body warm such as:

a- By wearing clothing suited.

c- By exercising.

d- By taking hot drinks

LIGHT IN MEDICINE

Light has some interesting properties, many of which are used in medicine:

1- The speed of light changes when it goes from one material into another. The ratio of the speed of light in a vacuum to its speed in a given material is called the index of refraction.

2- Light behaves both as a wave and a particle. As a wave it produces interference and diffraction. As a particle it can be absorbed by a single molecule.

3- When light is absorbed, its energy generally appears as heat. This property is the basis for the use IR light to heat tissues. Also the heat produced by laser beams is used to weld a detached retina to the back of eyeball and to coagulate small blood vessels in retina.

4- Some time when alight photon is absorbed, a lower energy light photon is emitted. This property is known as fluorescence.

4- Some time when alight photon is absorbed, a lower energy light photon is emitted. This property is known as fluorescence.

5- Light is reflected to some extent from all surfaces. There are two types of reflection

A- Diffuse reflection: occurs when rough surface scatter the light in many direction

B- Specular reflection: it is obtained from very smooth surface such as mirrors.

MEASUREMENT OF LIGHT AND ITS UNITS

- The three general categories of light-UV, Visible, and IR- are defined in terms of their wavelengths. Wavelength of light used to be measured in

- **Microns 1 μ = 10^{-6}m**
- **Angstroms 1 A° = 10^{-10}m**
- **Nanometer 1 nm= 10^{-9}m**

- Ultraviolet light has wavelengths from 100 to 400nm

- Visible light has wavelengths 400 to 700nm

- IR light has wavelengths from 700 to 10^4nm.

Each of these categories subdivided according to wavelength.

Ultraviolet	**UV-A**	has wave lengths from 320 – 400nm
	UV-B	has wavelengths from 290 -320nm
	UV-C	has wavelengths from 100 – 290nm

Visible light is measured in photometric units

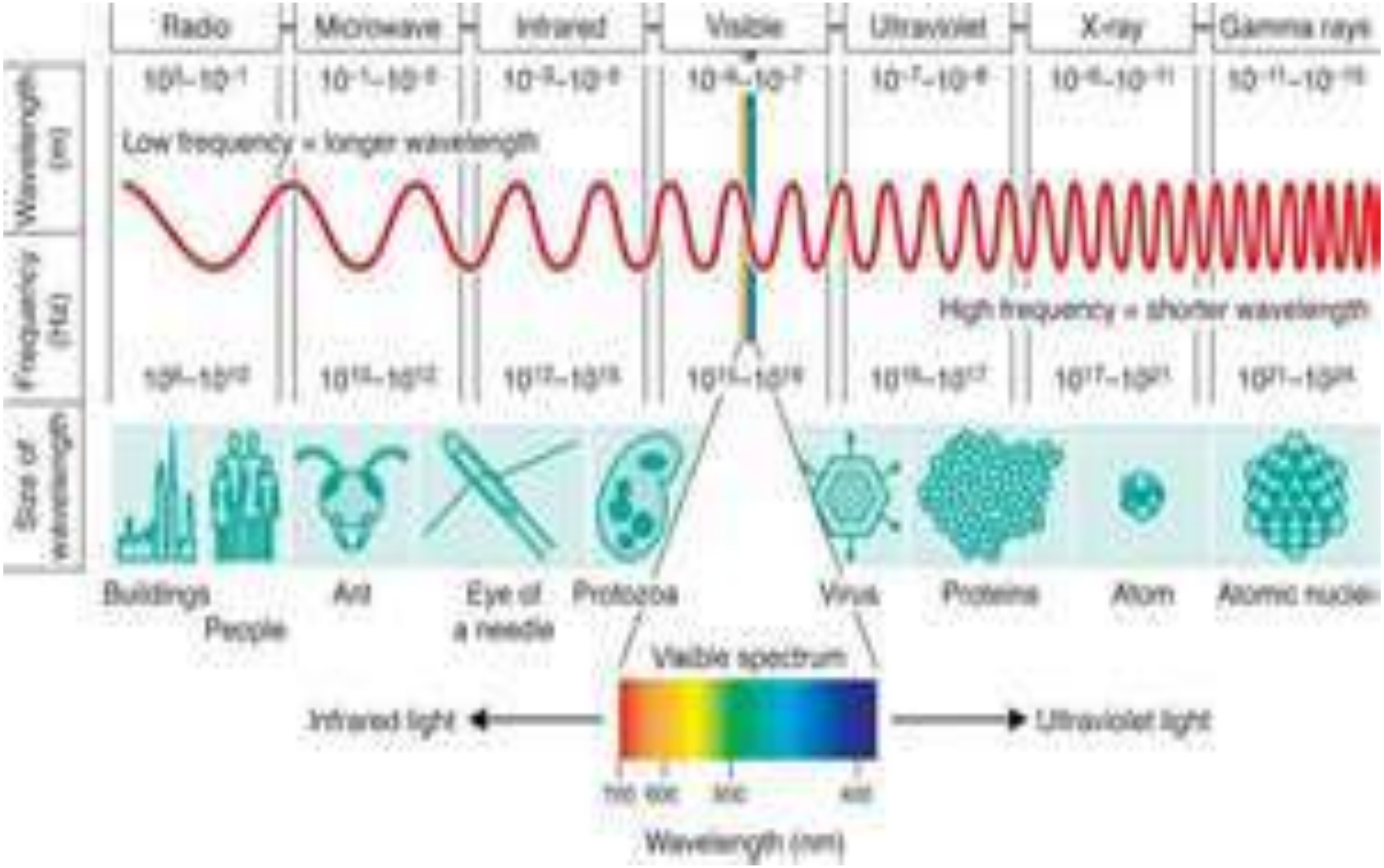
Illuminance the quantity of light striking a surface

Luminace the intensity of a light source.

UV and **IR** radiation can be measured in radiometric units

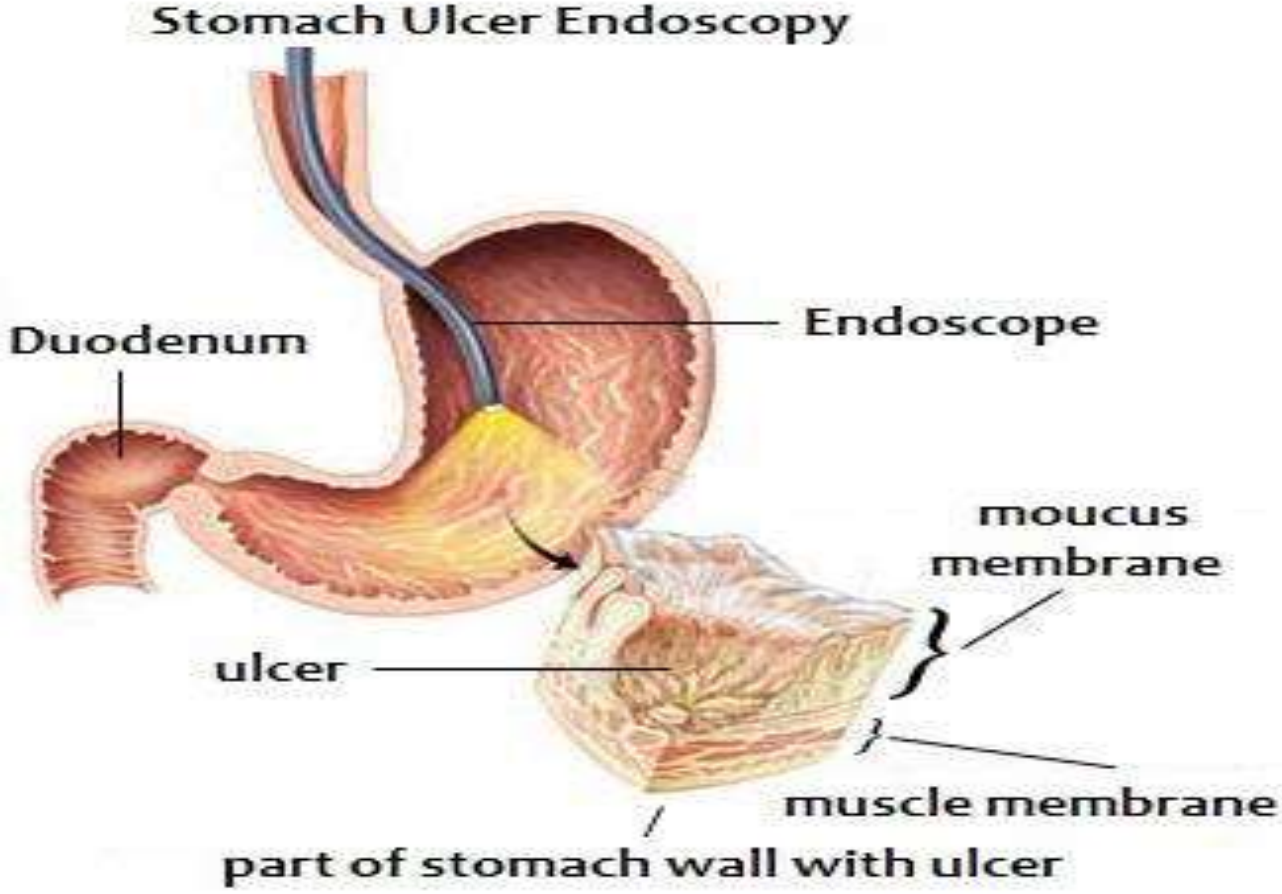
Irradiance the quantity of light striking a surface.

Radiance the intensity of a light source

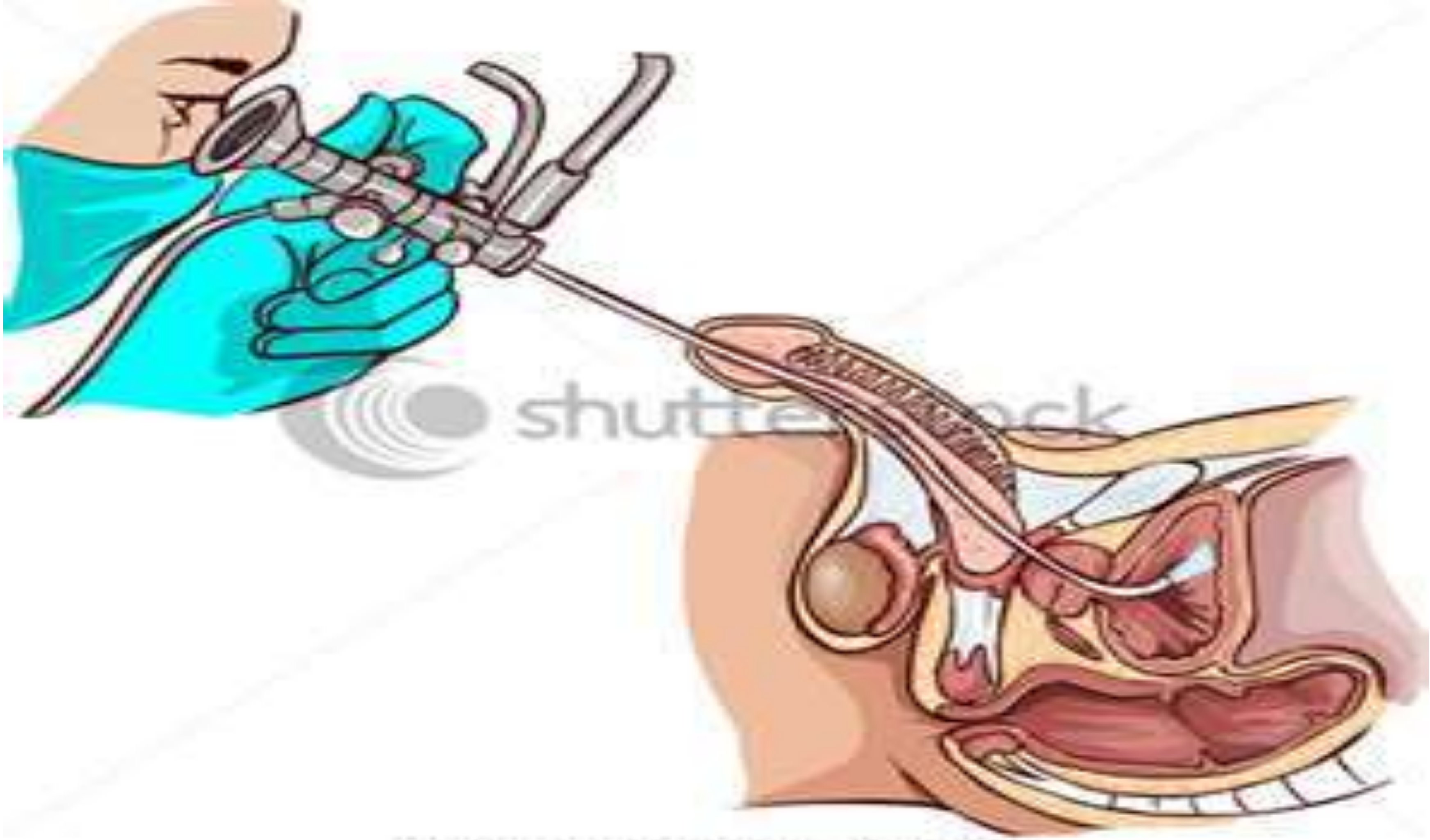

Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma rays
Wavelength (m)
$10^{3}-10^{-1}$
$10^{-1}-10^{-3}$
$10^{-3}-10^{-6}$
$10^{-6}-10^{-7}$
$10^{-7}-10^{-8}$
$10^{-8}-10^{-11}$
$10^{-11}-10^{-15}$
Low frequency = longer wavelength
High frequency = shorter wavelength
Frequency (Hz)
$10^{6}-10^{10}$
$10^{10}-10^{12}$
$10^{12}-10^{15}$
$10^{15}-10^{16}$
$10^{16}-10^{17}$
$10^{17}-10^{21}$
$10^{21}-10^{24}$
Size of wavelength
Buildings
People
Ant
Eye of a needle
Protozoa
Virus
Proteins
Atom
Atomic nucle
Visible spectrum
Infrared light
Ultraviolet light
700
600
500
400
Wavelength (nm)

APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

Endoscope: a number of instruments are used for viewing internal body cavities.

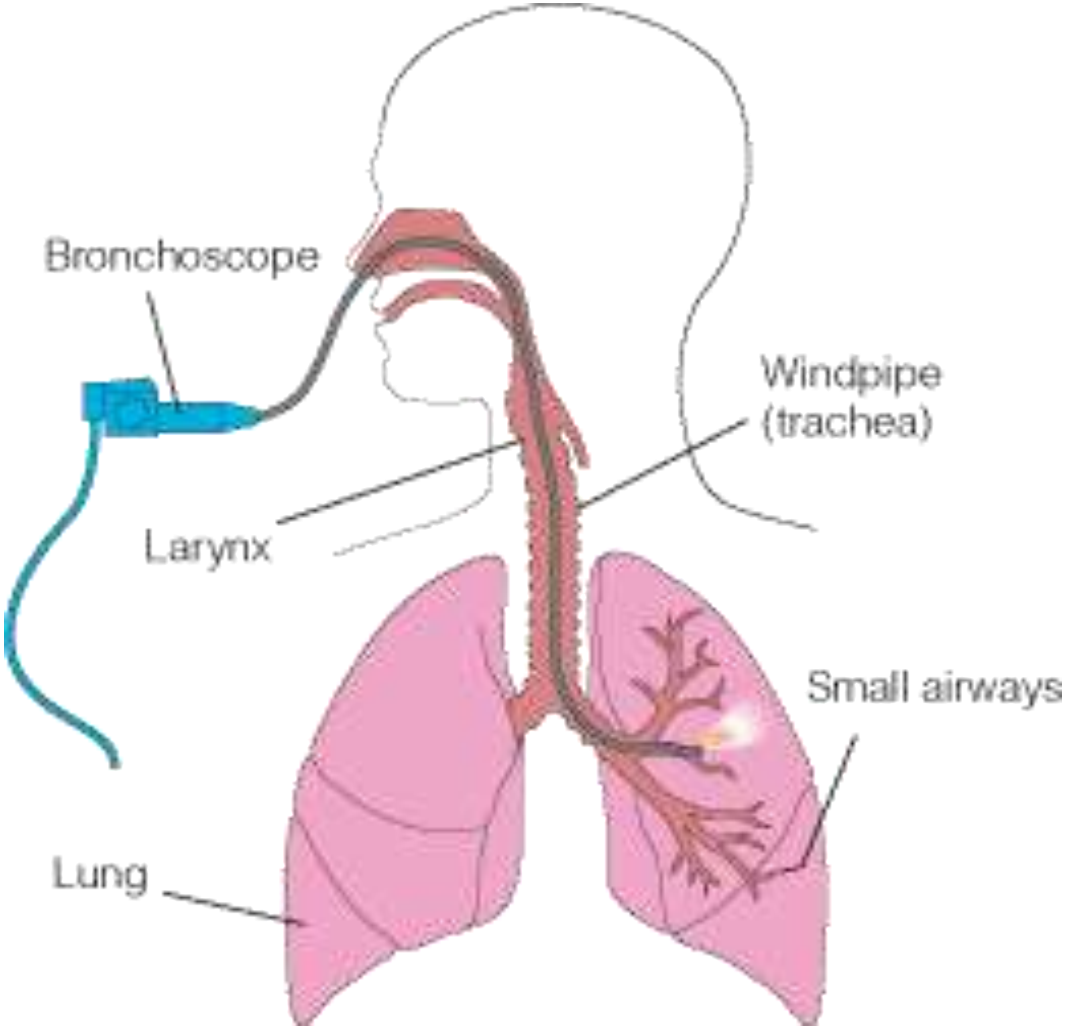


CYTOSCOPES: are used to examine the bladder.



BRONCHOSCOPE: **Are used for examining the air passages into lungs. Some endoscopes are rigid tubes with a light source to illuminate the area of interest.**

Flexible endoscopes can be used to obtain information from regions of the body that cannot be examined with rigid endoscopes, such as the small intestine and much of large intestine.



APPLICATIONS OF UV AND IR LIGHT INMEDICINE

- UV photons have energies greater than visible and IR light. Because of their higher energies, UV photons are more useful than IR photons.
- -UV can kill germs and used to sterilize medical instruments.
- -UV produces more reaction in the skin some of these reactions are beneficial, and some are harmful.

Beneficial effects of UV light from the sun is the conversion of molecular products in the skin into vitamin D.

Harmful effects of UV light can produce sunburn as well as tan skin. Solar UV light is also cause of skin cancer in humans. The high incidence of skin cancer among people who have been exposed to the sun a great deal, such as fishermen and agricultural workers, many be related to the fact that the UV wavelengths that produce sunburn are also very well absorbed by the DNA in the cells.

UV light has even shorter wavelengths than the visible light and is scattering more easily. About half of the UV light hitting the skin on a summer day comes directly from the sun and other half is scattered from the air in the other parts of the sky. Thus you can get a sunburn even when you are sitting in the shade under a small tree.

-UV light cannot be seen by the eye because it absorbed before it reaches the retina.

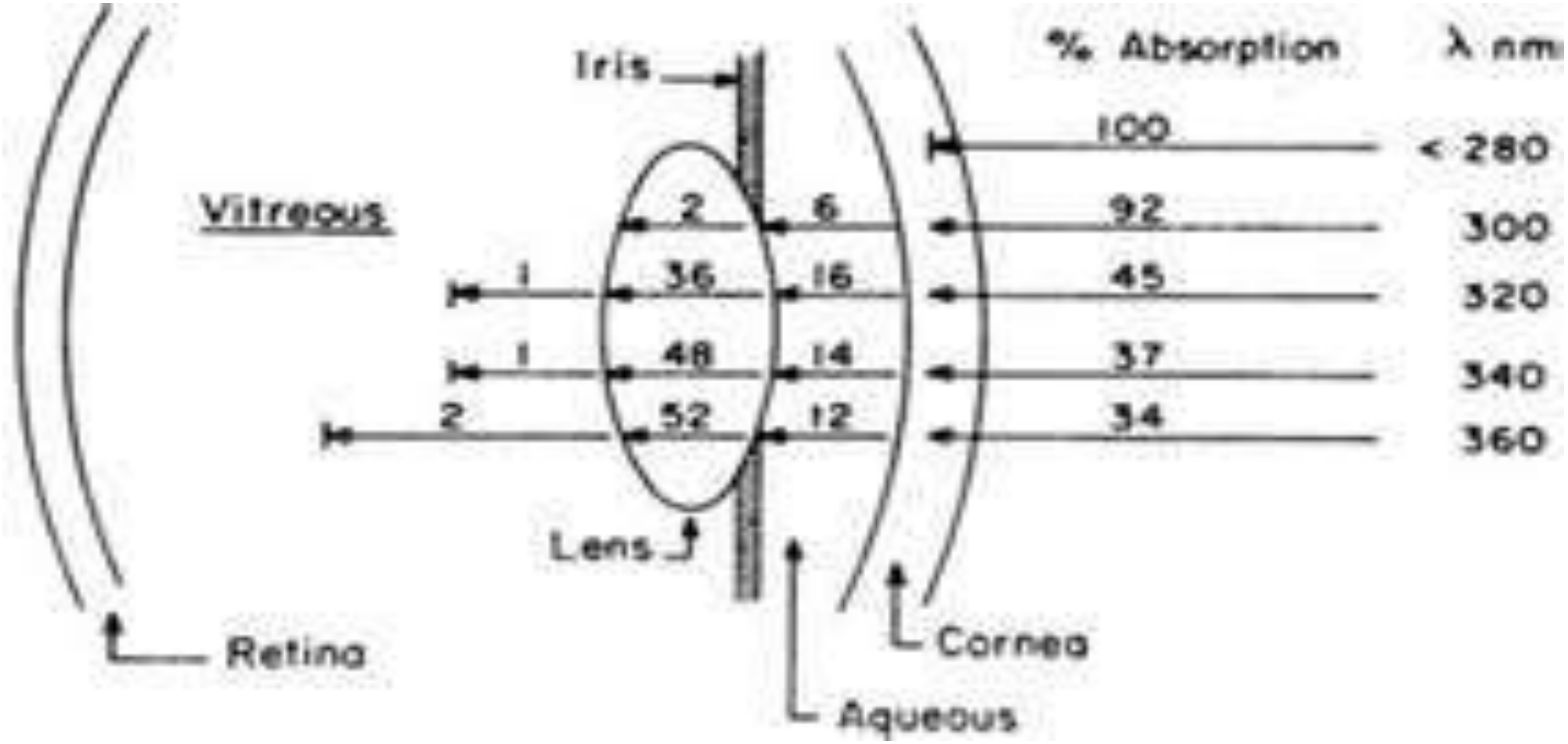


Fig shows the percentages of UV light of different wavelengths absorbed by the different structures of the eye

The IR rays are not usually hazardous even though they are focused by the cornea and lens of the eye onto the retina. However, looking at the sun through a filter (e.g., plastic sunglasses) that removes most of the visible light and allows most of the IR wavelengths through can cause a burn on the retina.

Heat lamps that produce a large percentage of IR light with wavelengths of 1000 to 2000nm are often used for physical therapy purposes.

Two types of IR photography are used in medicine:

1- Reflective IR photography

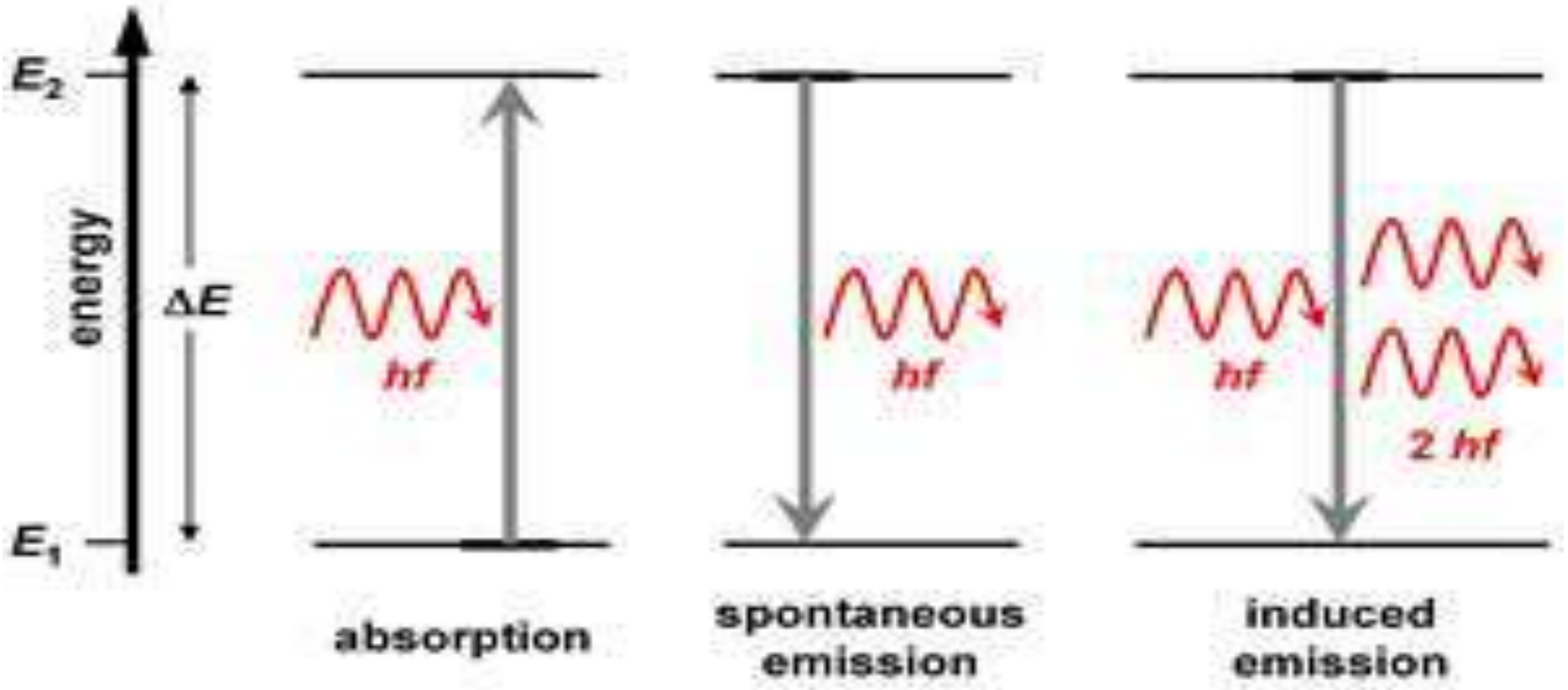
Which uses wavelength of 700 to 900nm to show patterns of viens just below the skin.

2- Emissive IR photography.

Which uses the long IR heat waves emitted by the body that give an indication of the body temperature, is usually called thermograph.

LASER IN MEDICINE

- When an electron makes a transition from higher energy to lower energy state, a photon is emitted. The emission process can be one of two types, spontaneous emission or stimulated emission.
- In spontaneous emission the photon is emitted spontaneously, in a random direction, without external provocation.
- In stimulated emission an incoming photon stimulates the electron to change energy levels. To produce stimulated emission, however, the incoming photon must have energy that exactly matches the difference between the energies of two levels, namely


E_2
E_1
energy
ΔE
hf
hf
hf
$2\ hf$
absorption
spontaneous emission
induced emission

The operation of lasers depends on stimulated emission.

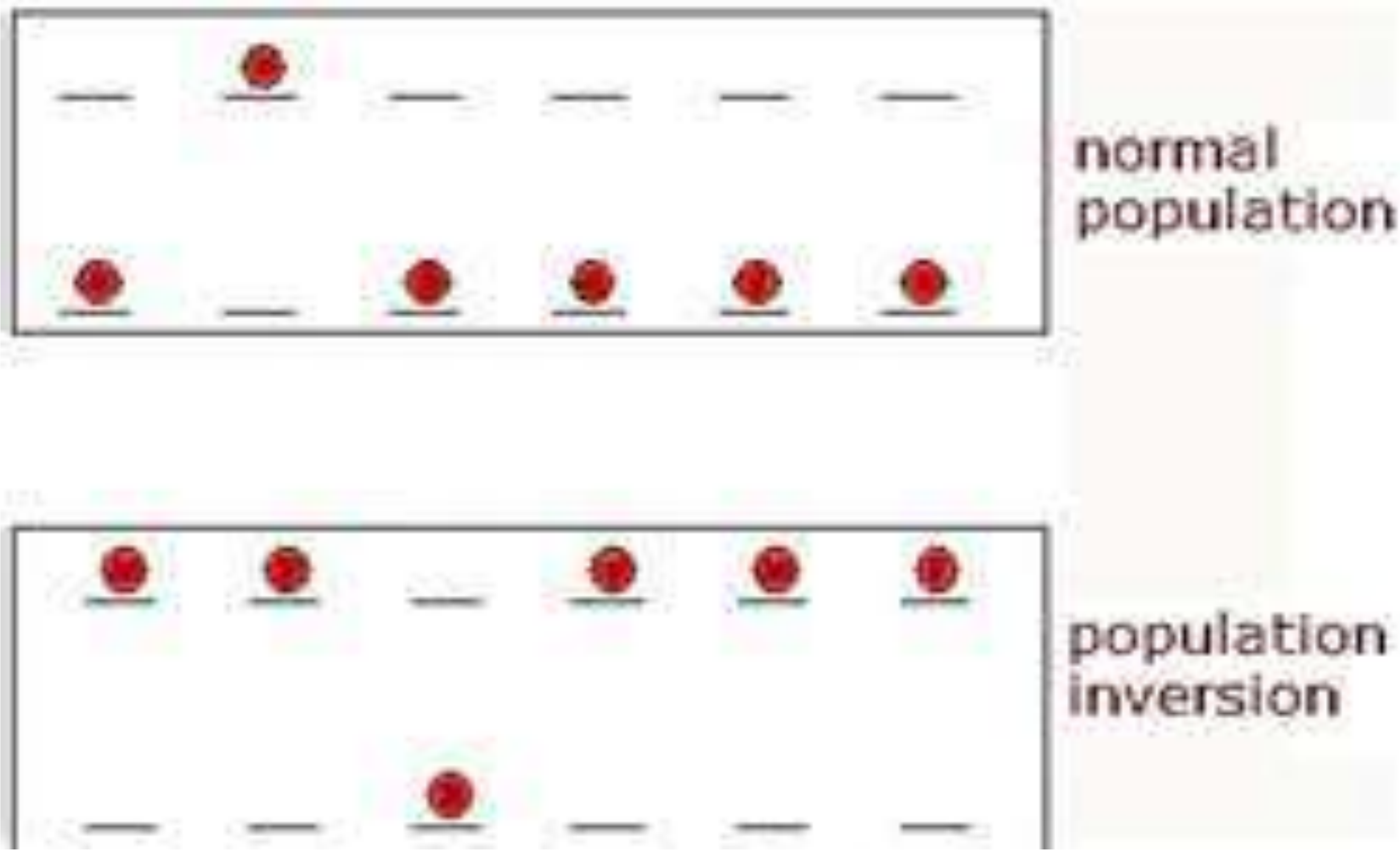
Stimulated emission has three important features.

1-One photon goes in and two photons come out. In this sence, the process amplifies the number of photons. This is the origin the word laser which is an a crony for light amplification by the stimulated emission radiation

2-The emitted photon travels in the same direction as incoming photon.

3-The emitted photon is exactly in step with or has same phase as the incoming photon. In other word, the two electromagnetic waves that these two photons represent are coherent.

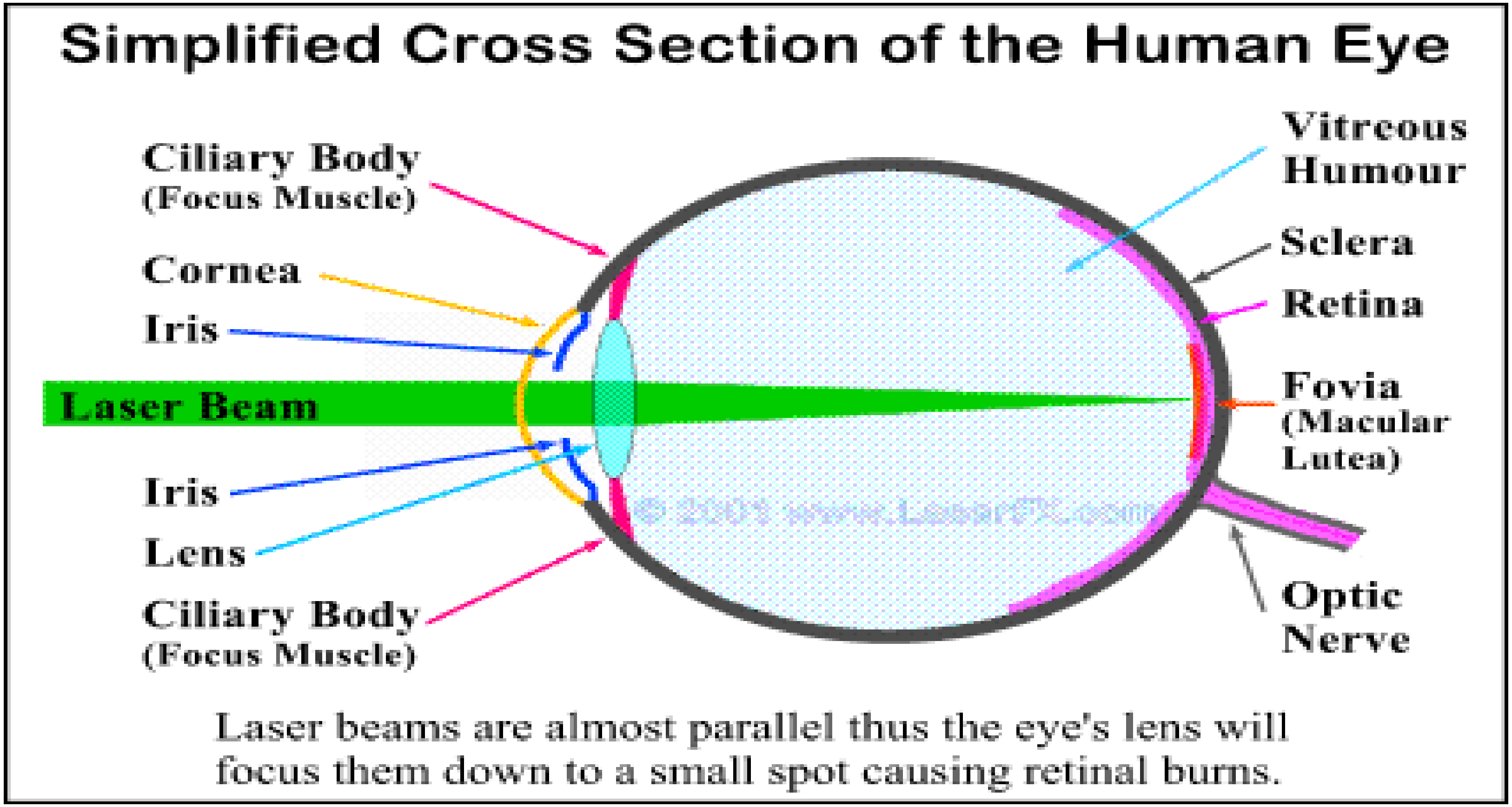
The energy can be provided in number of ways, including intense flashes of ordinary light and high voltage discharges. If efficient energy is delivered to atoms, more electrons will be excited to a higher energy level than remain in lower energy level, a condition known as population inversion. Figure compares a normal energy level population with a population inversion. The population inversion in lasers involve a higher energy state that is metastable, in the sense that electrons remain in it for a much long period of time than they do in an ordinary excited state (10^{-3}s versus 10^{-8}s)


normal population
population inversion

A laser is a unique light source that emits a narrow beam of light of single wavelength in which each wave is in phase with others near it. The physical characteristics of lasers and a few of their application in medicine.

Laser energy that has been stored in the laser material.

A laser beam can be focused to a spot only a few microns in diameter. When all of the energy laser concentrated in such a small area, the power density (power per unit area) becomes very large. The total energy of a typical laser pulse used in medicine, which measured in milli joules (mJ), can be delivered in less than a microsecond, and resultant instantaneous power may be in megawatts. The output of pulsed laser is usually measured by the heat produced.



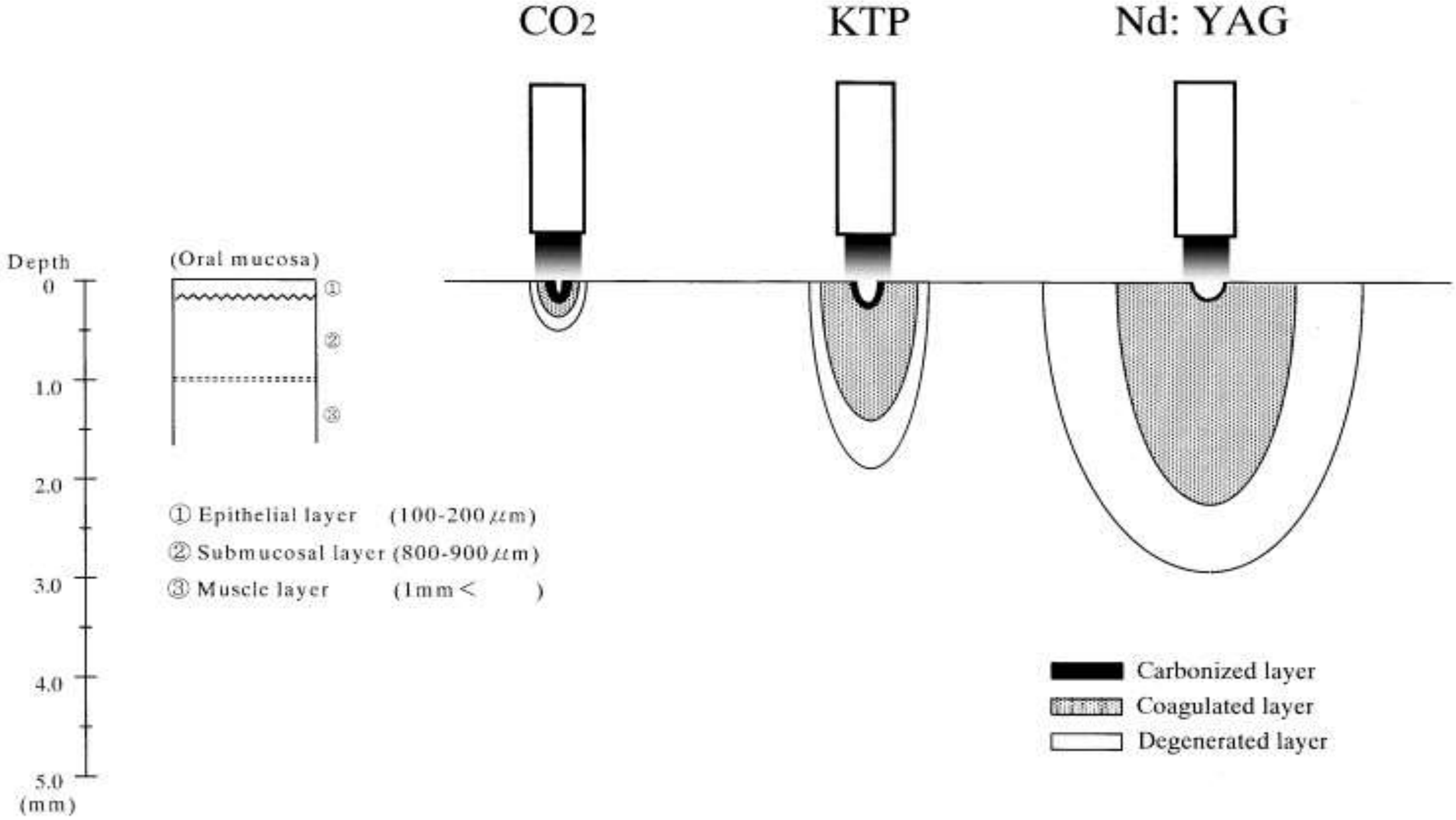
Simplified Cross Section of the Human Eye

Laser beams are almost parallel thus the eye's lens will focus them down to a small spot causing retinal burns.

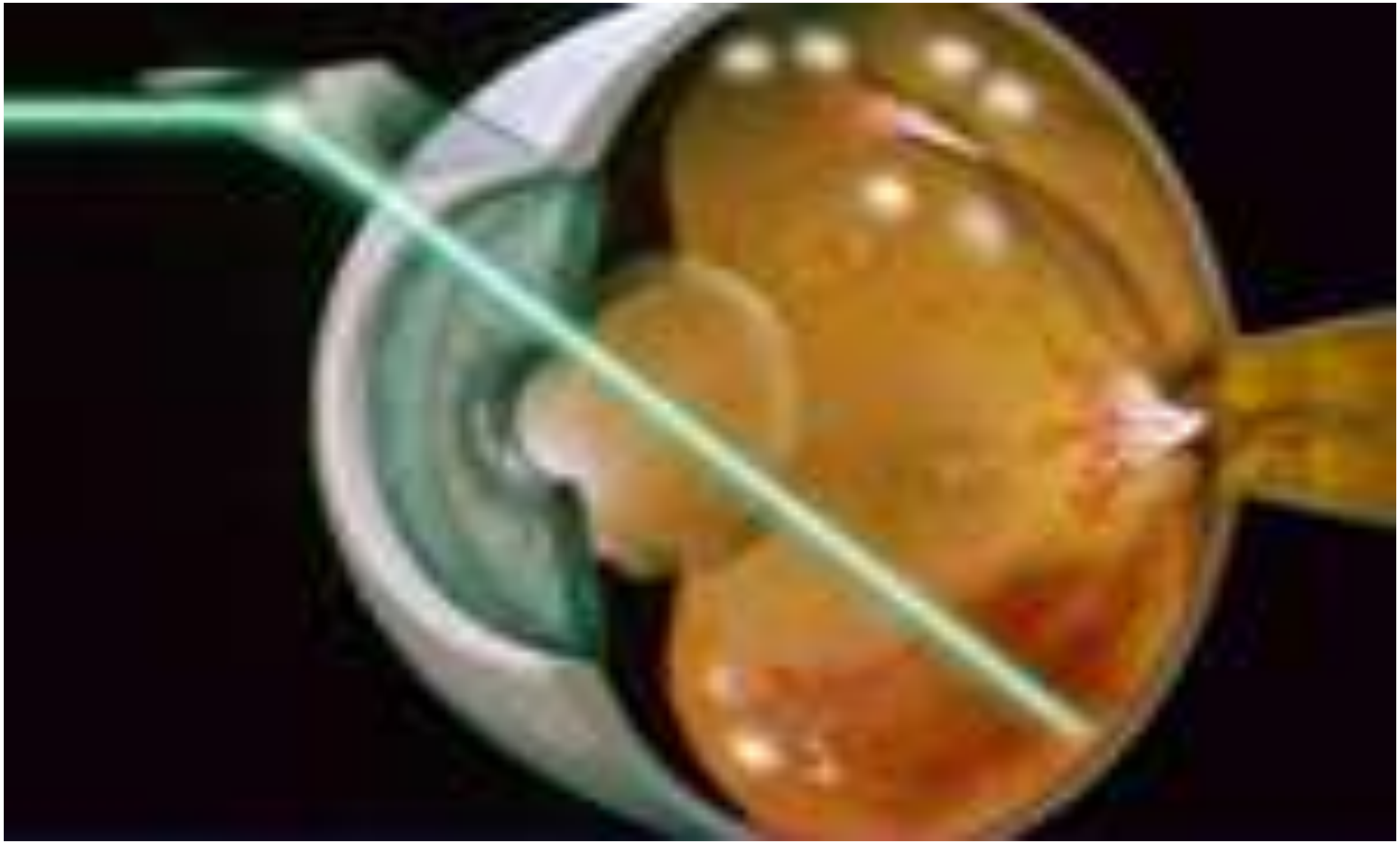
Since in medicine lasers are used primarily to deliver energy to tissue, laser energy directed at human tissue causes a rapid rise in temperature and can destroy the tissue. The amount of damage to living tissue depends on how long the tissue is at the increased temperature.

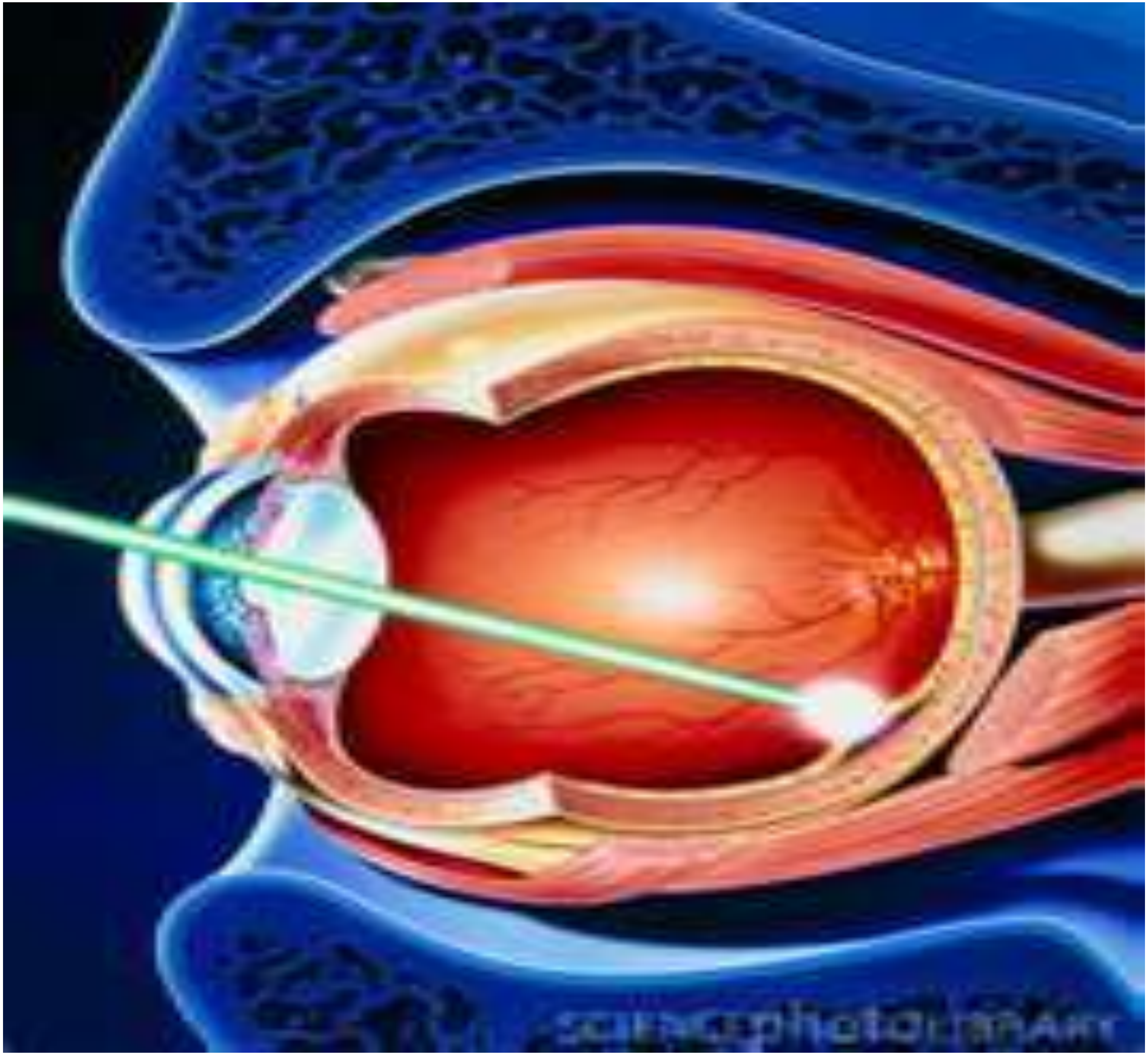
--For example, tissue can withstand 70C^{o} for 1 s, in general even the briefest exposure to temperatures above 100Co results in tissue destruction. However, not all laser damage is due to heat.

The laser used in medicine as a blood less knife for surgery. It can be focused by a lens to almost a mathematical point. This means that the energy per unit area in the focal spot can be made enormous, and small regions can be vaporized without harming the surroundings.



In medicine one of the most spectacularly successful uses of lasers has been in ophthalmic surgery. In eye the retina may become detached from the choroid owing to disease, injury, or degenerative changes. The laser are primarily used for photocoagulation of the retina, the heating a blood vessel to point where the blood coagulates and blocks the vessel.





….it has been found that a 1ms flash of light from a laser focused on the retina is highly efficient in welding the retina to choroid. Further, the patient feels no pain and no anesthetic is not required. The amount of laser energy needed for photocoagulation depends on the spot size used. In general, the proper dose is determined visually by the ophthalmologist at the time of the treatment.

The minimum amount of laser energy that will do observable damage to the retina is called minimal reactive dose(MRD).

Example:

The MRD for a 50μm spot in the eye is about 2.4mJ delivered in 0.25 s.

Typical exposure needed for photocoagulation are 10 to 50 times the MRD (i.e., 24 to 120mJ for 50μm spot in 0.25s)

Photocoagulation is useful for repairing retinal tears or holes that develop prior to retinal detachment. When the retina is completely detached, the laser is of no help. A complication of diabetes that effects the retina called diabetic retinopathy, can also be treated with photocoagulation. Because of the small spot sizes a available ($\sim 50 \mu m$) it is possible to use the laser even in the small region where our detail vision takes place.

Protective glasses must be worn in medical laser areas to protect the eyes of the patient and the workers. Since the laser energy is concentrated in a narrow beam for long distances, even reflected beam can be a hazard: thus the walls and other surfaces in the laser installation should have low reflectivity (e.g. flat black paint). The area should have adequate warning and system that prevents outsider from entering while lasers are in use.

PHYSICS OF EYES AND VISION

The sense of vision consists of three major components:

1-The eyes that focus an image from outside world on the light sensitive retina.
2-The system of millions of nerves that carries the information deep into the brain.
3-The visual cortex-that part of the brain where, it is all put together.

Blindness results if any one of the parts does not function.

The physics of the first part far better than the physics of the other two parts.

FOCUSING ELEMENTS OF THE EYE

The eye has two major focusing components:

1-The cornea is a fixed focus element.

2-The lens is variable in shape and has the ability to focus objects at various distances.

The cornea focuses by bending (refracting) the light rays. The amount of bending depends on the curvatures of its surfaces and the speed of light in the lens compared with that in the surrounding material. The index of refraction is nearly constant for all corneas, but the curvature varies considerably from one person to another and is responsible for most our defective vision.

1-If the cornea is curved too much the eye is <u>near sighted</u>.

2-Not enough curvature results in <u>far sightness.</u>

3-Uneven curvature produces <u>astigmatism</u>.

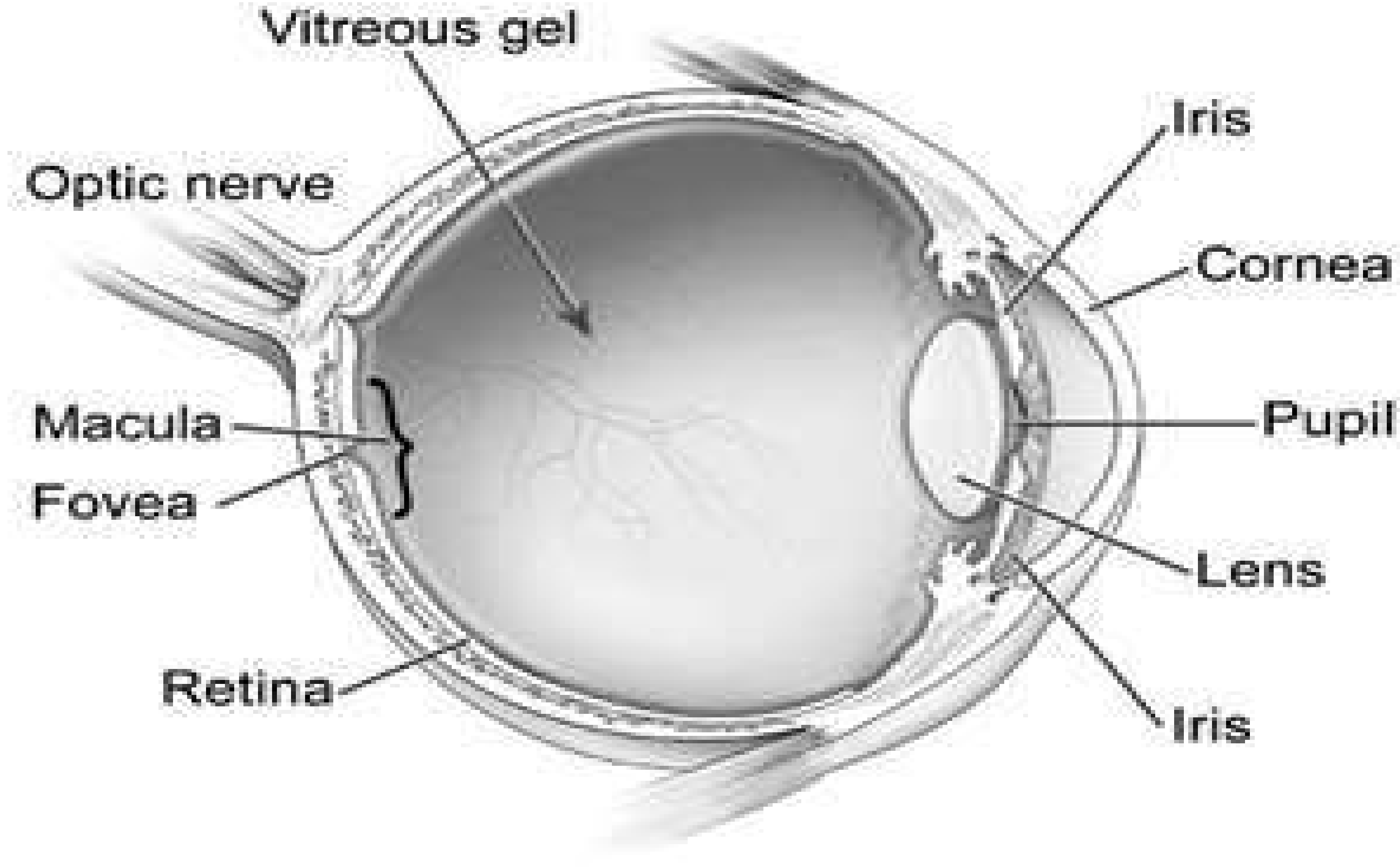
The lens has a flexible cover that is supported under tension by suspension fibers.
1-When the focusing muscle of the eye is relaxed this tension keeps the lens somewhat flattened and adjusted to its lowest power, and the eye is focused on distant objects. The point at which distant objects are focused when the focusing muscle is relaxed is called the <u>far point.</u>

2-For a near sighted, the circular muscle around the lens contracts into a smaller circle and takes some or all of the tension off the lens. The lens then has a greater focusing power, the closest point at which objects can be focused when the lens is its thickest is called the near point.

3-Young children have very flexible lenses and can focus on very close objects. The ability to change the focal power of the eye is called accommodation.

4-As people get older, their lenses lose some accommodation, presbyopia (old sight) results when the lens has lost nearly all of its accommodation.

SOME OTHER ELEMENTS OF THE EYE



Pupil is the opining in the center of the iris where light enters the lens. It appears black because essentially all of the light that enters is absorbed inside the eye. Under average light condition, the opining is about 4mm in diameter. It can change from about 3mm in diameter in bright light to about 8mm in diameter in dim light. The iris does not respond instantly to a change of light levels; about 300 s are needed for it fully open, and about 5 s are required for it to close as much as possible.

Aqueous humor fills the space between the lens and the cornea. This fluid, mostly water, is continuously being produced, and the surplus escapes through a drain tube.

Vitreous humor is a clear jelly that fills the large space between the lens and the retina. It helps keep the shape of the eye fixed and essentially permanent.

Sclera is the tough, white, light-tight covering over all of the eye except the cornea.

THE RETINA-THE LIGHT DETECTOR OF THE EYE

The retina, the light sensitive part of the eye, converts the light images into electrical nerve impulses that are sent to the brain.

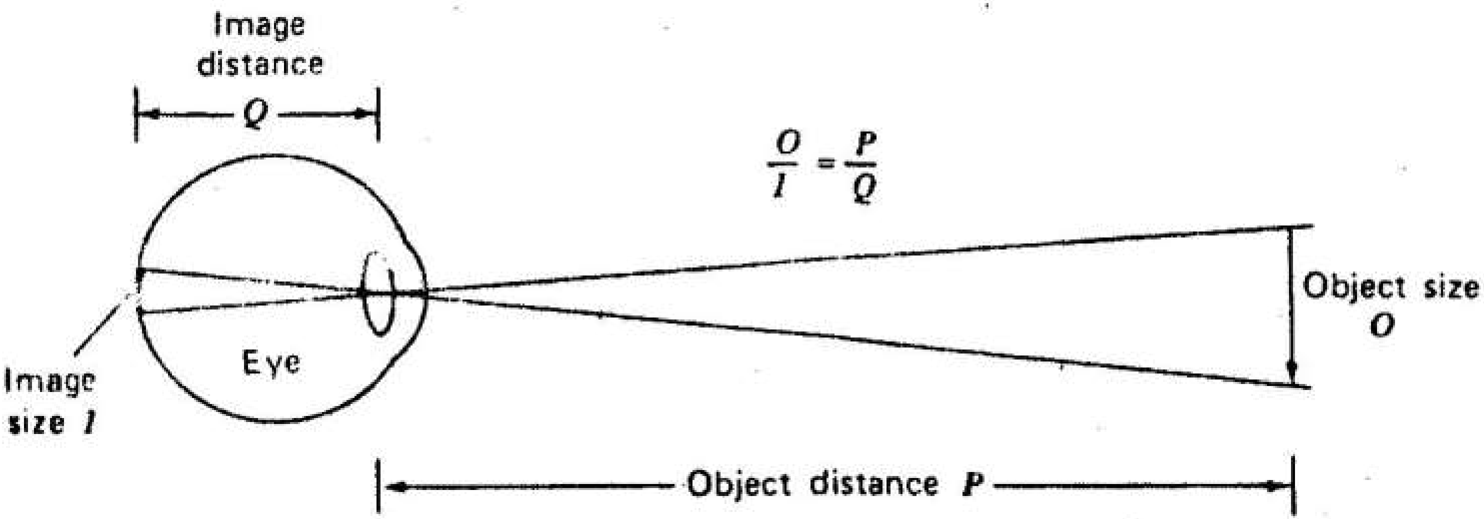
The absorption of a light photon in photoreceptor triggers an electrical signal to brain-an action potential. The light photon apparently cause a photochemical reaction in the photoreceptor which in some way initiates the action potential. The photon must be above a minimum energy to cause the reaction.

1-Infrared photons have insufficient energy and thus are not seen.

2-Ultraviolet photons have sufficient energy, but absorbed before they reach the retina and also are not seen.

The retina covers the black half of the eyeball. While this large expanse permits useful" warning" vision over a large angle, most vision is restricted to a small area called the macula lutea, or yellow spot. All detailed vision takes place in a very small area in the yellow spot ($\sim$0.3mm in diameter) called the fovea centralis .

The image on the retina is very small. A convenient equation for determining the size of image on the retina comes from the ratios of the lengths of the sides of similar triangles.



I: is image size

Q: is image distance

O: is object size

P: is object distance

Thus we can write $O/P=I/Q$

EXAMPLE:

How big is the image on the retina of a fly on a wall 3.0m away? Assume the fly is 3mm in diameter and Q=0.02m.

I= 0.02/3 x 0.03= 2 x 10^{-5}m=20µm

There are two general types of photoreceptors in the retina: the cones and the rods,the rods and cones are distributed symmetrically in all directions from visual axis except in one region-blind spot .

Throughout most of the retina the cones and rods are not at the surface of the retina but the lie behind several layers of the nerve tissue through which the light must passes.

Microscopic Anatomy of the Retina

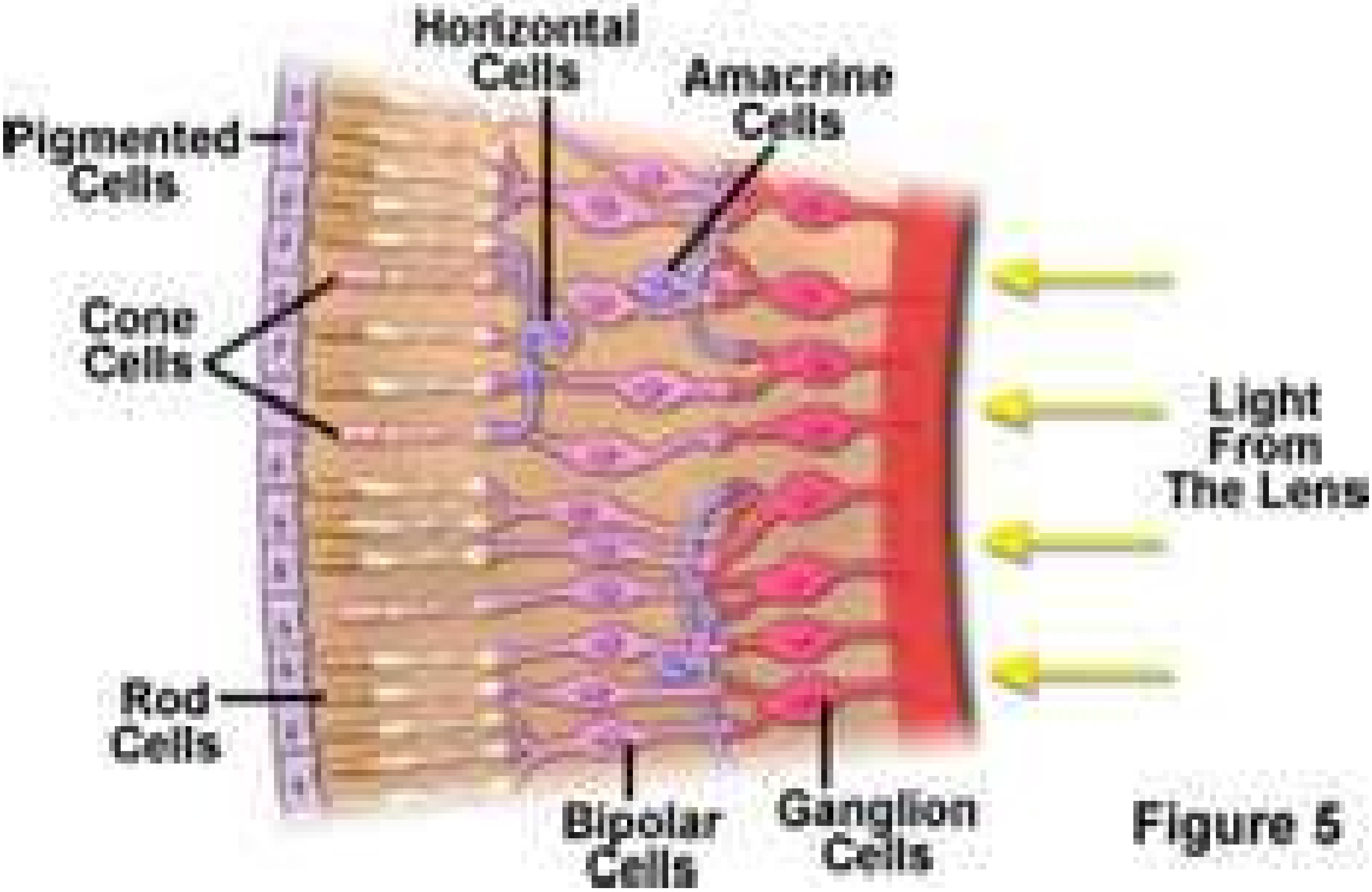
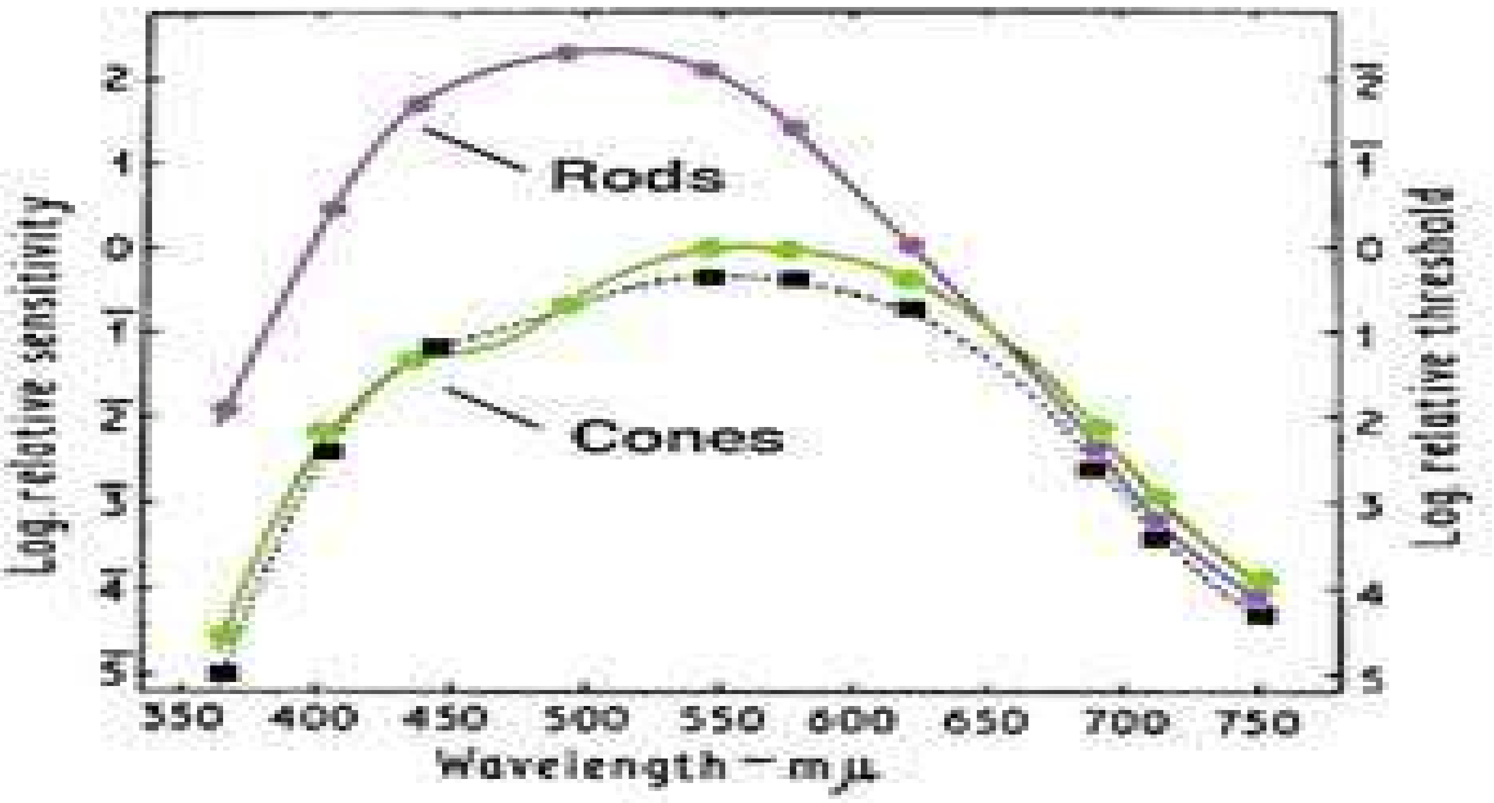
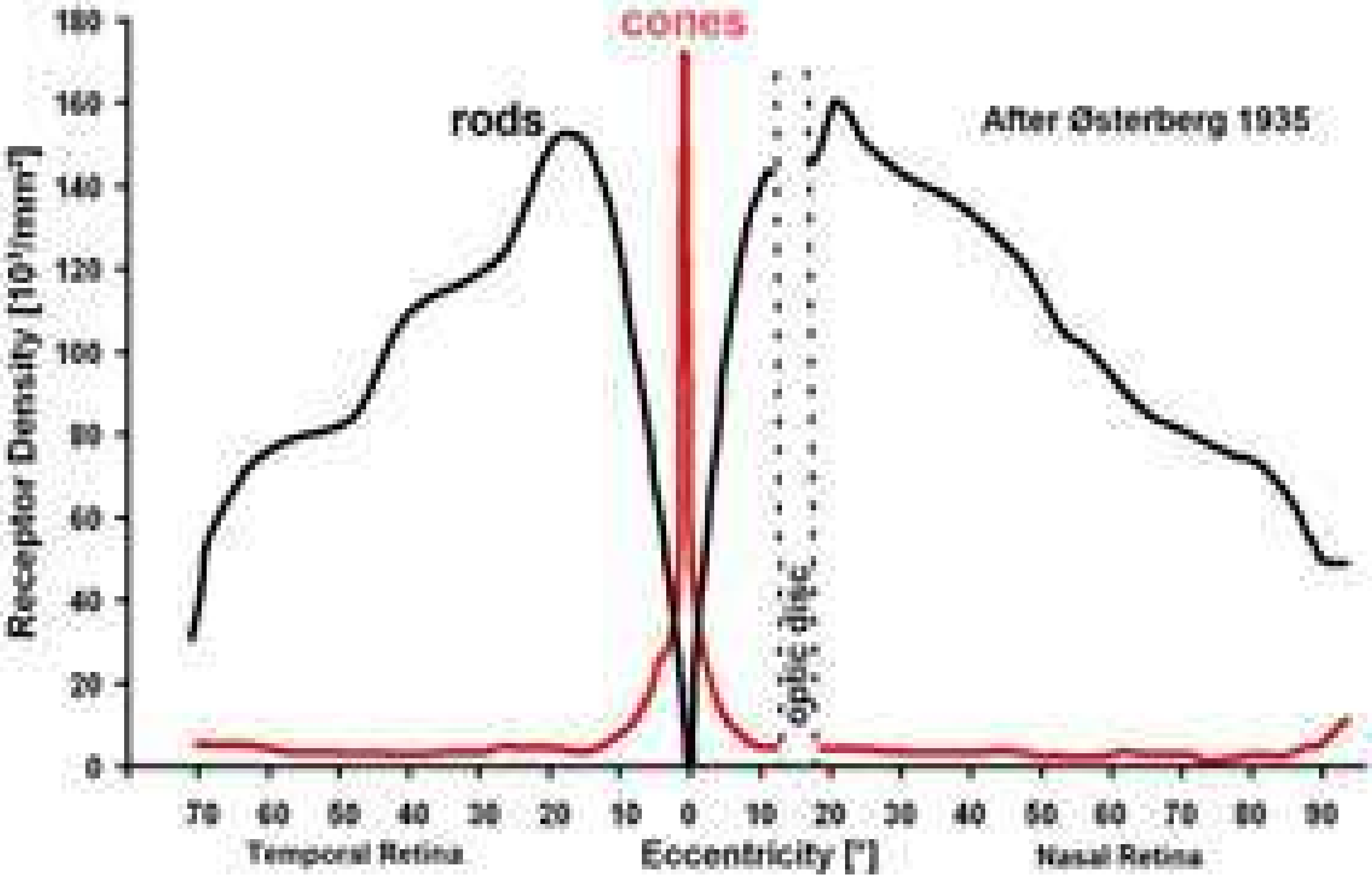


Figure 5

The cones are used for daylight, or photopic, vision. With we can see fine detail and recognize different colors. The cones are found in the fovea centralis. Each of the cones in the fovea has its own telephone line to the brain. The cones are not uniformly sensitive to all colors but have a maximum sensitivity at about 550 nm in the yellow – green region.



. THE RODS ARE USED FOR NIGHT, OR SCOTOPIC, VISION AND FOR PERIPHERAL VISION. THEY ARE NOT UNIFORMLY DISTRIBUTED OVER THE RETINA BUT HAVE A MAXIMUM DENSITY AT AN ANGLE OF ABOUT 20°.


cones
rods
After Østerberg 1935
optic disc
Receptor Density [10³/mm²]
0
20
40
60
80
100
120
140
160
180
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
Temporal Retina
Eccentricity [°]
Nasal Retina

That is, if you are looking at the sky at night, the light from a faint star displaced 20^{o} from your line vision will fall on the most sensitive area of your retina. If you look directly toward the faint star, its image will fall on your fovea which has no rods and you will not see it.

The rods are .

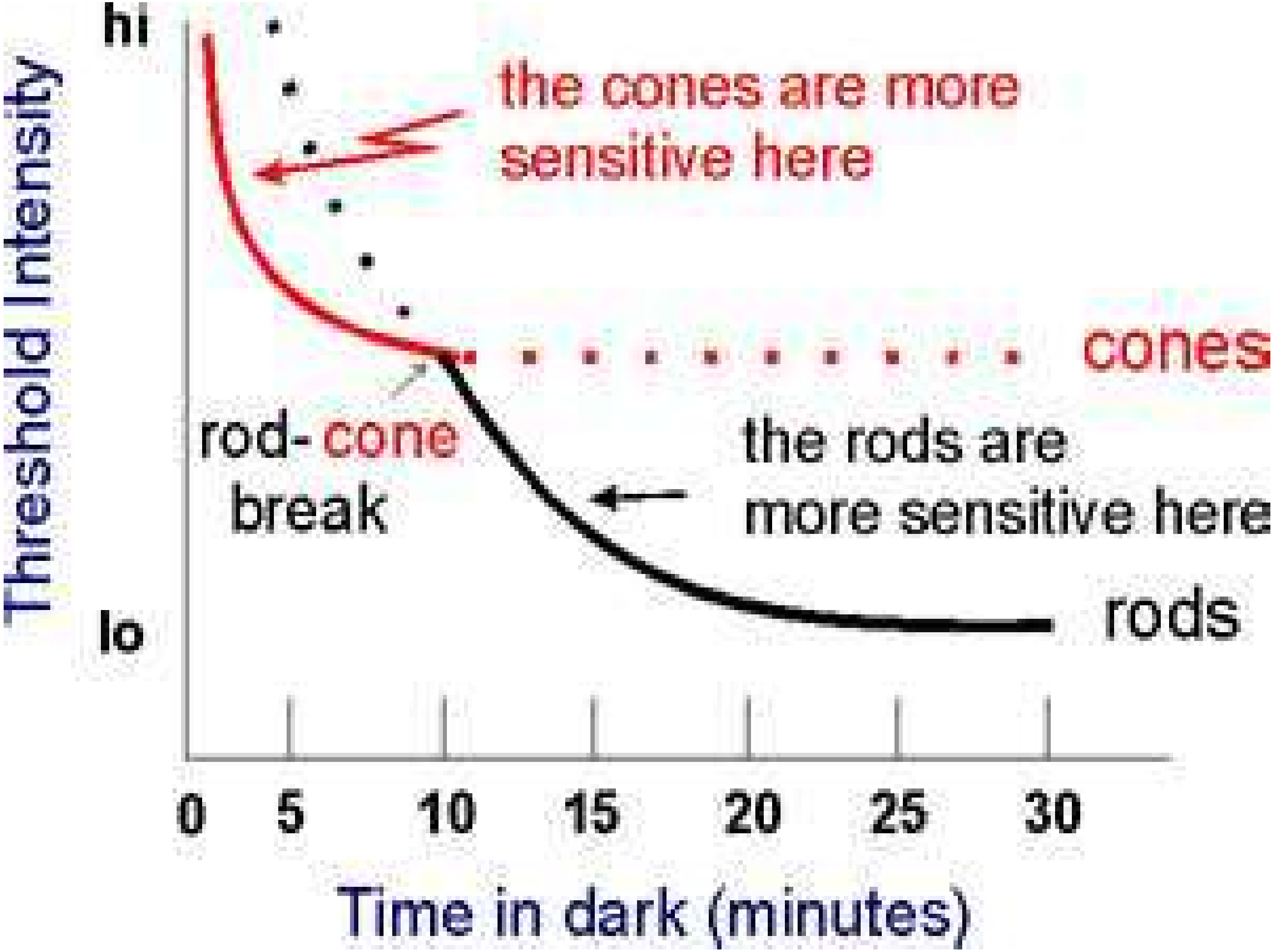
most sensitive to blue-green($\sim 510nm$)

The rods and cones are equally sensitive to red light (650 to 700nm).

Dark adaptation: is apparently the time needed for the body to increase the supply of photosensitive chemicals to the rods and cones.

The eyes do not have their greatest sensitivity to light under photopic conditions, if the light level suddenly decreases by a factor of 1000 we are momentarily "in dark", but after a few minutes we are able to see many of details that were not visible when it first became dark.

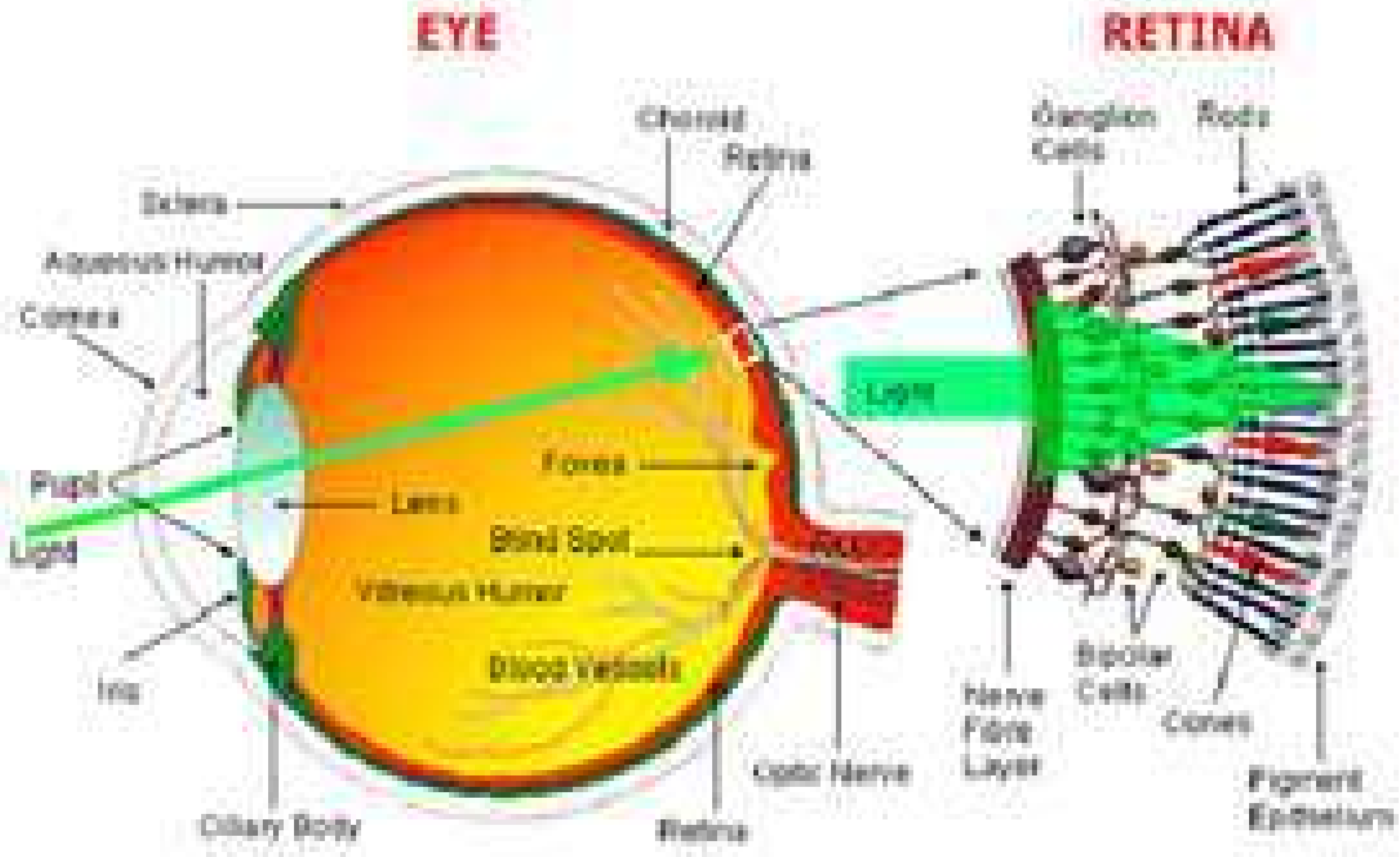
The cones adapt most rapidly; after about 5 min the fovea centralis has reached its best sensitivity. The rods continue to dark adapt for 30 to 60min, although most of their adaptation occurs in the first 15 min.


hi
lo
Threshold Intensity
the cones are more sensitive here
cones
rod- cone break
the rods are more sensitive here
rods
0
5
10
15
20
25
30
Time in dark (minutes)

Blind spot:

THAT HAS NEITHER RODS NOR CONES.

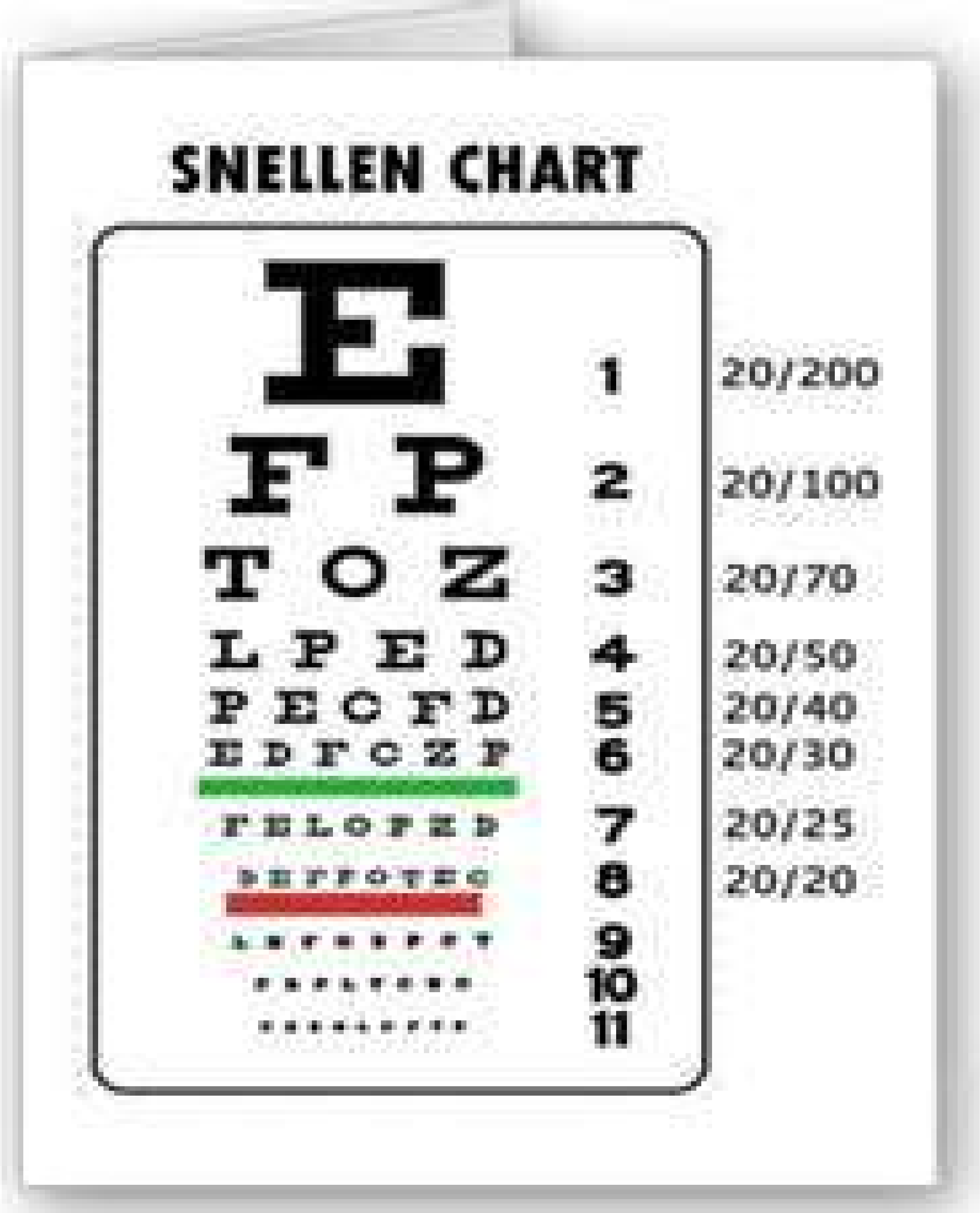
THAT THERE IS A REGION FROM ABOUT 13^{O} TO 18^{O}



Adapted from WEBVISION http://webvision.med.utah.edu/

HOW SHARP ARE YOUR EYES

The optometrist usually uses a snellen chart to test visual acuity. If he tells you that your eyes test normal at 20/20, he means that you can read detail from 20 ft that person with good vision can read from 20 ft. If your eyes test at 20/40, you can just read from 20 ft the line that a person with good vision can read from 40 ft.


SNELLEN CHART
E
1
20/200
F P
2
20/100
T O Z
3
20/70
L P E D
4
20/50
P E C F D
5
20/40
E D F C Z P
6
20/30
F E L O P Z D
7
20/25
D E F P O T E C
8
20/20
9
10
11

The ability of the eye to recognize separate lines also depends on the relative "blackness "and "whiteness" , the contrast between two areas is defined as optical density OD

$$OD = \log (I_o/I)$$

Where I_o is the light intensity without absorber and I is intensity with absorber.

EXAMPLE: A piece of film that transmits 10% of the incident light has an optical density

$$OD = Log(1/0.1) = 1.0$$

EXAMPLE: A film that absorbs 99% of the light has an optical density

$$OD = Log(1/0.01) = 2.0$$

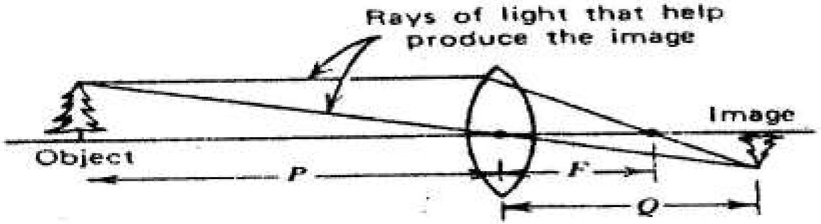
An OD=3 means that only 0.001 of the light transmitted.

DEFECTIVE VISION AND ITS CORRECTION

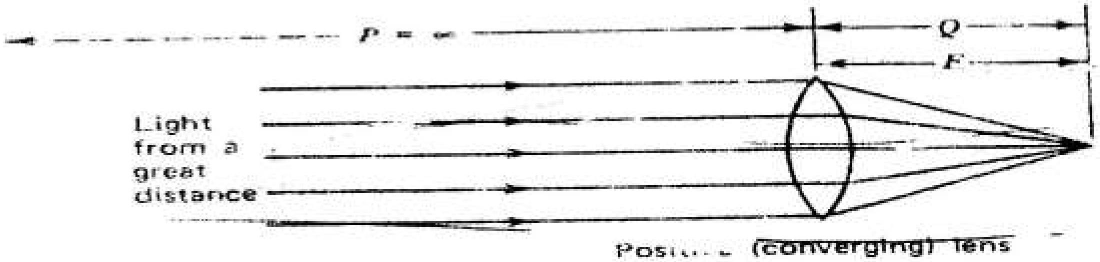
There is a simple relationship between the focal length **F**, the object distance **P**, and the image distance **Q** of the lens

$$\mathbf{1/F = 1/P + 1/Q}$$

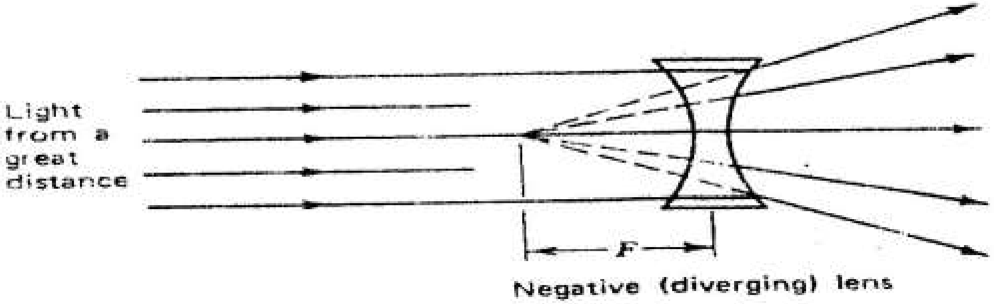
If **F** is measured in meters, then **1/F** is the lens strength in diopters **(D).**


Rays of light that help produce the image
Object
Image
P
F
Q

(a)


P = ∞
Q
F
Light from a great distance
Positive (converging) lens

(b)


Light from a great distance
F
Negative (diverging) lens

(c)

The ability of the eye to focus on objects over a wide range is called accommodation.

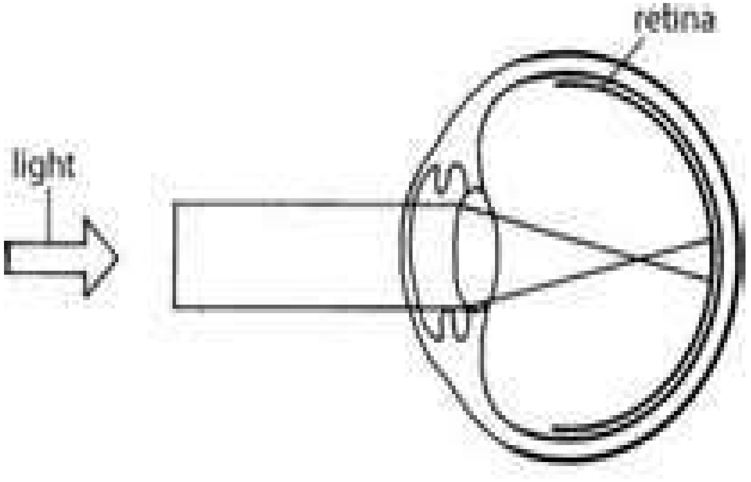
Power of accommodation of normal eye $= \frac{1}{F}$

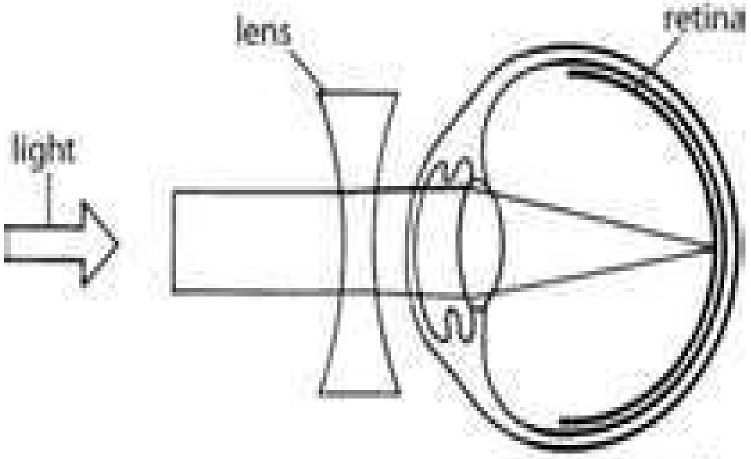
$$= \frac{1}{near\ point} - \frac{1}{far\ point}$$

$$= \frac{1}{0.25m} - \frac{1}{\infty} = 4 \text{ Diopter}$$

MYOPIA

The eyeball is too long, and parallel rays are focused by the relaxed eye to a position in front of the retina. Only near objects can therefore be seen clearly. This defect can be corrected by diverging lenses. If the spectacle lens is chosen to have a focal length equal in magnitude to the distance to the far point (F), then parallel rays striking the spectacles appear to the eye to diverge from the far-point. Note that the least distance of distinct vision for the spectacled eye is no longer d but increased to x.





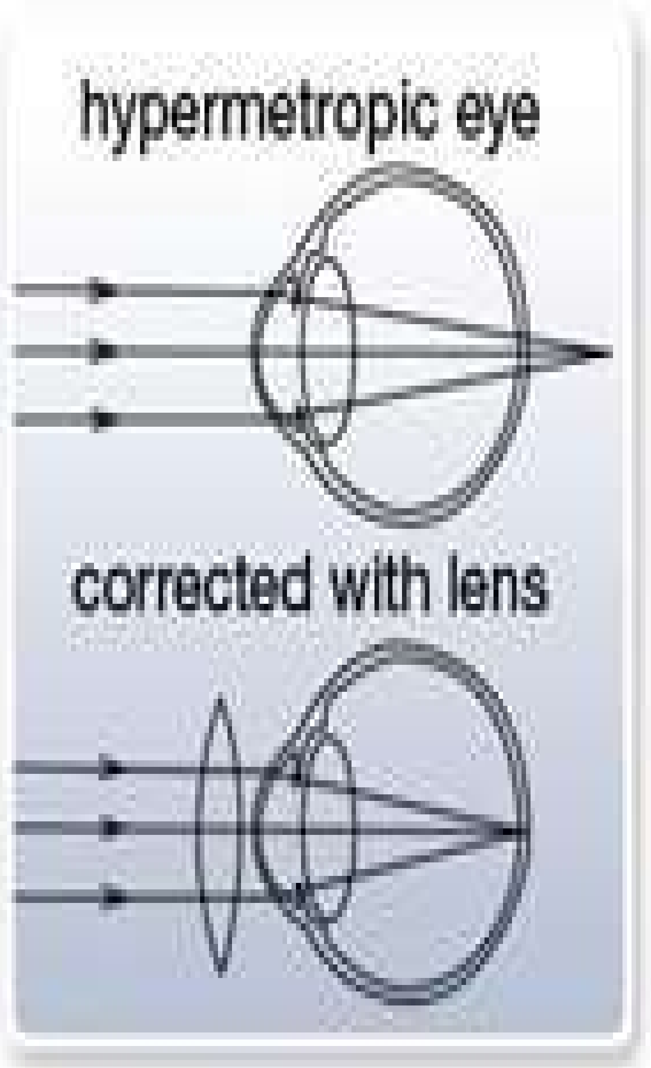
Cecile Duray-Bito

where $$\frac{1}{-F} = \frac{1}{x} - \frac{1}{d}$$

An object at distance x must produce a virtual image at d in the spectacle lens in order just to be brought to focus by the eye.

HYPERMETROPIA:

This is the opposite effect. The eyeball is too short and parallel rays are focused to a point behind the retina, this defect is corrected by using converging spectacle lenses, if the near point is at d^1. Then an object at d requires the lens to produce a virtual image of it at d^1 which will then be visible to the fully accommodation eye in the other words the focal length of the spectacle lenses must be F.



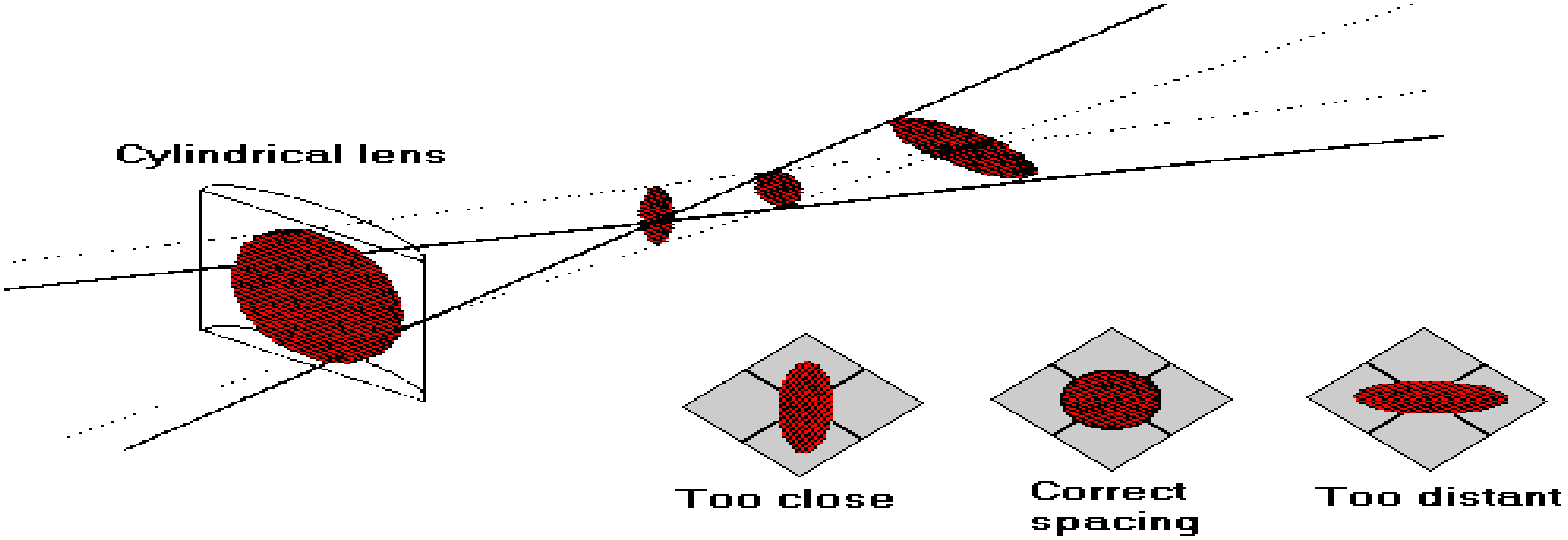
Where $$\frac{1}{F} = \frac{1}{d} - \frac{1}{d^1}$$

PRESBYOPIA:

As people get older the cillary muscles weaken and lens losses some of its elasticity . The power of accommodation diminishes with age. This defect is corrected by two parts of lenses upper half of each lens is diverging and corrects the myopia when the wears is looking ahead at distance objects, the lower half corrects the presbyopia with a suitable converging lens, and the wearer looks through this part when reading

ASTIGATISM

When astigmatism is present, point objects do not form point images on the retina. This is normally due to the corneas unequal curvature in different directions. If the curvature is greater in a horizontal section than in the vertical section, rays brought to a focus more quickly in the horizontal than in the vertical plane. The defect is corrected by the use of cylindrical spectacle lenses.



EX 1: A man has a near point 50cm and far point infinity, what is his useful accommodating power.

$$P = \frac{1}{near\ point} - \frac{1}{far\ point}$$

$$= \frac{1}{0.5m} - \frac{1}{\infty} = 2\ Diopter$$

EX 2: What spectacle lenses would be prescribed for the man of example 1.

$$1/F_{\text{corrected}} = 1/n.p_{\text{for normal eye}} – 1/n.p_{\text{defected}}$$

$$1/F_{\text{corrected}} = 1/0.25\text{m} - 1/0.5\text{m} = 2 \text{ Diopter}$$

$$F = 1/2 \text{ Diopter} = 0.5\text{m} = 50\text{cm}$$

EX 3: A myopic male has near and far point of 20cm and 250 cm respectively. What spectacle lens is prescribed for his defect and where is his near point.

$$1/F_{\text{corrected}} = 1/f.p_{\text{for normal eye}} - 1/f.p_{\text{defected}}$$

$$1/F_{\text{corrected}} = 1/\infty - 1/2.5\text{m} = -0.4 \text{ Diopter}$$

$$F = -2.5\text{m} \qquad \text{the lens is diverging}$$

The near point when wearing the spectacles will be

$$1/F_{\text{corrected}} = 1/n.p_{\text{after wearing glass}} - 1/n.p_{\text{without glass}}$$

$$1/-2.5\text{m} = 1/n.p_{\text{after wearing glass}} - 1/0.2\text{m}$$

$$1/n.p_{\text{after wearing glass}} = 1/0.2\text{m} - 1/2.5\text{m}$$

$$= 5 \text{ Diopter} - 0.4 \text{ Diopter} = 4.6 \text{ Diopter}$$

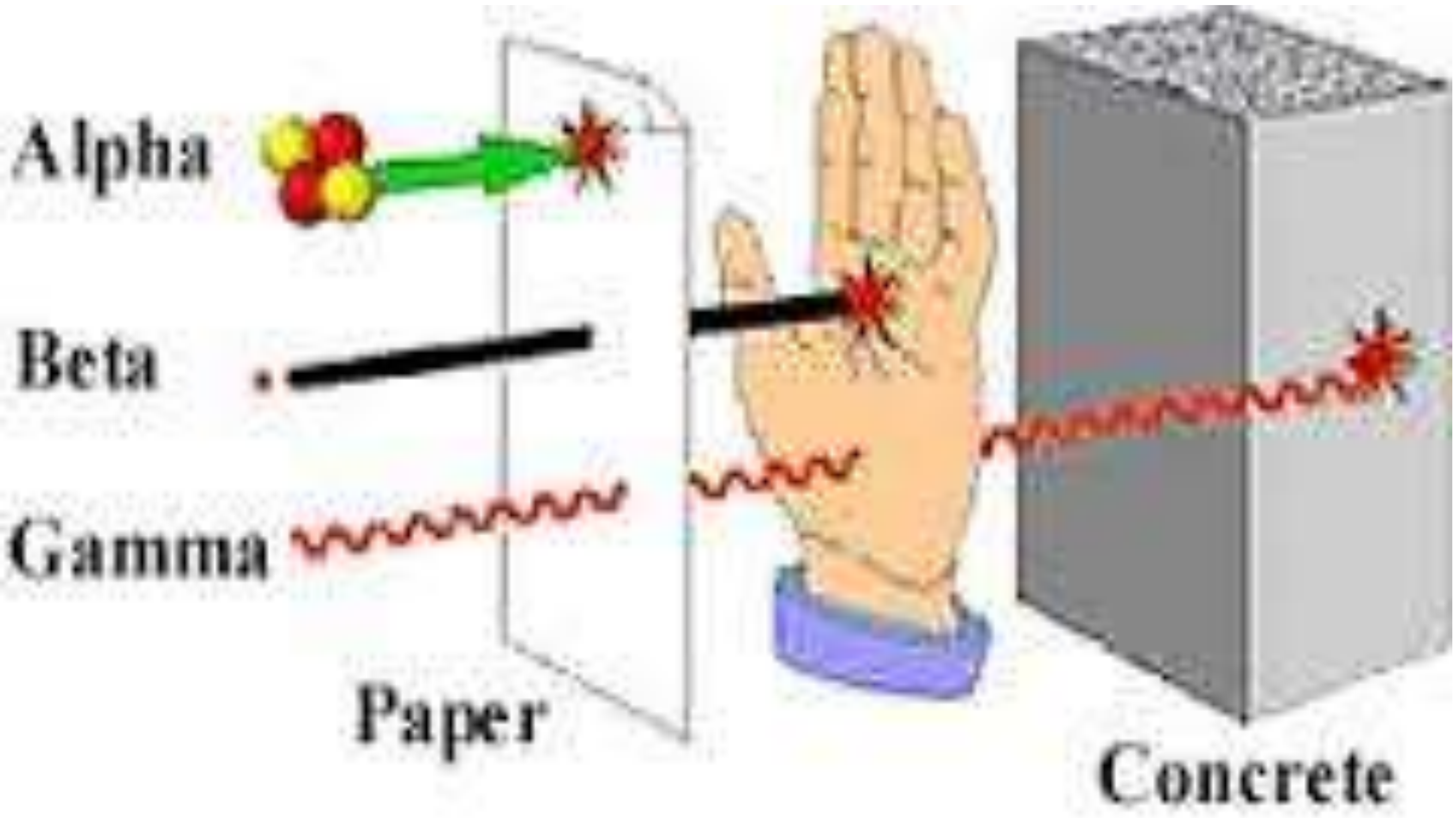
$$n.p_{\text{after wearing glass}} = 1/4.6 \text{ Diopter} = 0.217\text{m} = 21.7\text{cm}$$

PHYSICS OF NUCLEAR MEDICINE

Radioactivity

A certain natural elements, heavy have unstable that disintegrate to emit various rays. Alpha(α), Beta(β), and Gamma(γ)rays.

Alpha(α)	Beta(β)	Gamma(γ)
1-Positive charge	**Negative charge**	**Without charge**
2-Affected by magnetic& electric field	**Affected by magnetic& electric field**	**Doesn't affected**
3-Stop in a few centimeter of air (low penetrating power	**It is stopped in a few meters of air and a few millimeters of a tissue(the penetrating power is more than α and less than γ**	**High energy photon(high penetrating power).**
4-Is Helium atom($_2He^4$)	**High speed electron**	**It is photon**
5-Has a fixed energy for a given source	**Has spread of energy up to max**	**Has a fixed energy for a given source**


Alpha
Beta
Gamma
Paper
Concrete

Isotopes

Nuclei of a given element with different numbers of neutrons.

There are two types:

1-Stable isotopes if they are not radioactive. Ex:(^{12}C,^{13}C)

2-Radioisotopes if they are radioactive. Ex: (^{11}C,^{14}C,^{15}C)

Radio-nuclides:

Is used when several radioactive elements are involved.(Radioisotopes are used when referring to single element).

Neutrino:

A mass less, charge less, particle, Takes up the difference in energy between the actual beta energy and the maximum beta energy.

Alpha (α):

Is helium atom($^{4}_{2}He$) with mass number (A) = 4 and atomic number (Z) = 2. The result of alpha emission is a daughter whose atomic number is two less than of the parent, and whose atomic mass number is four less than that of the parent. In the case of ^{210}Po for example, the reaction is

$$^{210}_{84}Po \longrightarrow {}^{4}_{2}He + {}^{206}_{82}Pb$$

Or in general

$$^{A}_{Z}X \longrightarrow {}^{4}_{2}He + {}^{A-4}_{Z-2}Y$$

Beta emission:

$$^{32}_{15}P \longrightarrow {}^{32}_{16}S + {}^{0}_{-1}e$$

Or positron

$$^{22}_{11}Na \longrightarrow {}^{22}_{10}Na + {}^{0}_{1}e$$

Activity of Radioactive materials

-half-life

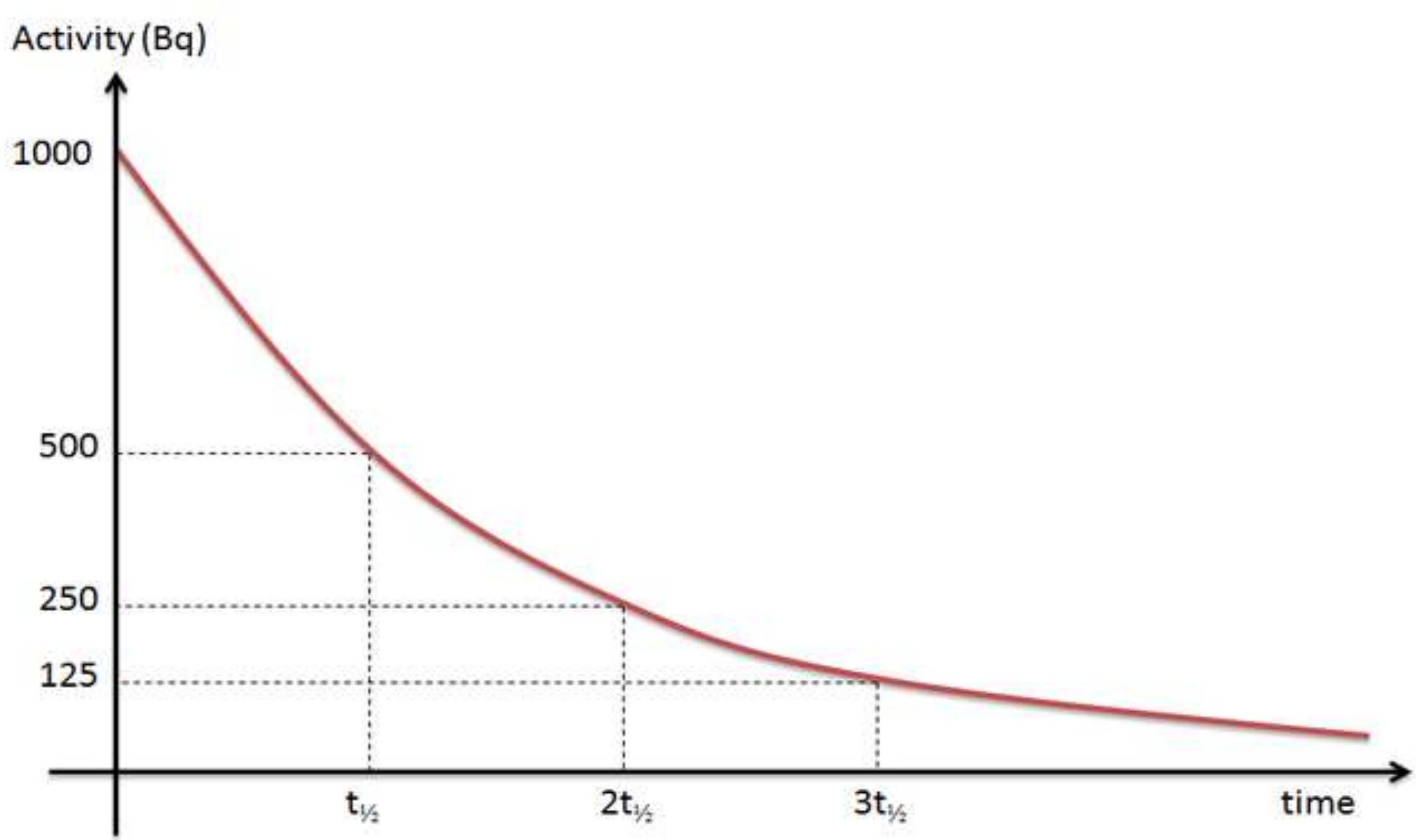
-mean life

-decay constant

-background

Half life ($T_{1/2}$):

The time needed for half of the radioactive nuclei to decay.



$$A = A_0 \, e^{-\lambda t} \qquad \text{……….} \; (1)$$

Where:

A : activity in disintegration per second after time(t)

A_o: initial activity

λ : decay constant(sec^{-1},$hour^{-1}$,$year^{-1}$)

t : time since activity (sec, hour, year)

$T_{1/2} = 0.693 / \lambda$ ………. (3)

$A = \lambda N = (0.693/ T_{1/2}$(mass/atomic weight)x Avogadro number

1 year = 3.15 x 10^7sec

$T_{1/2}$ = should be in second

The average or mean time T = 1/ λ

1/ λ from the equation (3) = 1.44 $T_{1/2}$

So T = 1.44 $T_{1/2}$

T mean life time (tau) is the average lifetime of a radioactive particle before decay.

Example 1.

a. If you have 1g of pure potassium 40 (^{40} K) that is experimentally determined to emit about 10 ^{5} beta rays per second. What is the decay constant λ?

Solution:

$A = \lambda N = \lambda$ (mass/atomic weight)x Avogadro number)

$10^5 = \lambda \times 1/40 \times 6.02 \times 10^{23}$

So $\lambda = 6.7 \times 10^{-18}\ s^{-1}$

b. Estimate the half-life of ^{40}K from .

$T_{1/2} = 0.693/\ \lambda = 10^{17}$

$T_{1/2} = 10^{17}/3.15 \times 10^7 = 3 \times 10^9$ years

Back ground counts:

Is the counts without the radioactive source and this is due cosmic rays, natural radioactivity ……etc

Units of activity:

The unit of activity of radioactive is Ci (Curie)

1 Ci = 3.7 x 10^{10} dis/s of Bq (Becquerel)

(micro)μ Ci = 10^{-6}Ci

(nano)η Ci = 10^{-9}Ci

(pico)ρ Ci = 10^{-12} Ci

Questions:

1- A solution counting a radioactive isotope which emits β-particles with half-life 12.26 days' surroundings a Geiger counter which records 480 counts/minute. What counting rate will be obtained 49.04 days later?

Solution

A_o = 480 counts/min

A = ?

t = 49.04 days

$T_{1/2}$ = 12.26 days

$\lambda = 0.693/ T_{1/2} = 0.693/12.26$ days

$A = A_0 e^{-\lambda t}$

A =480 counts/min x $e^{-(0.693/12.26 \text{ days})\, 49.04 \text{ days}}$

A = 480 counts/min x e -4(0.693)

A = 480 counts/min x $1/ 2^4$

A = 480/16 = 30 counts/min

2- Radium 226 has a half life of 1620 years. What is the mass of a sample which undergoes 20000 disintegrations per second?

Solution:

$T_{1/2}$ = 1620 years = 1620 x 3.15 x 10^7 s

λ = 0.693/ $T_{1/2}$ = 0.693/(1620 x 3.15 x 10^7 s)

A = 2x 10^4 dis/s

A = N λ

2x 10^4 dis/s = (m/226) x 6.02 x 10^{23} x 0.693/(1620 x 3.15 x 10^7 s)

m = 55x 10^{-6}g

3- What is the mass of 1ci of ^{227}Th?

If the half-life is 1.90 years.

Solution:

$T_{1/2}$ = 1.90 years = 1.90 x 3.15 x 10^7 s

λ = 0.693/ $T_{1/2}$ = 0.693/(1.90 x 3.15 x 10^7 s)

A = 1 ci = 3.7 x 10^{10} dis/s

A = N λ

3.7 x 10^{10} dis/s = (m/227)x6.02x10^{23} x 0.693/(1.90 x 3.15 x 10^7 s)

m = 1.21x 10^{-3}g

4- Iodine-131 is used to destroy thyroid tissue in the treatment of an overactive thyroid. The half – life of ^{131}I is 8 days. If a hospital receives a shipment of 200g of ^{131}I, how much ^{131}I would remain after 32 days?4

Solution:

$\lambda = 0.693/\ T_{1/2} = 0.693/8\text{days}$

$t = 32\ \text{days}$

$A = A_0\ e^{-\lambda t}$

$m = m_0\ e^{-\lambda t}$

$m = 200\text{g} \times e^{-(0.693/8\text{days}) \times 32\text{days}}$

$m = 200\text{g} \times e^{-4(0.693)} = 200\text{g} \times 1/16 = 12.5\text{g}$

5- If 10mg of iodine-131 is given to a patient, how much is left after 24 days? The half – life of ^{131}I is 8 days.

Solution:

$t = 24\text{days}$

$\lambda = 0.693/\ T_{1/2} = 0.693/8\text{days}$

$m = m_0\ e^{-\lambda t}$

$m = 10x\ 10^{-3}g\ x\ e^{-(0.693/8\text{days})x24\text{days}}$

$m = 10^{-2}g\ x\ e^{\ -3(0.693)} = 10^{-2}g\ x\ 1/8 = 1.25\ x10^{-3}g = 1.25mg$

6- Technetium -99m (^{99m}Tc) is used for brain scans, if a laboratory receives a shipment of 200gm of this isotope and after 24 hours only 12.5 g of this isotope remain, what is the half-life of ^{99m}Tc.

$m_o = 200g$

$m = 12.5g$

$t = 24$ hr

$m = m_0 e^{-\lambda t}$

$m_o/m = e^{\lambda t}$

$200/12.5 = e^{24\lambda}$

$16 = e^{24\lambda}$

$\text{Log } 16 = 24 \lambda \text{ Log } 2.7$

$\lambda = 0.116 \text{ hr}^{-1}$

$T_{1/2} = 0.693/0.116 = 6$ hr

7- Mercury-197 is used for kidney scans and has a half-life of 3 days. If the amount of mercury -197 needed for a study is 1.0 g and the time allowed for shipment is 15 days, how much mercury -197 will need to be ordered.

$m = 1g$

$m_o = ?$

$T_{1/2} = 3$ days

$\lambda = 0.693/3days$

$m_o/m = e^{\lambda t}$

$m_o/1 = e^{(0.693/3days)15days}$

$m_o = 32g$

8- The half –life of strontium – 90 is 25 years, how much half-life will it take for 10g of it to be reduced to 1.25g.

Answer: 3 $T_{1/2}$

9-The half-life of ^{99m}Tc is 6 hours, after how much time will 1/16 of the radioisotope remain.

Answer: 24 hours

10- Radioactive ^{24}Na, which has a half life of 15 h, is sent from laboratory to a hospital . What should be its activity when it leaves laboratory if the activity is to be 10mCi (milli curies) when it used in the hospital 3 h later.

Answer: 11.5mCi

Pressure

Pressure is defined as the force per unit area. The pressure P under a column of liquid can be calculated from the following low:

$$P = \rho g h$$

Where the: ρ is the density of the liquid

g is the acceleration due to the gravity h is height of the column

Ex:- what height of water will be produced the same pressure as 120 mmHg.

Solution: $P = \rho\ g\ h = 13.6 \text{x} 980 \text{x} 12$

$= 1.6 \text{x} 10^5\ dy/cm^2$

For water $P = \rho\ g\ h$

$1.6 \text{x} 10^5 = 1 \text{x} 980 \text{x} h$

So $h = 163\ cm\ H_2o$

Or $P_{Hg} = P_{H2o}$

$(\rho\ g\ h)_{Hg} = (\rho\ g\ h)_{H2o}$

$\rho_{Hg}\ h_{Hg} = \rho_{H2o}\ h_{H2o}$

$h_{H2o} = (13.6 \text{x} 12)/1 = 163\ cmH_2o$

Ex:- Calculate the atmospheric pressure in N/m^2

- Solution:- 1 atm =760 mmHg =76 cmHg

- The atmospheric pressure in N/m^2 is equal

- $P = \rho g h = 13600 kg/m^3 x 9.8 m/s^2 x 0.76 m$

$= 1.01x10^5 N/m^2$

Gauge Pressure

- The excess pressure over atmospheric pressure.

Negative Pressure

- Any pressure lower than atmospheric pressure. For example: The lung pressure during inspiration is a few centimeter of water negative ,a person drink through a straw the pressure in his mouth must be negative.
- There are numbers of places in the body where the pressure is lower than atmospheric pressure or negative .For example when we breath inspire the pressure in the lungs must be lower than the atmospheric pressure .

The most common clinical instrument used in the measuring pressure is the sphygmomanometer, which measure s blood pressure.

Typical pressure in the normal body

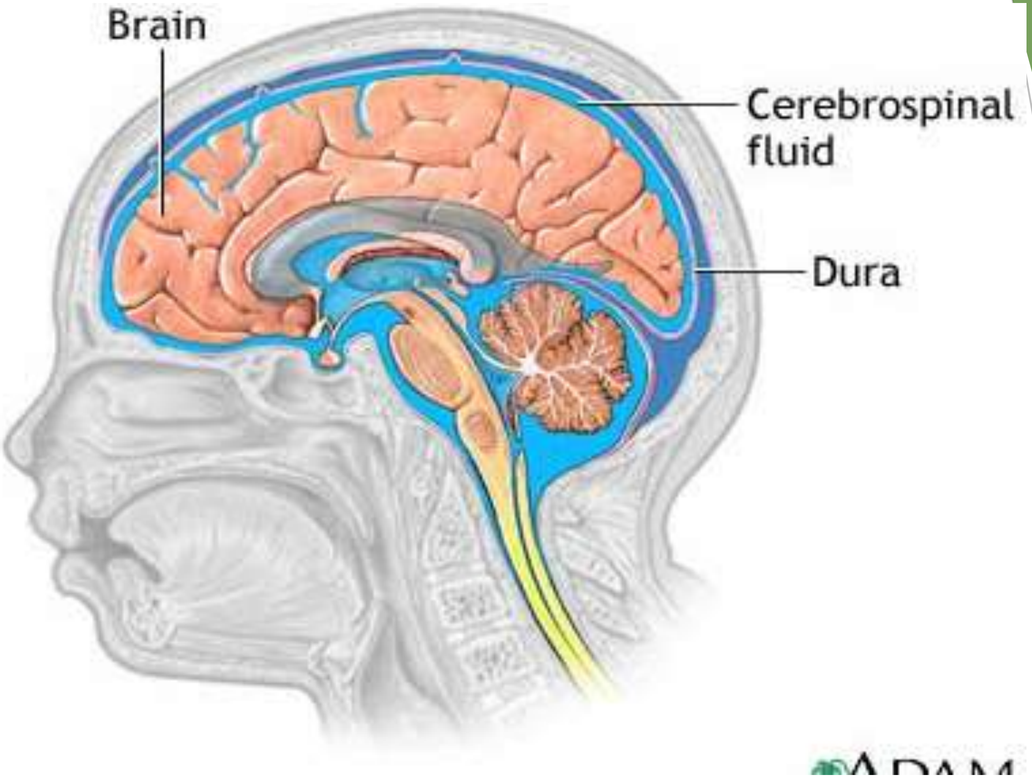
Different parts of the body	Typical pressure(mmHg)
Arterial blood pressure	
Max.(systole)	100 - 140
Min.(diastole)	60 - 90
Venous blood pressure	3 - 7
Middle ear pressure	less than 1
Eye pressure	20
CSF inside the brain	5 - 12

Measurement of pressure in the body

An instrument that measures pressure is called a manometer. The common clinical instrument used in measuring pressure is the sphygmomanometer .Two types of pressure gauges are used in sphygmomanometer, they are

Pressure inside the skull

- The brain contains approximately 150cm3of cerebral spinal fluid (CSF) in a series of inter connected openings called ventricles



CSF (brain)----to ventricles-----to spinal column-----to circulatory system.

One of the ventricles, the aqueduct is especially narrow.

-If at birth this opening is blocked for any reason, the CSF is trapped inside the skull and increases the internal pressure. The increased pressure causes the skull to enlarge. This serious condition is called hydrocephalous.

Measuring the CSF pressure

- It is not convenient to measure the SCF pressure directly. There are two methods:
- 1-Crude method: This method can measure the pressure inside the skull by measuring the circumference of the skull just above the ears. Normal values for newborn infants are from (32-37) cm, and a

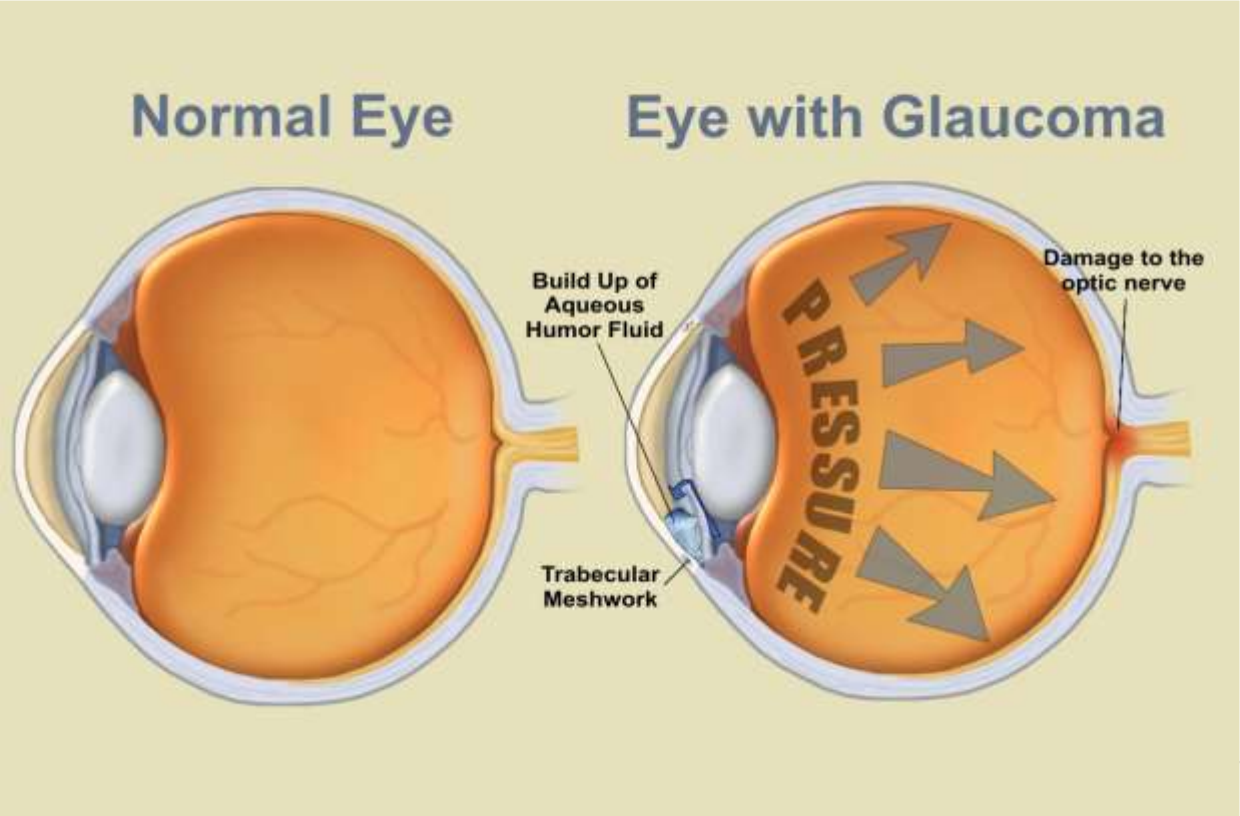
larger value may indicate hydrocephalus.

2-Transillumination: is a qualitative method of detection. Make use of the light -scattering properties of the rather clear CSF inside the skull.

A bright light is shined through a body cavity or organ such as the brain

A.D.A.M.

Eye pressure



The clear fluids in the eye ball (aqueous and vitreous humors) that transmit the light to the retina (the light sensitive part of the eye), are under pressure and maintain the eye ball in a fixed size and shape

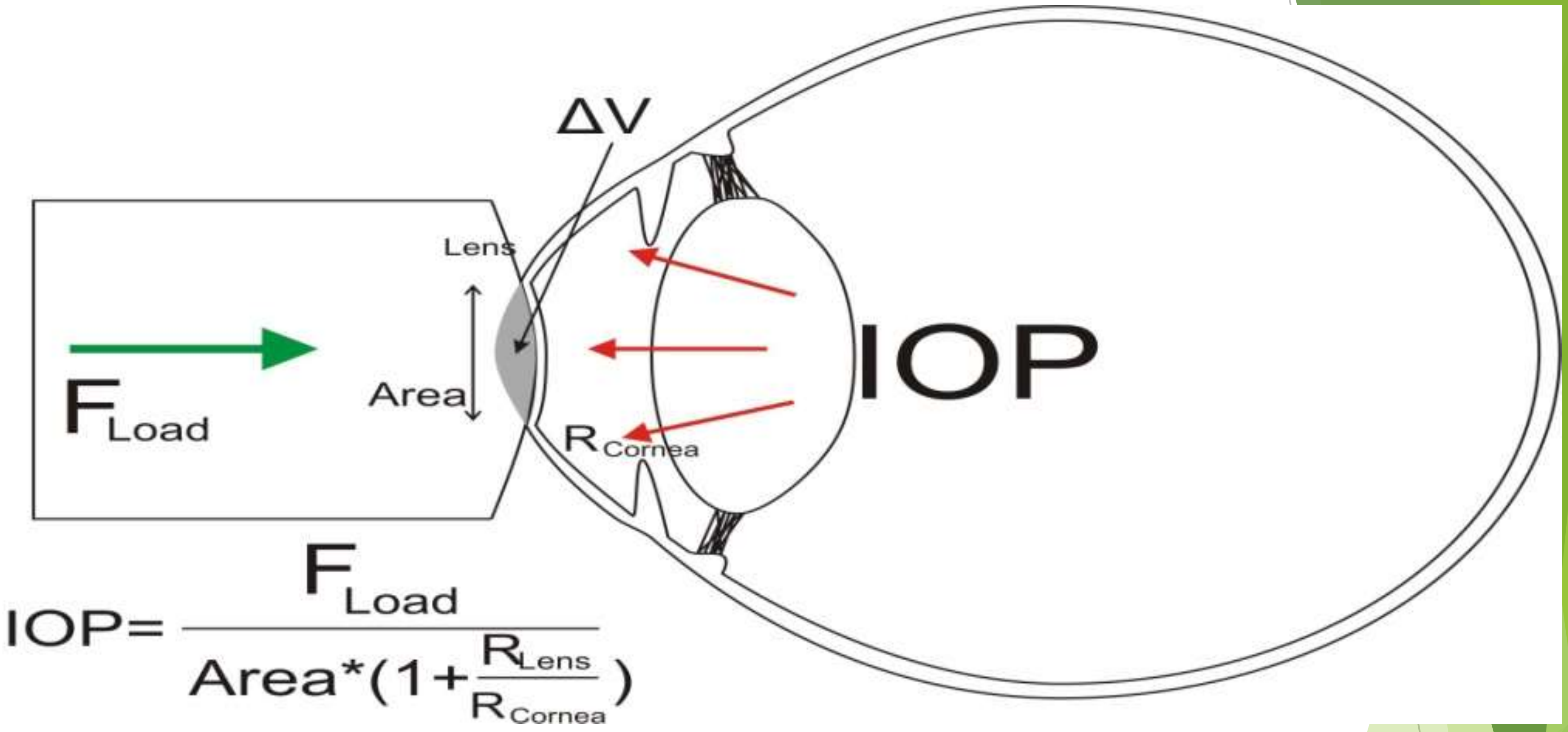
-If a partial blockage of the drain system occurs, the pressure increase of restrict the blood supply to the retina then affect the vision. This condition, called glaucoma.

Glaucoma: 1- moderate---------tunnel vision
2- severe--------------blindness

-The pressure in normal eyes ranges from (12 - 23) mmHg.

Measuring the eye pressure

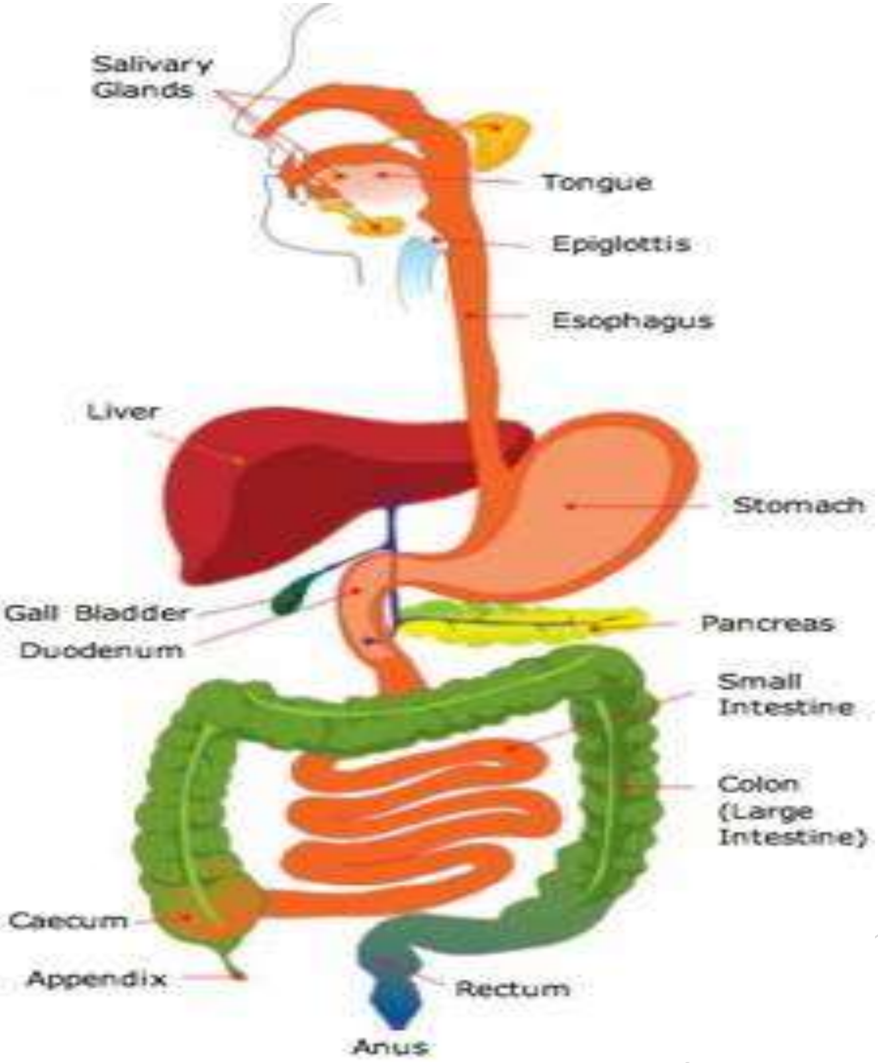
- 1-By feel the physicians estimate the pressure inside the eye by feel as they pressed on the eye with their fingertips.
- 2-By the tonometer



$$IOP = \frac{F_{Load}}{Area*(1+\frac{R_{Lens}}{R_{Cornea}})}$$

An instrument is used to measure intraocular pressure(IOP).

Pressure in the Digestive System



-Opening through the body
-Over 6 m
-Closed in the lower end and has several restrictions
-Valves and sphincters permit unidirectional flow of food.
Pressure in the gastrointestinal (GI) system
-Greater than atmospheric pressure in most parts

-Esophagus pressure is usually less than atmospheric pressure

-Pressure in the stomach

A-Eating increases the pressure in the stomach slowly due to increased volume

B-Air swallowed during eating increases the pressure in the stomach → burping or belching

-Pressure in the gut

A-Bacteria action generates gas (flatus) →increase gut pressure

B- Belts, girdles, or swimming → affect gut pressure

Pylorus : valve

-Prevents the flow of food back into the stomach from the small intestine

-blockage in the small or large intestine → high pressure between the blockage and the pylorus → blockage of blood flow to critical organs → death

-Treatment

A-Intubation: a hollow tube though the nose, stomach, and pylorus

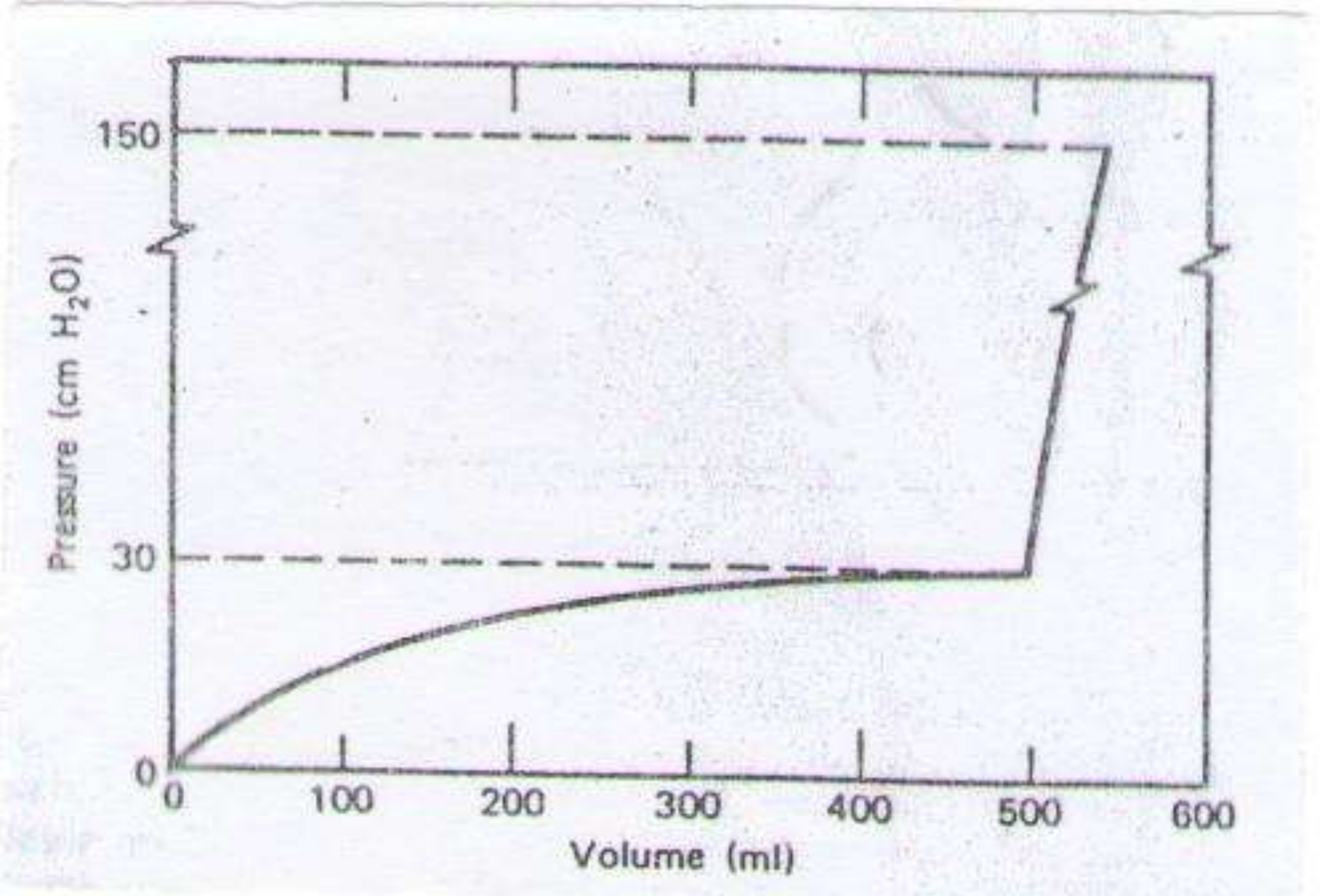
B-Surgery in a pressure-controlled operating room

Pressure in the skeleton

- -the highest pressures in the body are found in the weight bearing bone (joints).
- -The pressure in the knee joint may be more than 10 atm $P= F/A$---------------------(1)
- -The surface area of a bone at the joint is greater than its area either above or below the joint. The larger area at the joint distributes the force, thus reducing the pressure, according to equation (1).
- -Bone has adapted in another way to reduce pressure, the finger bones are flat rather force is spread over a larger surface, this reducing the tissues over the bones according to $P=F/A$.

Pressure in the urinary bladder

- -The interval pressure in the bladder is due to the accumulation of urine. The figure below shows the typical pressure-volume curves for the bladder, which stretches as the volume increase.


150
30
0
Pressure (cm H_2O)
0
100
200
300
400
500
600
Volume (ml)

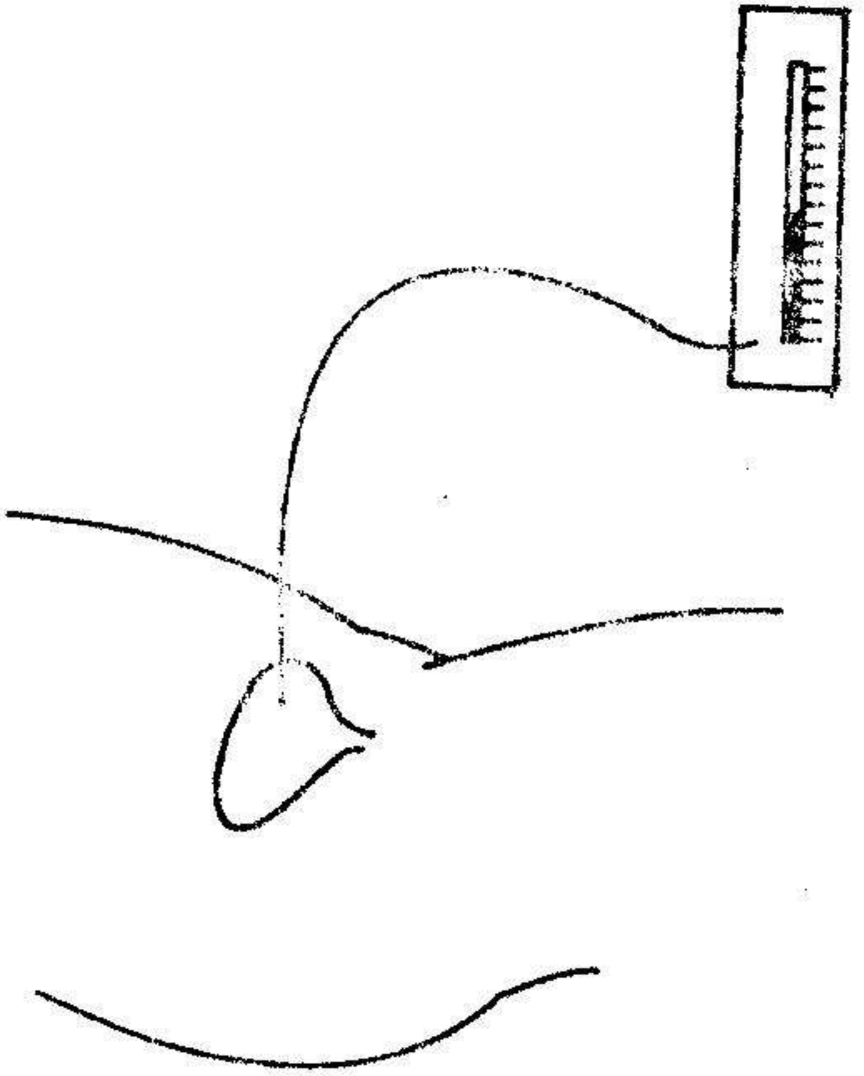
-For adult, the typical max. Volume in the bladder before voiding is 500ml. At some pressure nearly 30cmH2o the micturition reflex occurs.

-The resulting sizable muscular contraction in the bladder wall produces a momentary pressure of up to 150cmH20.

The pressure in the bladder can be measured:

1-By passing a catheter with a pressure sensor into the bladder through the urinary passage (urethra).

2-By a needle inserted through the wall of the abdomen directly into the bladder. This technique gives information about the function of the exit valves that cannot be obtained with the catheter technique.



-The bladder pressure increases during coughing , straining , sitting up , also during pregnancy the weight of fetus over the bladder increase the bladder pressure and causes frequent urination.

Normal voiding pressure is fairly low (20 - 40) cmH2o but for men who suffer from prostate obstruction of the urinary passage it may be over 100 cmH2o

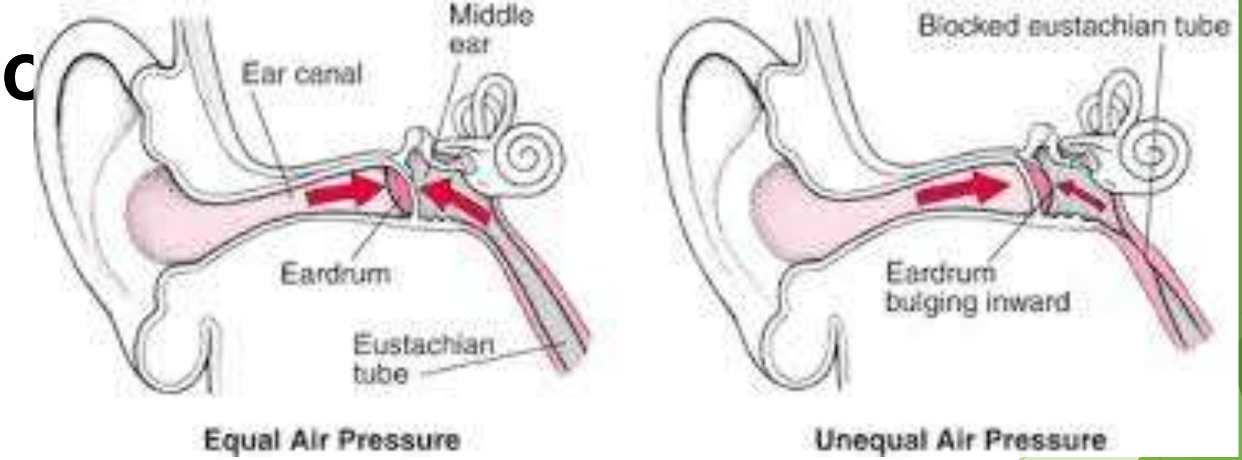
Pressure effects while diving

- The body is composed primarily of solids and liquids, which are nearly incompressible. Pressure changes; do not greatly affect most of it . However, there are gas cavities in the body where sudden pressure changes can produce profound effects.

Boyles law

- For a fixed quantity of gas a fixed temperature the product of the absolute and volume is constant.
- PV= constant
- $P_1V_1=P_2V_2=$ constant
- That is, if the absolute pressure is doubled, the volume is halved.

-The middle ear is one of the air cavities that exist within the body. For comfort the pressure in the middle ear should be equal to the pressure to the pressure on the outside c



$$P_{\text{middle ear}} = P_{\text{outside eardrum}}$$

This equalized is produced by air flowing through the Eustachian tube, which is usually closed except during swallowing, chewing, and yawning

-When diving many people has difficulty obtaining pressure equalization and feels pressure on their ears.

-(120mmHg) across the eardrum , which can occur in about 1.7 m of water ,can cause damage (rupture) to the eardrum . One method of equalization used by diver is to raise the pressure in the mouth by holding the nose and trying to blow

The pressure in the lung

- Pressure in the lung at any depth greater than the pressure in the lung at sea level. This means that the air in the lung is denser under water and that the partial pressure of all the air components are proportionately higher.

1-The higher partial pressure of O_2 causes more O_2 molecules to be transformed into the blood, and oxygen poisoning results if the partial pressure of the O_2 gets high. Partial pressure of O_2 is 0.8 atm and absolute air pressure is 4 atm at depth of 30m.

2-Breathing air at a depth of 30m is also dangerous because it may result in excess N_2 in the blood and tissues, there is a possibility of having:

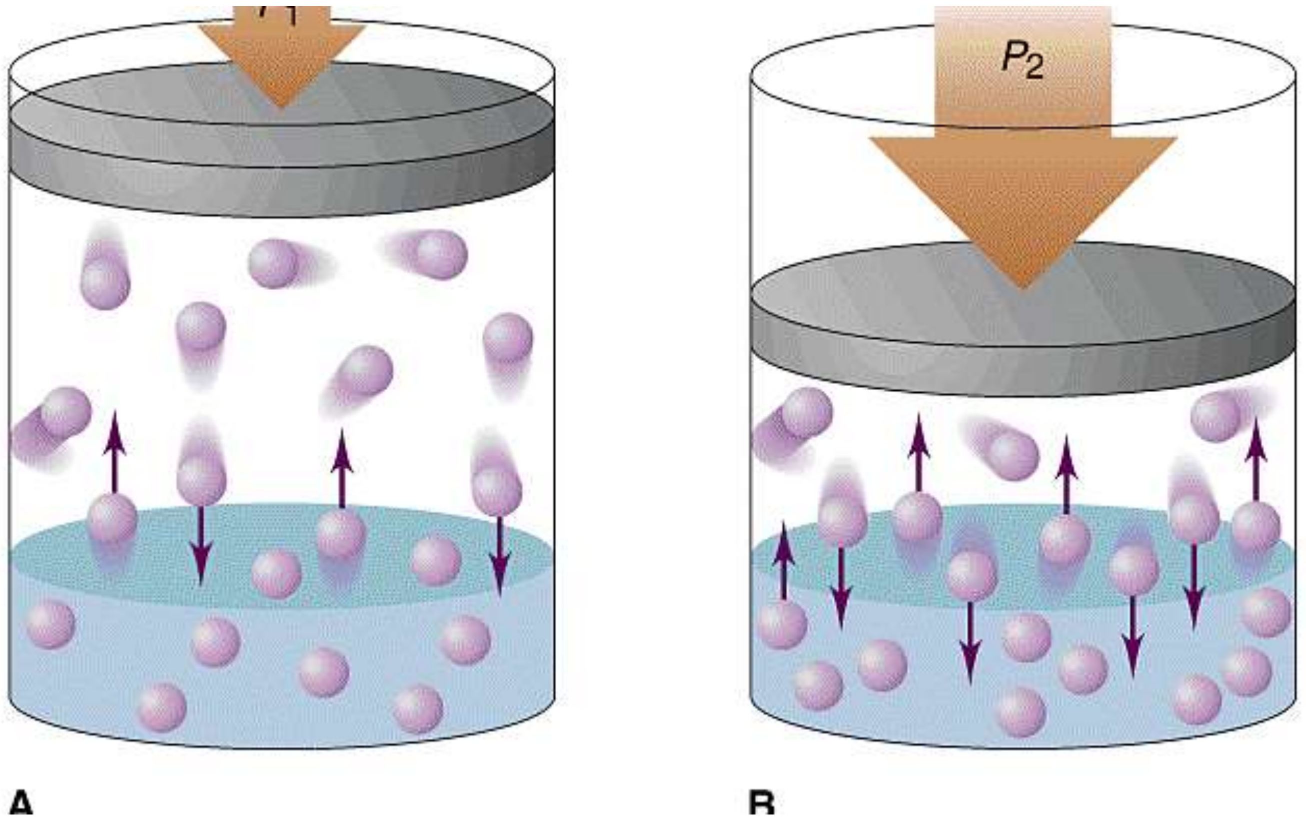
-Nitrogen narcosis (intoxication effect)

-The bends or decompression sickness

(a scant problem).

O_2 is attached to red blood cells, while N_2 is dissolved in the blood and tissues.

Henrys law



The amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas in contact with the liquid.

Hyperbaric oxygen therapy (HOT)

- The body normally lives in an atmosphere that is about one fifth O_2 and four-fifth N_2. In some medical situations it is beneficial to increase the proportion of O_2 in order to provide more O_2 to the tissue.

1-Gas gangrene:

The bacillus causes gas gangrene then it's treated with (HOT). That is due to bacillus cannot survive in the presence of oxygen

2-Carbon monoxide poisoning:

-The red blood cells cannot carry O_2 to the tissues because the carbon monoxide fasters to the hemoglobin at the places normally used by O_2.

-Normally the amount of O_2 dissolved in the blood is about 2% of that carried on the red blood cells.

-By using the (HOT) technique, the partial pressure of O_2 can be increased by a factor of 15 , permitting enough O_2 to be dissolved to fill the body's needs

3-Treatment of cancer:

(HOT) with radiation is given to the patient in transparent plastic tank. The theory was that more oxygen would make the poorly oxygenated radiation -resistant cell in the center of the tumor more susceptible to radiation damage.


SECHRIST

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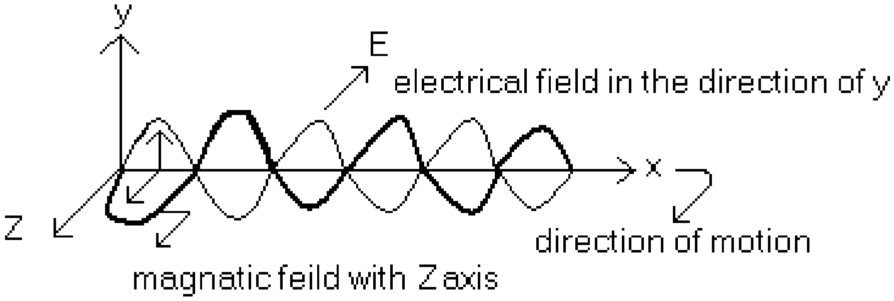
X – Rays

X – rays:- electromagnetic radiation **(EMR)** of very short wave length **($\lambda \leq 1 \rightarrow 0.1\ A^o$)** & very high penetrating power. It is very useful in diagnosis & radio therapy.



The amount of energy carried by each photon depends on the frequency of radiation:

$$\mathbf{E = h\upsilon = hc/\lambda}$$

Where

h = Plan's constant = $6.6*10^{-34}$ (joule. sec)
c = velocity of light = $3*10^{8}$ m/sec
υ = frequency of radiation

X – rays production :

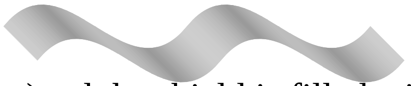
To produce photons of X – rays we need :

1. A filament (***is a concave part of cathode***) which is a source of electrons.

2. Target (anode) which is strike by the electrons which have a negative charged and these electrons are repelled by the cathode at attracted to the anode reaching it with very high kinetic energy.

3. High positive voltage applied between the cathode and anode to accelerate the negative electrons. In diagnostic radiography, this usually within the range ***40 to 120 Kev.***

4. An evacuated space (***with low pressure 10^{-6} tor***) : which is accelerate the electrons from the
cathode to the anode.



5. The space between the tubes insert(the enveloped and electrode)and the shield is filled with oil, the oil converts heat from the insert to the tube shield(***oil used to cool the target***)

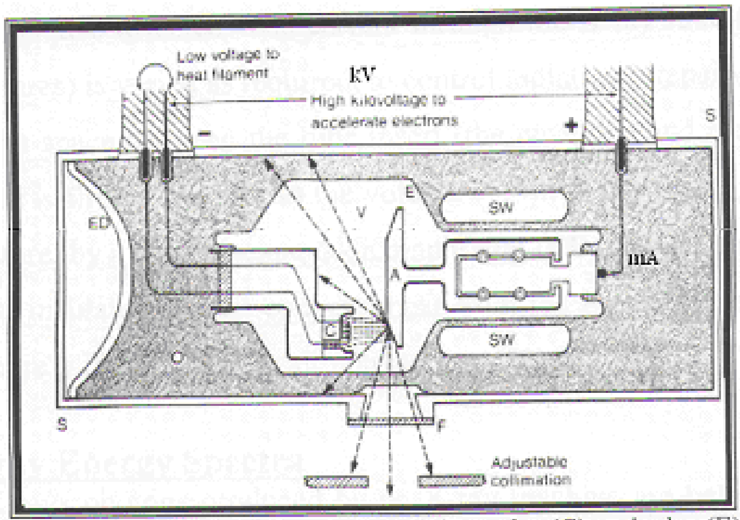


Figure. A rotating anode X-ray tube.: (A) anode; (C) cathode; (E) envelope; (V) vacuum; (SW) stator windings; (O) oil; (ED) expansion diaphragm; (F) aluminum filter; (S) shield[8].

NOTE: The energy of most electrons striking the target **(99.8%)** is dissipated in the form of heat. The remaining few energy **(0.2%)** produce useful X- rays.

*** The intensity of X – ray beam produced when the electron strike the anode is highly dependent on the anode material:**

1. the higher the atomic number (Z) of the target, the more efficiency X-ray are produced.
2. The target material used should also have a high melting point since the heat produced when the electrons are stopped in the surface of the target is substantial.

* Nearly all X – ray tubes use tungsten targets. The atomic number (Z) of tungsten is 74, and its melting point is about 3400C^{o}.

Production of x-ray:-

There are two different mechanisms by which X-rays are produce. One give rise to Bremsstrahlung (continuous) X-rays and the other characteristic X-rays.

Bremsstrahlung(continuous)X-Ray:-

When the electron get close enough to the nucleus of a target atom to be diverted from its path and emits an x-ray photon that has some of its energy. X – ray produced in this way is ***Bremsstrahlung*. And it is also called white radiation since it is analogous to white light and has a range of wavelengths.**

The amount of *Bremsstrahlung* produced for a given number of electrons striking the anode depends upon two factor:

1. the **Z** of the target ,the more protons in the nucleus the greater the acceleration of electrons.
2. the kilovolt peak-the faster the electrons ,the more likely they will penetrate into the region of the nucleus.

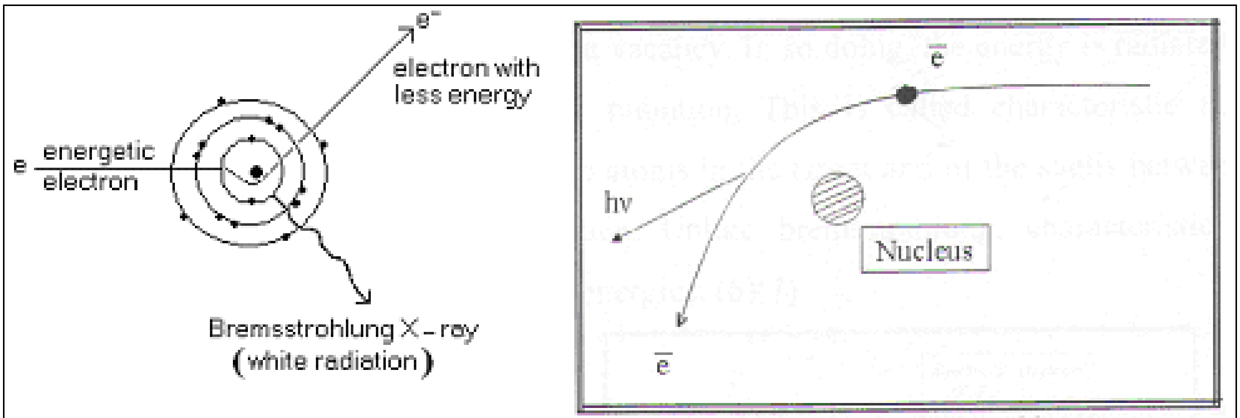


Figure : Illustration of Bremsstrahlung process.

Characteristic X-ray:

A-fast electron strikes a **K** electron in a target atom and knocks out of its orbit and free of the atom. The vacancy in the **K** shell is filled almost immediately when an electron from an outer shell of the atom falls into, as indicated in figure, and in the process, ***a characteristic K X-ray*** photon emitted.

when an electron falls from the **L** level to the **K** level is called a $\mathbf{K_\alpha}$ ***characteristic x-ray*** and that emitted when an electron falls from the **M** shell to the **K** shell is called a $\mathbf{K_\beta}$ x-ray.

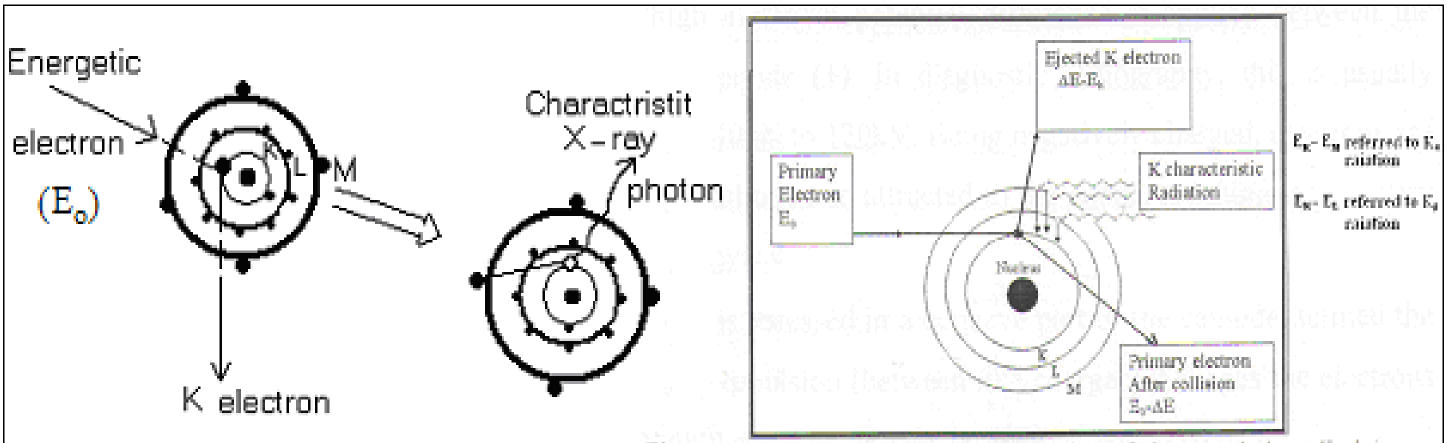


Figure ; diagram to explain the production of characteristic radiation.

X-ray Energy Spectra

X-rays photons produced by an X-ray machine are heterogeneous in energy.

The spectrum of x-rays produce by a modern x-ray generator is shown in figure, the broad smooth curve is due to ***the bremsstrahlung*** and the spikes represent ***the characteristic X-ray***.

Many of the low energy (soft) x-ray photons produced are absorbed in the glass walls of the x -ray tube.

**** If no filtration inherent or added***, of the beam is assumed, the calculated energy will be a ***straight line*** **(shown as doted line in fig).**

**** The purpose of added filtration is to enrich the beam with higher energy photon by absorbing the lower energy components of the spectrum, and hence improving the penetration power of the beam.***

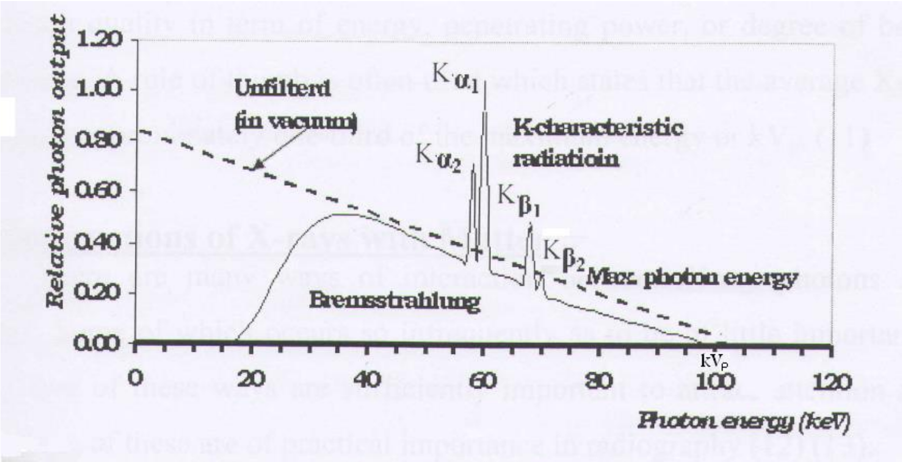
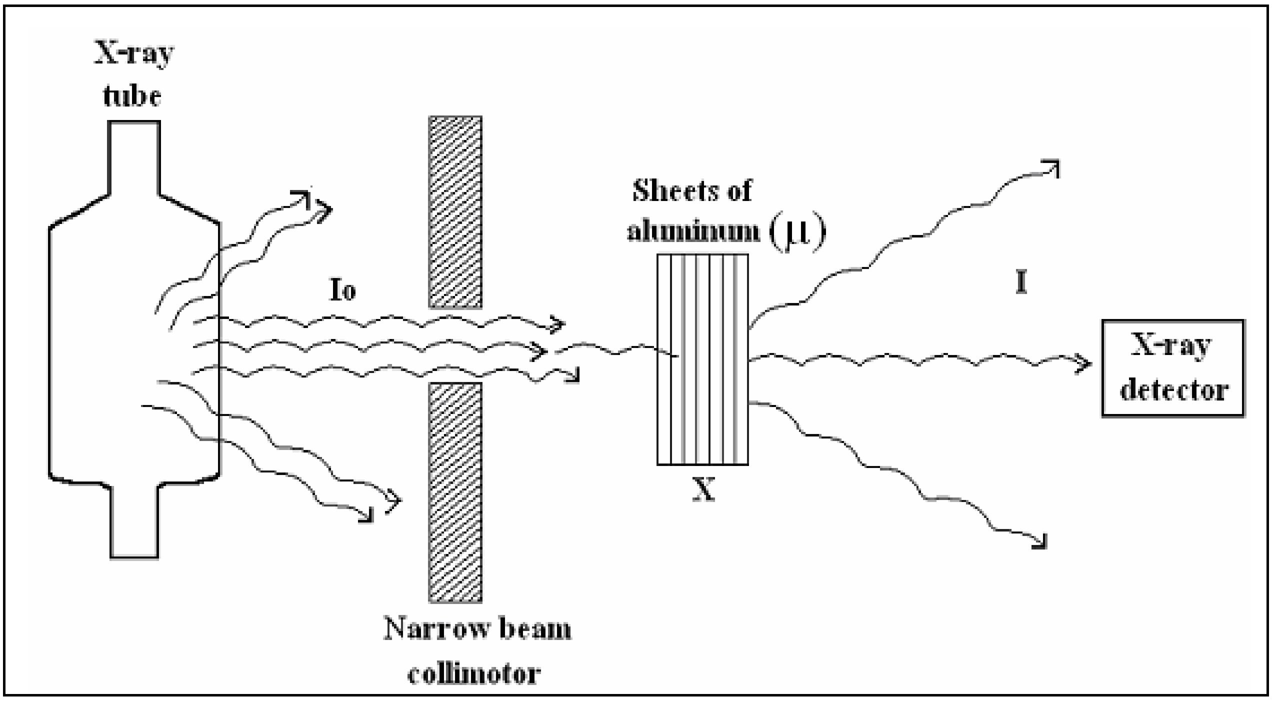


Figure: diagrams the energy of K-characteristic X-rays of tungsten, superimposed on the continuous spectrum (Bremsstrahlung)

Attenuation of X-rays:

Is the reduction of x-ray beam due to the absorption & scattering of some of photons of the beam.

**** To measure the un attenuated (transmitted) beam intensity I, we use.***



$$I = I_o e^{-\mu x} \quad \text{----------(1)}$$

where

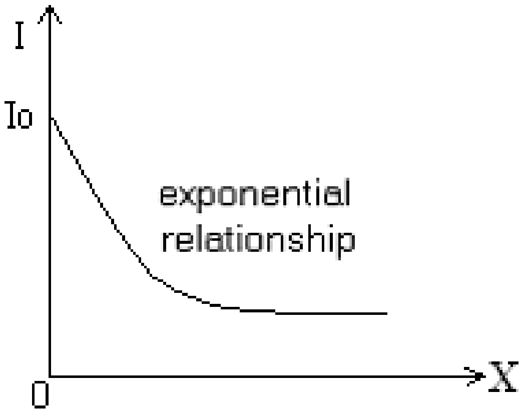
I_o = initial beam intensity.

I = un attenuated (transmitted) beam intensity.

μ = linear attenuation Coefficient.

e = 2.718

x = Thickness of the attenuator such as (brain tumor, bone, aluminum)



Linear attenuation Coefficient (μ): measure the probability that photon interact (absorbed or scattered) per unit length it travel in specified material**.**

It depends on:

1. energy of x-rays
2. atomic number (**Z**)
3. density (**ρ**) of material

Half value thickness HVT ($X_{1/2}$) : is the thickness of material which reduce the intensity of the beam of radiation one – half of its value **(50%).**

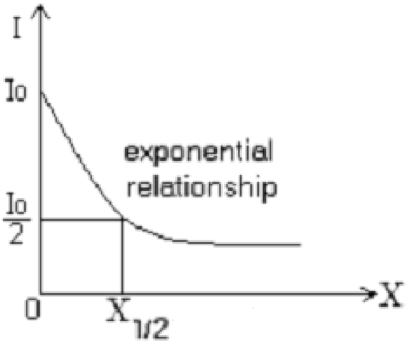


Figure. Transmitted intensity of x-ray versus the thickness of aluminum attenuator

At time $x = x_{1/2}$ then $I = (1/2)\,I_o$

Substitute this condition in the equation (1) :

$$I = I_o\, e^{-\mu x}$$

$$\therefore \quad (1/2)\; I_o = I_o\; e^{-\mu X_{1/2}}$$

$$(1/2) = e^{-\mu X_{1/2}}$$

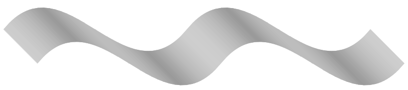
$$2^{-1} = e^{-\mu X_{1/2}}$$

By taking Ln of both sides we get:

$$-\mathrm{Ln}\,(2) = -\mu\, X_{1/2} \times \mathrm{Ln}\, e$$

$$0.693 = \mu\, X_{1/2} \times 1$$

$$\therefore \quad X_{1/2} = 0.693 / \mu$$



Biological Effects :

Mass attenuation – coefficient :a portion of X-ray energy that will be absorbed by the biological material & can produce changes at the cellular level.

The mass attenuation coefficient (μ/ρ) is obtained by dividing the linear coefficient by the density of the material. Therefore independent of density and depends only on the atomic number and photon energy.

$$\mu_m = \mu / \rho$$

There for the equation

$$I = I_o \, e^{(-\mu/\rho).\rho x}$$

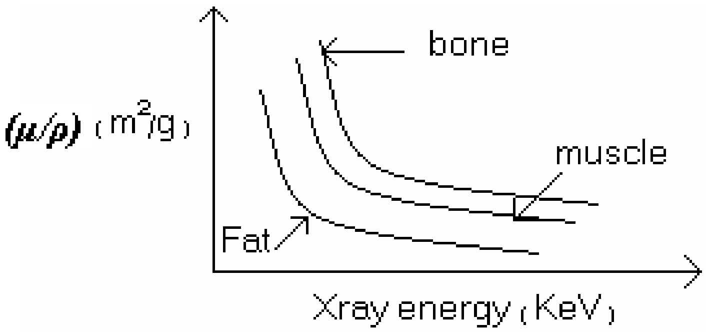


Figure. Mass attenuation coefficient (μ/ρ) for various tissues,

Interaction of X-rays with matter:

There are three types of interaction between X-ray with matter contribute to attenuation.

1. Photoelectric effect (P.E):

The photoelectric effect is one way x-ray lose energy in the body. It occur when the incoming x-ray photon transfers all of its energy to an electron which escapes from the atom (Fig).

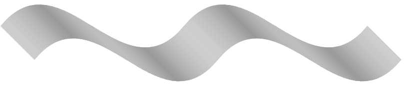
P.E is more apt to occur in the intense electric field near the nucleus than in the outer levels of atom and it is more common elements with high (**Z**) than in those with low **Z**.

When the energy of the x-ray is just slightly greater the binding energy of electron, the probability that P.E effect will occur increase.

In the other word :

The energy of the photon is completely absorbed by the electron(e^-). The (e^-) eject out of the atom & the atom will be positive ion.

Probability of photon electric occur at low X-rays energies.



It usually occur at a high atomic number (Z) of material. e.g.:

Muscles ≤ 30 KeV
Bone ≤ 50 KeV

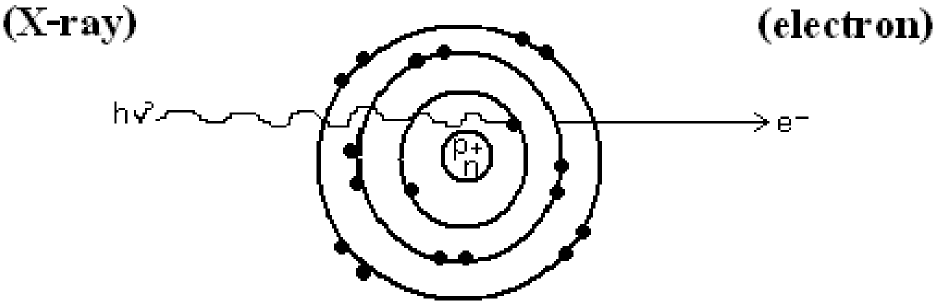


Figure. X-ray lose energy in the photoelectric effect

2. Compton effect (C.E):

Another important X-ray lose energy in the body is done by **C.E**. Compton suggested that an X-ray photon can collide with loosely bound outer electron much like a billiard ball collides with another billiard ball.

At the collision, the electron receives part of energy and the remainder is given to a Compton **scattered** photon ,which then travels in a direction different from that of the original x-ray(figure)

In the other word :

The energy of the photon is partially absorbed by the electron (e^-) which is ejected out of the atom, the atom will be positive ion

The energy of a photon is reduce from hυ to hύ ,and they scattered in different direction.

C.E. occur greatest at low Z material. e.g.:

*** In water or soft tissue C.E. is more probable occur than P.E effect at energy $\geq$ 30 KeV.**

*** In bone C.E. is more probable occur than the P.E. effect at energy $\geq$ 100 KeV.**

*** At 30 kev bone absorbed x-ray about 8 times better than tissue due to P.E effect.**

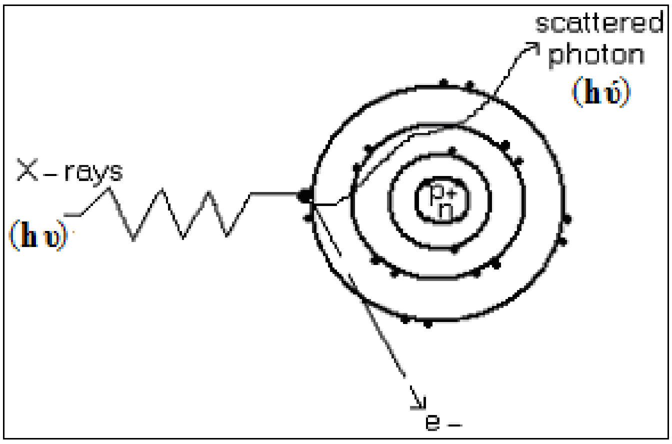


Figure. X-ray lose energy in the Compton effect

3. Pair Production (P.P):

P.P is the third major way x-ray give up energy. When a very energetic photon enters the intense electric field of the nucleus ,it may converted into two particles an electron and positron (**β**)(positive electron).

Providing the mass of the two particles requires a photon with an energy of at least 1.02 Mev and the remainder of the energy over 1.02 Mev is given to the particles as kinetic energy.

After it has spent its kinetic energy in ionization it does a death dance with an electron Both then vanish ,and their mass energy usually appear as two photon of **511 kev** each called ***annihilation radiation.***

Since a minimum of **1.02 Mev** is necessary for **P.P**,this type of interaction is only impotent at very high energies.

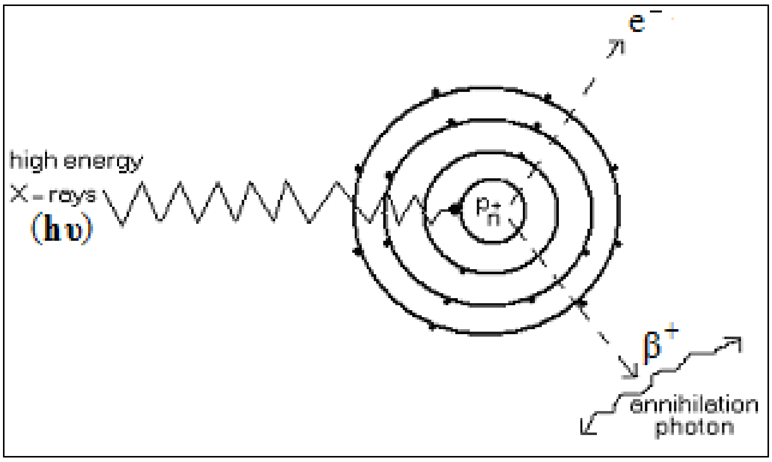


Figure. X-ray lose energy in the pair production

*** P.P is more apt occurs in high Z element than low Z element.**
*** P.P. is no use diagnostic radiology** ***because*** of high energy needed .
*** P.E. is more useful used in diagnostic** than Compton effect ***because*** it need low energy and primate us to see bone & other heavy material such as bullets in the body.

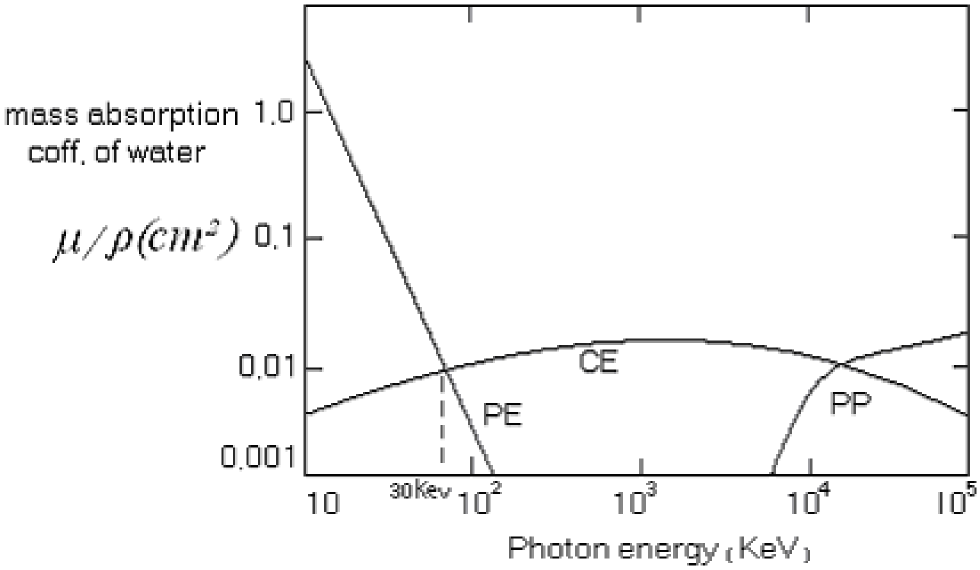


Figure. Mass absorption coefficient for water.

(P.E. and C.E. are about equally probable at about 30 kev,
P.P. occurs only at high energies and is of no important in diagnostic radiology.

Film

X-ray film: is photographic film consisting of photographically active, or radiation-sensitive, emulsion that is usually coated on both sides of transparent sheet of plastic, called the ***base.***

* ***Firm attachment*** between he emulsion layer and the film base is achieved by use of a thin layer of ***adhesive***, as shown in figure:

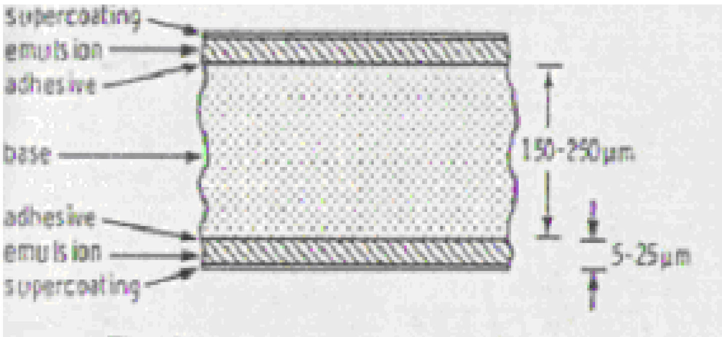


Fig. Cross-sectional view of radiographic film. The bulk of the film is the base. The emulsion contains the diagnostic information.

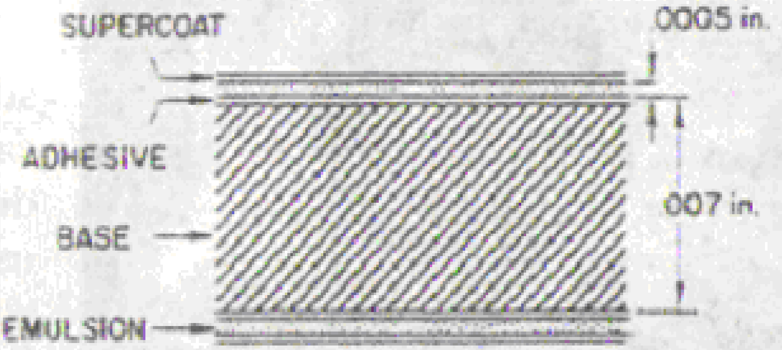


Figure. Cross section of a double emulsion x-ray film

* ***The adhesive layer*** allows the emulsion and base to maintain proper contact and integrity during use and processing.

Emulsion

The two most important ingredients of a photographic emulsion are **gelatin** and **silver halide,** and has emulsion coated on both sides of the base.

Gelatin.

Photographic gelatin for X-ray film is made from bone, mostly cattle bone from India. It keeps the silver halide grains well dispersed and prevents the clumping of grains.

Processing (developing and fixing) solutions can penetrate gelatin rapidly without destroying, and gelatin is available in a reasonably large quantity and uniform quality.

Silver halide.

Silver halide **(AgI, AgBr)** is the light-sensitive material in the emulsion. The halide in medical X-ray film is about **90 to 99%** silver bromide **(AgBr)** and about **1 to 10%** silver iodide **(AgI)** (the presence of **AgI** produces an emulsion of much higher sensitivity than a pure **AgBr** emulsion).

Latent Image

Metallic silver is black**. **It is silver that produces the dark areas seen on a developed radiograph.

The energy absorbed from a light photon gives an ***electron*** in the bromide ion enough energy to escape :

$$\mathbf{Br^{-} + light\ photon \rightarrow Br + electron}$$

The electron gives the sensitivity speck a negative charge, and this attracts the mobile interstitial $\mathbf{Ag^{+}}$ ions in the crystal

$$\mathbf{Ag^{+} + electron \rightarrow Ag}$$

These clumps of ***silver atoms*** are termed **latent image centers,** and are the sites at which the developing process will cause visible amounts of ***metallic silver*** to be deposited.

Photographic process: as follows :

1. **Development** :Immerse the exposed film in the developer solution to free the silver atoms in those grains which have received sufficient exposure & contain latent image center.
2. **Fixing** : Fixing to neutralize the developer on the film & stop the developing action.
3. **Washing** : the film washed in running water to remove the fixing chemicals &dissolve silver halides.
4. **Drying** :The final step in processing is to dry the radiograph, and this is done by blowing warm dry air over both surfaces of the film as it is transported through the drying chamber.

**** The total sequence the events involved in manual processing requires over 1hr.***
**** Most modern automatic processors are identified as 90 sec.***

Photographic density

The X-ray image is present in the space between the patient and the X-ray film, we have seen how the energy of the X-ray beam may be used to produce a visible pattern of black metallic sliver on the X-ray film.

The degree of film blackening is directly related to the intensity of radiation reaching the film . The measurement of film blackness is called "film density".

* when the light(X-rays)passes **100%** of the beam there is no absorption at all, means ***film density*** ($\boldsymbol{\rho = 0}$). **It is determined by:**

1. Quantity of X-rays
2. Sensitivity of the film

Film Density	Light penetration%
0	100
1	10
2	1
3	0.1

Note: ***More x-rays photons incident on the film more blacking color occur in the film, if less X-rays photons incident on the film more whiting color occur in the fil***

Sandwich Film: Usually put in light box and exposed to the light of this box for about **2 min.**

Factors Affecting the image quality:

* The image of a stationary structure produce by the beam from an ideal point source would be perfectly sharp. At the edge of shadow, the intensity of X-rays would change suddenly from a height to a low value (***Penumbra*****).**

1. Using a small focal spot → ***to reduction. Penumbra*****.**
- **a.** Small focal spot **1 mm.**
- **b.** Large focal spot **2 mm.**

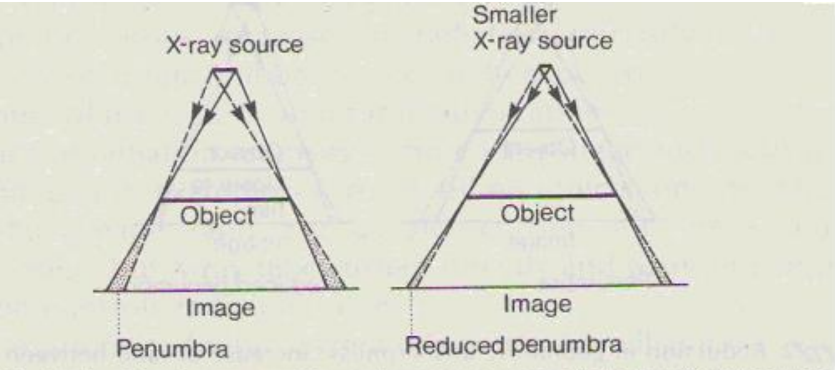


Fig. Reduction in geometric unsharpness: use of smaller X-ray source

2. The patient is placed as close to the film as possible (decreasing the object - film distance) **to reduce the penumbra:**

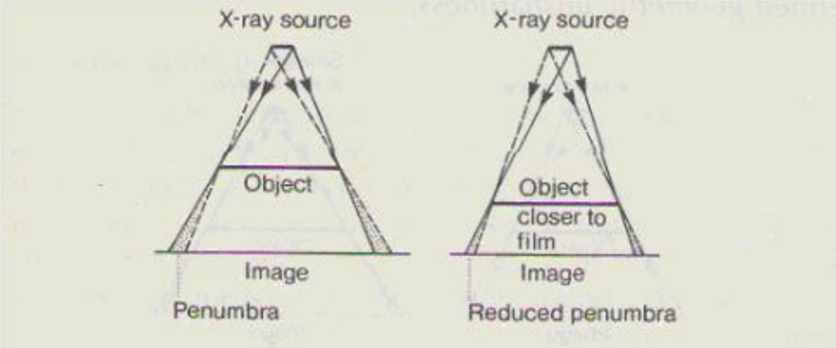
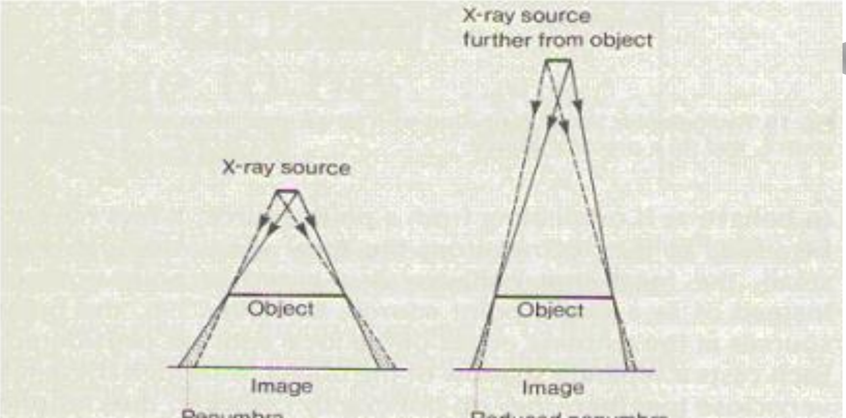


Fig. Reduction in geometric unsharpness: increase of ratio between focus-object distance and object-film distance.

3. Increasing the distance from the X-ray tube to the film (chest film distance is 180)**.**



4. Reduction the scattered radiation at the film by using **a grid** .

A grid. An "antiscatter" grid, seen in cross-section in figure, consists of thin (0.07 mm) strips of a heavy metal (such as lead) sandwiched between thicker (0.18 mm) strips of interspaced material (plastic, carbon fiber, or aluminum) , which are transparent to X- rays.

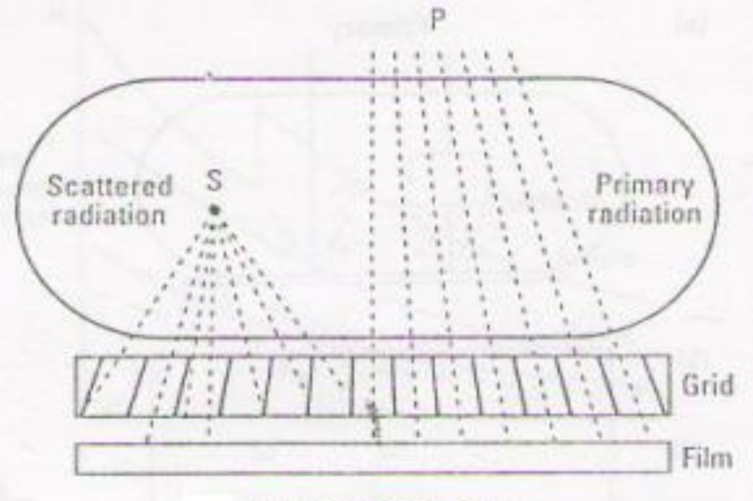


Fig. Focused grid.

The lead strips absorb (say, 90% of) the scattered rays which hit the grid obliquely, while allowing (say, 70% of) the primary rays to pass through the gaps and reach the film

Contrast media

One of the problems in radiography is the ***low contrast*** between soft tissues. One way to Increasing contrast is to **use a lower kV**;another way by **using a contrast medium.**

Radioopaque media: are chosen to have a sufficiently high atomic number to maximize photoelectric absorption.**(Iodine Z=53, Barium Z=56)** are used as contrast media. Contrast media are compounds of one or other of these elements.

Contrasting : This technique is made to make further use of the photoelectric effect radiologists often inject **high Z material** into different part of the body ***(contrasting media).***

e.g.:

1. Iodine injected into the blood stream to show the ***arteries***

2: Oily mist containing **iodine** is sometimes sprayed into the lungs to make ***airways Visible***.

3. Barium compound is given **oral** to see parts of the ***upper Gl.***

4. Barium enemas to view the other end of the digestive system **(*lower GI*).**

5. Air is used to replace some of fluid ventricles of the ***brain***, which a a pneumoecphalogram is taken.

6. Air & barium are used separately to show the ***same organ*** in a double contrasting study.

To avoid shadows in x-rays image

The radiologist must often take x-ray images from different directions, e.g. ..from the back, the side & intermediate angle . Body section radiology or image of slices of the body are known as ***tomography***.

Axial tomography :

Is an image of slice across the body & is taken **by rotating** the X-ray tube & film around the patient → useful in planning the treatment of cancer.

Computerized Axial Tomography (C.A.T) :

There is no image receptor, such as film. A collimated x-ray beam is directed on the patient, and the attenuated remnant radiation is measured by a detector whose response is transmitted to a computer.

The computer analyzes the signal from the detector, reconstructs an image, and displays the image on a television monitor. The computer reconstruction of the cross sectional anatomy is accomplished with mathematic equations adapted for computer processing called **algorithms**

Operational Model

First-Generation Scanners

The previous description of a finally collimated X-ray beam-single detector assembly **translating** across the patient and between successive translations is characteristic of early CT designs. These are now called ***First-generation*** CT scanners**.**

The original EMI scanner required 180 translations, each separated by a 1 degree rotation

- ***Scan time for first generation units was almost 5 minutes***.

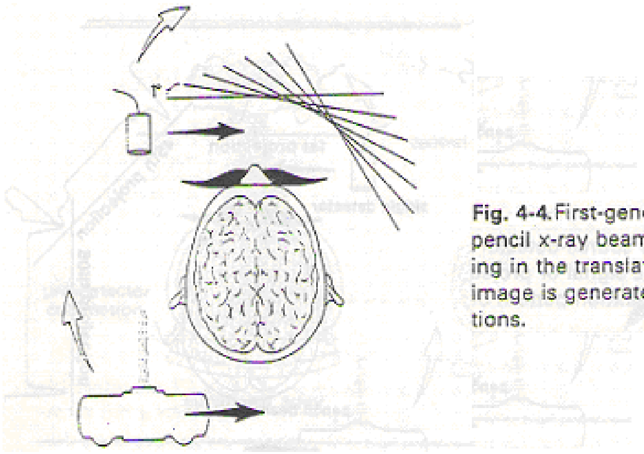


Fig. 4-4. First-generation CT scanners used a pencil x-ray beam and a single detector moving in the translate-rotate mode. A single slice image is generated following many such motions.

Second-Generation scanner

Were also of **the translate-rotate type**, but these units are no longer produced. These units incorporated the natural extension of the single detector to a multiple detector assembly intercepting a fan-shaped rather than a pencil beam.

* The principal limitation of second-generation CT scanner was examination time, ***most units were designed for scans times of 20 s or more.***

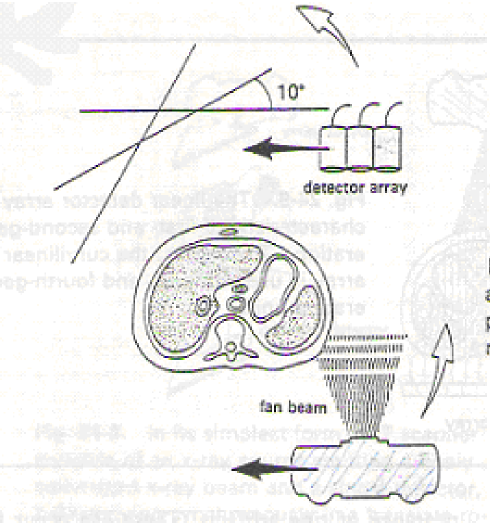


Fig. 4-6. Second-generation scanners operated in the translate-rotate mode with a multiple detector array intercepting a fan-shaped x-ray beam.

Third-generation scanners

Third-generation scanners evolved in which the X-ray tube and detector array were rotated concentrically about the patient. ***As rotate-only units, third generation scanners accommodate scan times as low as 1 s.***

* The third-generation scanner employs a curvilinear detector array containing at least ***thirty*** **elements** and a fan beam. The number of detectors and the width of the fan beam, ***between 30 and 60 degree***

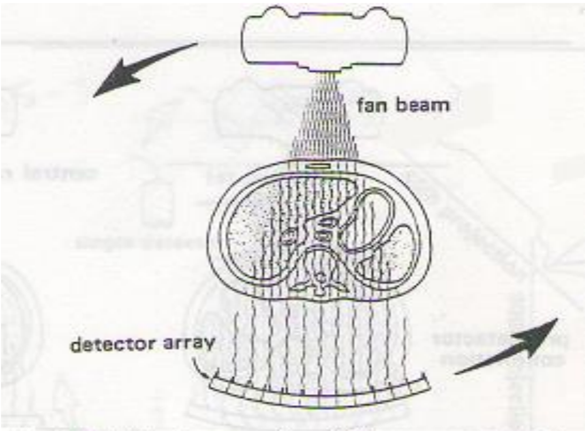


Fig. 4-7. Third-generation CT scanners operate in the rotate-only mode with a fan x-ray beam–multiple detector array revolving concentrically around the patient.

Fourth-Generation Scanners

The fourth-generation design for CT scanner is, as for those of the third generation, ***a rotate-***

only motion.

*** *With fourth-generation machines,*** however, the X-ray source rotates but the detector assembly does not. Radiation detection is accomplished through a fixed circular array of detectors, ***which contains as many as 1000 individual elements.***

* ***These units are capable of 1 s scanning times***.

*** *The principal disadvantage*** of fourth-generation machines appears to be patient dose, which is somewhat higher than that with other types of scanners.

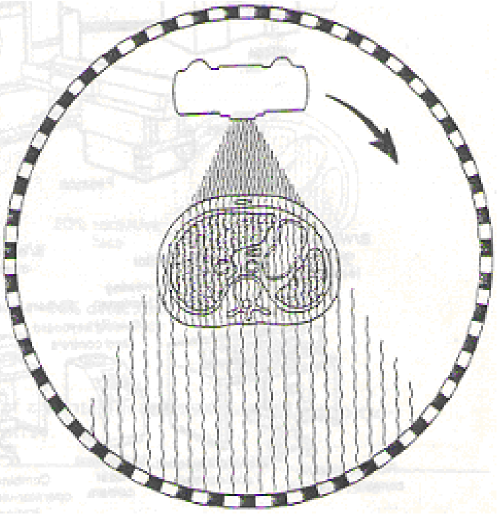


Fig. Fourth-generation CT scanners operate in the rotate mode, but only the source rotates; the detector array is fixed.

Magnetic Resonance imaging (MRI) or Nuclear MRI

MRI has several significant advantages over other diagnostic imaging modalities:
Best low-contrast resolution
No ionizing radiation
Direct multiplanar imaging
No bone or air artifacts
Direct flow measurements
Totally noninvasive

Magnetic Moments

Moving charges give rise to magnetic fields, charged and spinning would also posses a magnetic field. This is indeed true. Consider the simplest nucleus, that of hydrogen, shown in figure. the charge and spinning of the nucleus of hydrogen give rise to a magnetic field. The nucleus is said to be a magnetic dipole, and the name for its magnetism is magnetic moment.

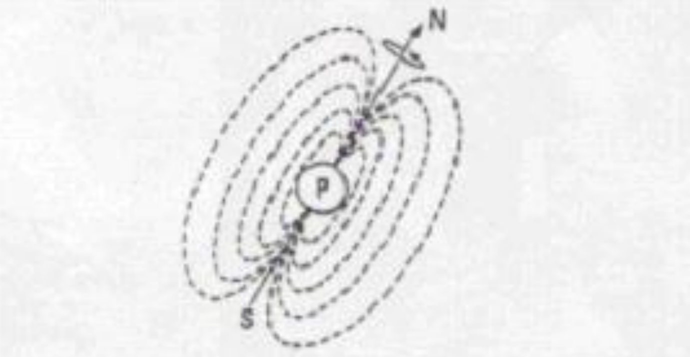


Fig. The spinning proton of a hydrogen nucleus creates a magnetic field with a magnetic moment.

* In most materials, such as soft tissue, these little magnetic moments are all oriented randomly, as shown in figure other magnetic moments will be oriented in various direction.

* This random orientation causes all the spins and magnetic moments to cancel, so that the **net magnetization (M)** in the patient of figure is zero.

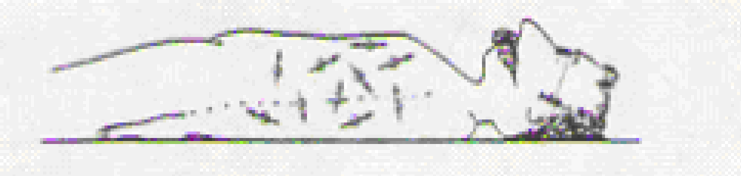


Fig. In most materials and in all patients magnetic moments are randomly oriented. Consequently, the net magnetization is zero.

* If the patient however, is placed in a strong magnetic field (B_0), as in figure, the magnetic moments will align themselves in the same direction as the external magnetic field, in fact nearly as many align against the field as with it. A small excess of moments aligned with the field gives the patient a net magnetization M. **The patient becomes a magnet.**

Fig. Individual magnetic moments become aligned in the presence of an external magnetic field, creating net magnetization. By convention, the *z*-axis of an MR imager is horizontal.

* ***In summary the magnetic moments of individual hydrogen nuclei tend to align themselves with the external magnetic field and add together to produce a net magnetization.***

* Before RF (***Radio frequency***) transmission the nuclei are said to be at equilibrium with the external magnetic field

* If the RF was ***transmitted*** into the patient as a pulse, nuclear excitation exists only momentarily. One by one the nuclei flip and return alignment with B_0.

The complex manner of retuning to equilibrium is called ***relaxation*** and time required for return is the ***relaxation time***.

* ***During relaxation an RF*** signal is emitted .as shown in figure, and this action is related to the Magnetic Resonance Image (MRI) signal used to make an MR image.

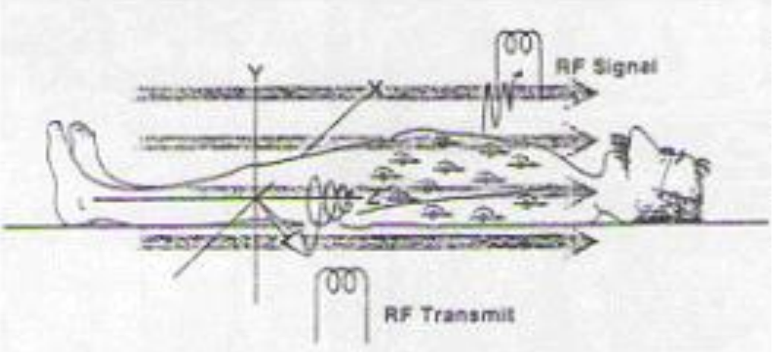


Fig. Relaxation occurs when the nuclei return to their normal state of equilibrium after the RF is turned off.

The MRI signal emitted by the patient during relaxation is called ***a free induction decay (FID),*** as shown in figure:

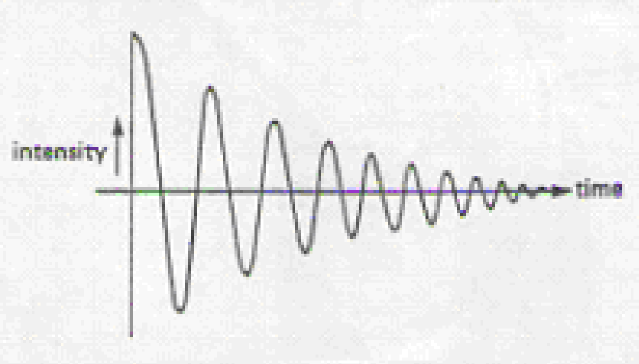


Fig. Free induction decay (FID) signal from hydrogen.

This shows how the signal intensity varies with time. If one takes this relationship and

performs a rigorous mathematic exercise called **a *Fourier transform,*** the result is an Nucleur Magnetic Resonance (NMR) spectrum, as seen in figure:.

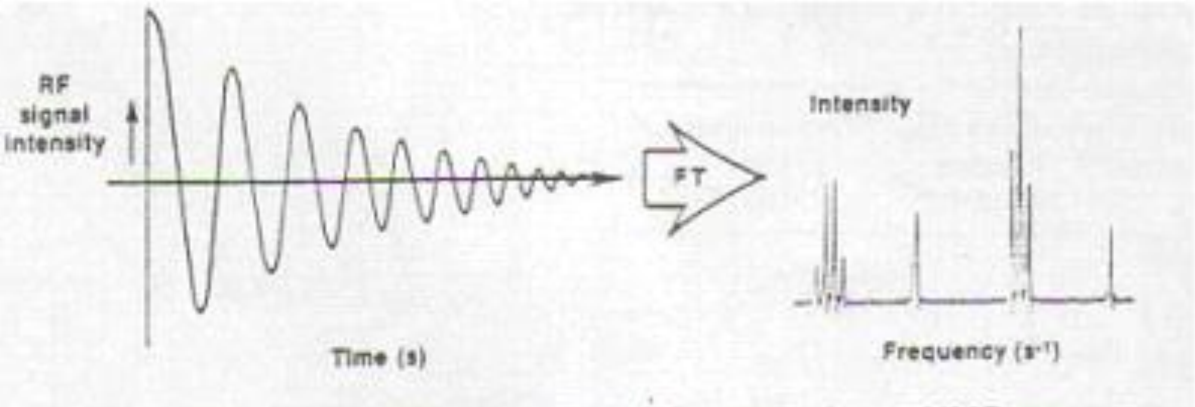


Fig. Fourier transformation of an FID results in an NMR spectrum.

* ***Fourier transformation*** converts the relationship of signal intensity versus time to signal intensity versus inverse time or frequency (Hz).