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# Heat and Cold in Medicine

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**Specialist in physical medicine and physical therapy probably used heat and cold the most. Other medical specialists, including family practice physicians, often prescribe heat or cold for therapeutic purposes. Surgeons sometimes use extreme cold (cryosurgery), and radiologists are often involved in interpreting thermographic images.**

# Physical basis of heat and temperature

**Matter is composed of molecules that are in motion. In a gas or liquid the molecules move about, hitting one another or the walls of container; even in a solid the molecules have some motion about the sites that they occupy within the crystal structure. The fact that the molecules move means that they have kinetic energy, and the kinetic energy is related to the temperature. The average kinetic energy of the molecules of an ideal gas can be shown to be directly proportional to the temperature; liquids and solids show similar temperature dependence. In order to increase the temperature of a gas it is necessary to increase the average kinetic energy of its molecules. This is can be done by putting the gas in contact with a flame. The energy transferred from the flame to the gas causing the temperature rise is called heat.**

- **Heat: is the total energy of molecular motion in a substance.**

- **Temperature: is a measure of the average energy of molecular motion in a substance**.

**If enough heat is added to a solid, it melts, forming a liquid. This liquid may be change to a gas by adding more heat. Adding still more heat converts the gas to ions. While adding heat to a substance increase its molecular kinetic energy, thereby increasing its temperature, the reverse is also true: heat can be removed from a substance to lower the temperature. Low temperatures are referred to as the cryogenic region. The ultimate in cold is "absolute zero" (-273.15°C), a temperature that is experimentally unattainable.**

## Thermometry and Temperature Scales

**Temperature is difficult to measure directly, so we usually measure it indirectly by measuring one of many physical properties that change with temperature. We then relate the physical property to temperature by a suitable calibration.**

**There are three types of Temperature Scales**

1. **Fahrenheit ($^o$ F) scale: In United States the most common temperature scale is the Fahrenheit. Water freezes at 32 $^o$ F and boils at 212 $^o$ F, and the normal body temperature (rectal) is about 98.6 $^o$ F .**
2. **Celsius ($^o$ C ) scale :Most scientists in the United States used the Celsius ($^o$ C) scale (formerly called the centigrade scale), which is in common use throughout most of the world . Water freezes at 0 $^o$ C and boils at 100 $^o$ C, and the normal body temperature (rectal) is about 37 ° C.**

3- **<u>Kelvin (° K) scale:</u> Another important temperature scale used for scientific work is the Kelvin (° K), or absolute scale, which has the same degree intervals as the Celsius scale; 0 ° K (absolute zero) is -273.15 ° C. On the absolute scale, water freezes at 273.15 ° K and boils at 373.15 ° K, and the normal body temperature (rectal) is about 310 ° K. This temperature scale is not used in medicine.**

**The relationships between the different temperature scale are**

**° K= 273.15+ ° C**

**° C= (5/9)×( ° F-32)**

**° F= (9/5) × ° C+32**

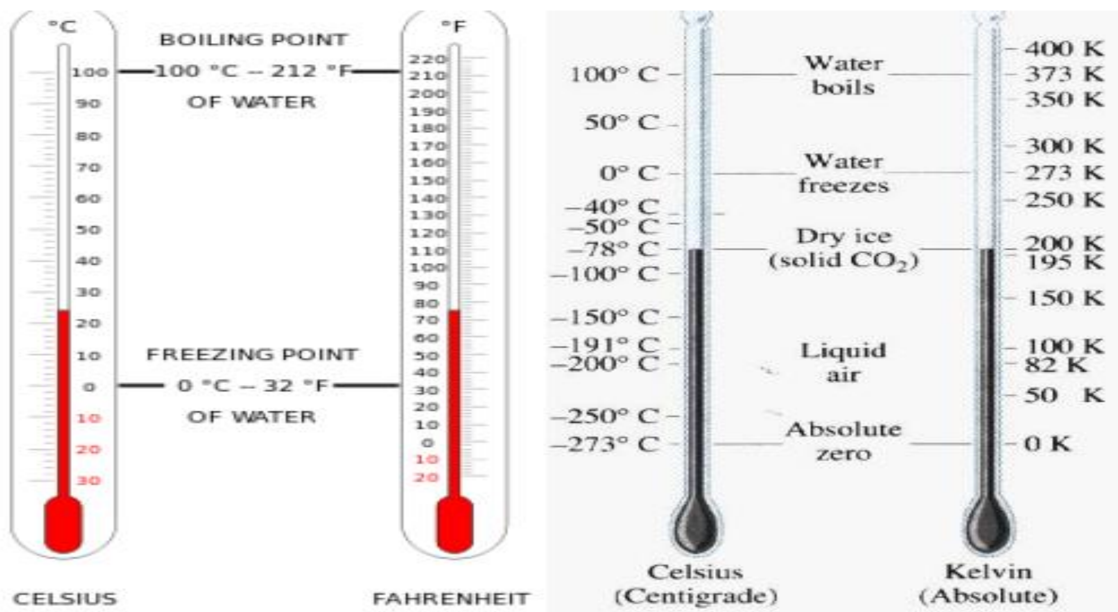



**Figure (1)**

## **Example:-**

**The temperature of the human body is normally about 98.6°F.calculate the temperature of the body in °C and °K?**

**° C = (5/9)×( ° F-32) =5/9(98.6-32)=37 ° C**

**° K = 273.15+ ° C =37+273=310.15 ° K**

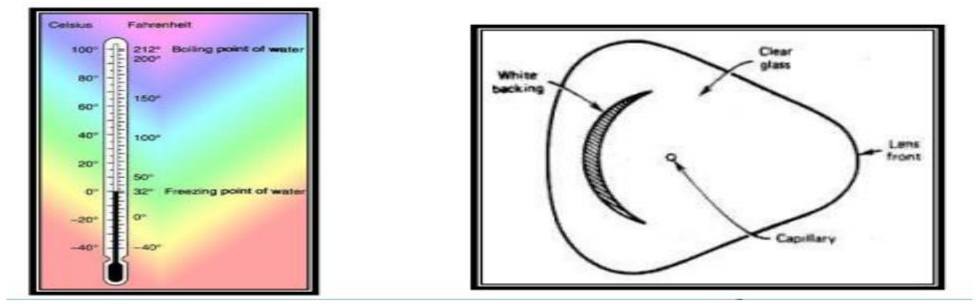
## **Temperature Measurement**

**Thermometer is a device used to measure the temperature. For the medical and biological purposes, there are several important types of thermometers are:-**

**1) Glass-liquid thermometer**

**This thermometer composed of glass capillary tube ends with a bulb a store for liquid, the liquid can be mercury or alcohol for low temp. measurement. When the thermometer is heated the liquid inside will expand more than the glass causing the liquid to rise in the capillary, for mercury it expand 1.8%from (0- 100°C). As the fever temp. is needed to be precise it has a thin capillary less than 0.1mm in diameter, which makes the mercury to rise higher per degree. In addition to that the fever thermometer has a restriction above the bulb making the mercury not to return if the thermometer is exposed to low temp. unless the thermometer is moved rapidly with proper snap of the wrist. This is unlike the room thermometer if used to check the patient fever it will change as soon as it is taken out from the mouth of the patient, for this reason and others such as the thermometer design not for medical use in addition to its low sensitivity the room thermometer are not used in medicine. In the fever thermometer, because the mercury is raising in**

a very thin capillary a better vision is made by making the front glass tube convex to act like a magnifying lens and the back of the tube is opaque, white colored. The temp. usually taken underneath the tongue or in the rectum.




-a- -b

**Figure2:**

**a- a glass liquid thermometer. b-cross section of glass liquid thermometer**

The capillary of a fever thermometer has a restriction just above the bulb so that after the liquid is forced into the stem by expansion it does not return when the temperature falls. In order to return the mercury to the bulb it is necessary to take advantage of some elementary physics involving centrifugal forces or by giving the thermometer a sharp jerk.

## 2)Thermistors:

**It's composed from a bridge of four resistances with a source of electricity. These resistors are in balance and one of them is used for temp. measurement (resistor T).This resistor as any other resistance changing with heat but this particular resistance has the property of rapid change with heat ( 5 %/°C).A bridge circuit with a thermistor in one of the legs, initially the four resistors are equal, the bridge is balanced, by symmetry, the voltages at each end of the meter are equal and no current flows through the meter. A temp. change causes the thermistor resistance to change . This unbalance the bridge, the voltages at each end of the meter become un equal, causing a current to flow through the meter, and the resulting meter deflection can be calibrated for temp., with thermistors it is easy to measure temp. changes of 0.01°C,therefore are used quite often in medicine because of their sensitivity. Thermistors are placed in the nose to monitor the breathing rate of patients by showing the temp. change between inspired cool air and expired warm air (pneumograph) .**

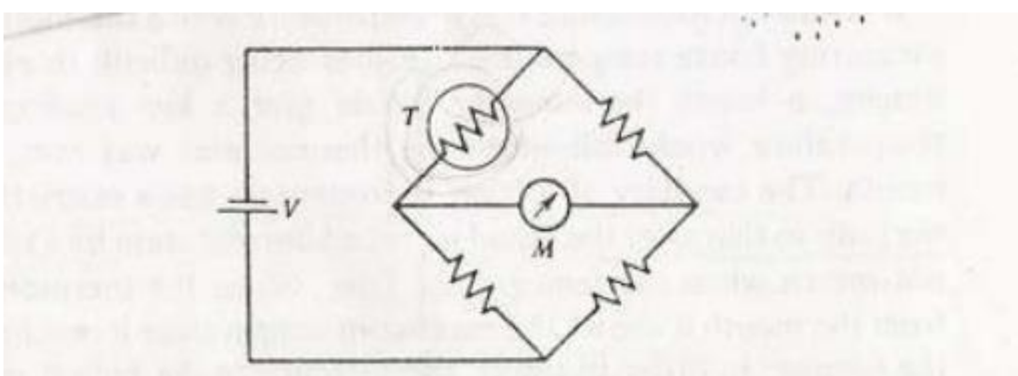



**Figure3: Thermistors**

2) **Thermocouple**:

**A thermocouple consists of two junctions of two different metals. If the two junctions are at different temperatures, a voltage is produced that depends on the temperature difference. Usually one of the junctions is kept at a reference temperature such as in an ice-water bath. The copper-constantan thermocouple can be used to measure temperatures from (-190 to 300 $^0$C). For a 100$^0$C temperature difference, the voltage produced is only about 0.004V (4mV). Thermocouples can be made small enough to measure the temperature of individual cells.**

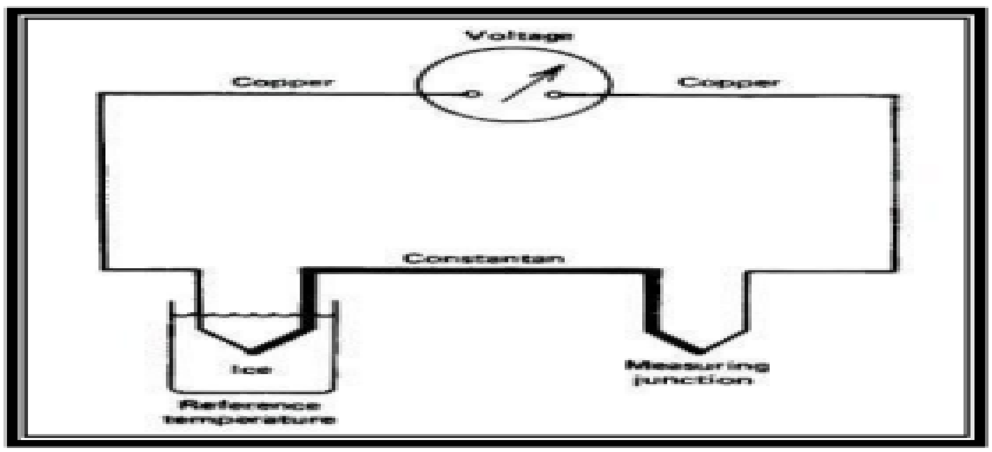



**Figure4: Schematic diagram of Thermocouple.**

## Thermograph-mapping the body's temperature

## Thermography:

**Process to measure the body surface temperature, indicate that the surface temperature various from point to another depend on:**

**1) External physical factors**

**2) internal metabolic**

**3) Circulatory process near the skin-blood flow near the skin is the dominant factor.**

**Measurement of surface temperature is thought to be useful in diagnoses of some diseases, which may change locally the skin temperature. All objects regardless of their temperature emit heat radiation. The body heat can give (IR) infrared radiation of long waves, which are not visible unlike the red-hot object, which is visible. Thermograph is the process in which the infrared radiation emitted by the body is used to produce a (thermal image) or (temperature map) of the surface of the body. The images are called Thermograms and are normally displayed on a TV screen .Different temperatures are represented by different colors, in a black and white display by different shades of gray.**

**A basic thermographic unit used to measure the radiation emitted from a part of the body. (IR) radiation from a small area of patient is passed by mirror through a chopper to a detector. The chopper changes the continuous radiation to an alternating signal. That it can be more easily amplified. The IR transparent filter removes visible light, and detector converts IR to electrical signal that is proportional to the temperature of the body. The position and magnitude of radiation from the patient displayed on the cathode tube (CRO).**

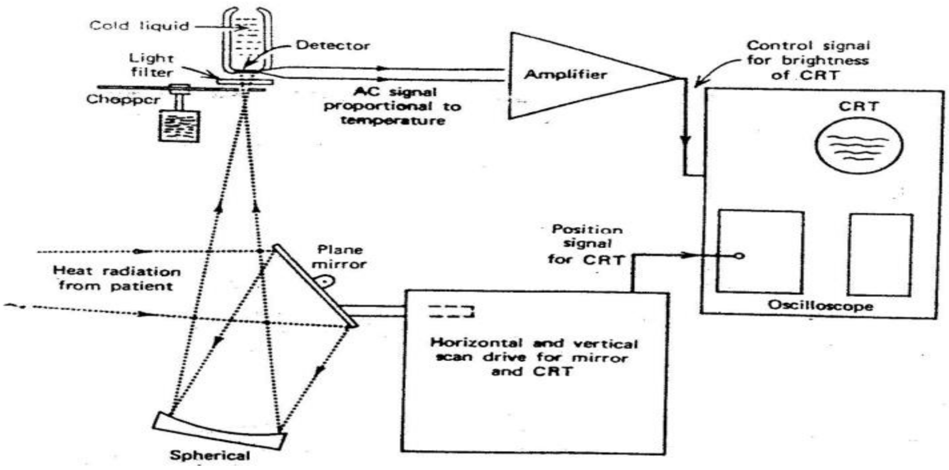



**Figure 5. Diagram of a typical thermographic unit**

**<u>Thermograph uses:</u>**

**A-Cancer detection: Breast cancer could be characterized by an elevated skin temperature in the region of the cancer. The surface temperature above a tumor was typically about 1 °C higher than that above nearby normal tissue, and it was thought that this will be a good procedure for early breast cancer detection.**

**B- Thermograph used to study the circulation of blood in the head, differences in the blood supply between left and right sides can indicate circulatory problems. In diabetic patients: Thermograph has had consider able success in reducing leg amputation in diabetic. The blood supply in diabetic's leg is usually adequate, but if the tissues break down and an ulcer is**

**formed, the need for blood in the leg may double. The circulation problems of the diabetic then become evident: the ulcer dose not heals and often becomes infected .With thermograph, the presence of a hot spot on the foot can be determined before an ulcer forms.**

**The basic equation describing the radiation emitted by a body was given by Max Plank For our purposes the Stefan-Boltizman law for total radiative power per surface area W is more useful, it i s**

**$W = e \sigma T^4$**

**W; is total radiative power per surface area**

**T; is absolute temperature**

**E; is the emissivity =1 for radiation from the body**

**σ; is the Stefan Boltizman constant= $5.7 x 10^{-12} W/cm^2.K^4$**

**<u>Example :</u>**

A. **What is the power radiated per square centimeter from skin at a temperature of $306^o$ K?**

**$W = e\sigma T^4 = (5.7 \times 10^{-12})(306)^4 = 0.05 W/cm^2$**

B. **What is the power radiated from a nude body $1.75m^2$ in the area**

   **$W = (0.05)(1.75 \times 10^4 cm^2) = 875W$**

**C- <u>In the Dentistry</u>**

**Dentists recommend the use of medical thermograph in monitoring control in the inflammation process into oral cavity and reaction of the regional lymphatic nodes, maxillary joint disease and other chronic disease of the bones, nerves located in the maxilla facial area.**

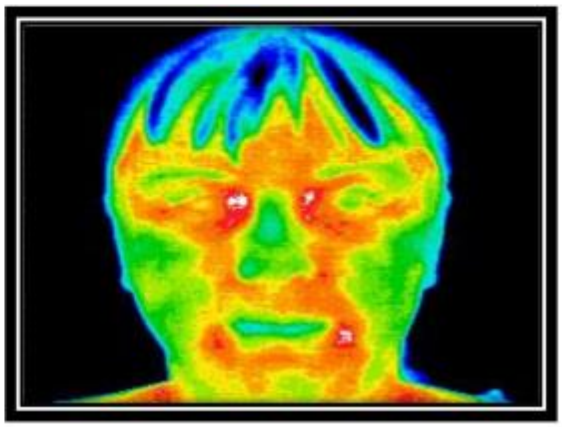


**Figure6: focal tooth infection picture.**

## Heat therapy

**The primary therapeutic effects take place in the heated area**

**1-There is an increase in the metabolism resulting in a relaxation of the capillary system.**

**2-There is an increase in the blood flow, as blood moves into cool the heated area.**

**The physical methods of producing heat in the body;**

1) **The conductive method:**

**Heat can transfer by conduction, the quantity of heat transfer depends on**

the temp. difference, the time of contact, the area of contact, and the thermal conductivity of the materials. This can be done by several ways such as hot bath, hot 10 packs, and electric heating pad. This can lead to local surface heating and using in the treatment of arthritis, neuritis, strains, sinusitis and back pain.

## 2) Radiant (IR) heat:

Heat radiation can be achieved by using infrared radiation (IR), it penetrates about 3mm in the skin. It can be produced glowing coils and by 250 watts incandescent lamps. The wavelengths used are between (800-40000nm) an excessive exposure can cause reddening and sometimes swelling (edema) longer exposure can cause skin browning or hardening. It is considered to be more effective than conductive heating because it can penetrate deeper.

## 3) Radio wave heating (Diathermy):

Short wave diathermy utilized electromagnetic wave in radio range (=10m) and microwave range (12cm), short wave diathermy penetrate deep into tissue (more than conductive and radiant). Heat from diathermy penetrates deeper into the body than radiant and conductive heat, thus it is useful for internal heating and has been used in the treatment of inflammation of skeleton, bursitis, and neuralgia . Different methods are used for transferring the electromagnetic energy into the body: A-The part of the body to be treated is placed between two plates (electrodes) connected with high frequency power supply. The 11 charged particles of the tissue will be attracted to one plate and to other depending upon the sign of the alternating voltage on the plate. This movement will produce resistive (joule) heating.

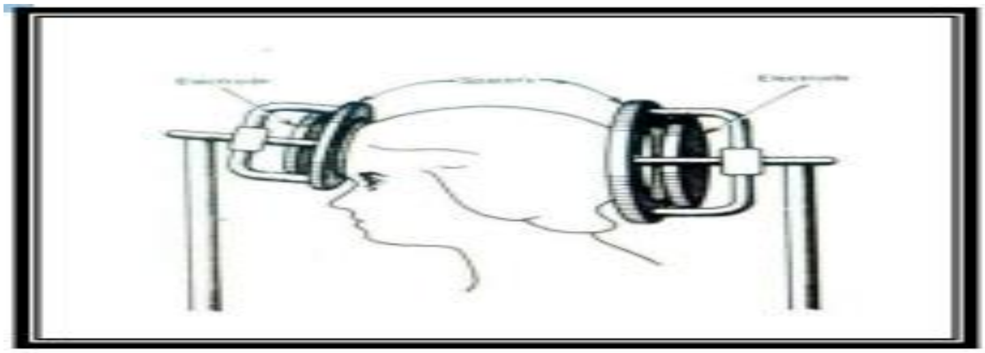


**Figure 7: Capacitance method of short wave diathermy.**

**B) By transferring short wave energy into the body by magnetic induction. This can be done by either placing a coil around the region to be treated or by (pancake) coil placed near the part of the body to be treated. The alternating current in the coil produces an alternating magnetic field in the tissue, consequently an alternating (eddy) currents are induced , producing joule heating in the region b treated. Short wave diathermy can penetrate deep into tissue. It can be used in relieving muscle spasms, protruded intervertebral disc pain, joints with minimal soft tissue coverage such as knee, elbow.**

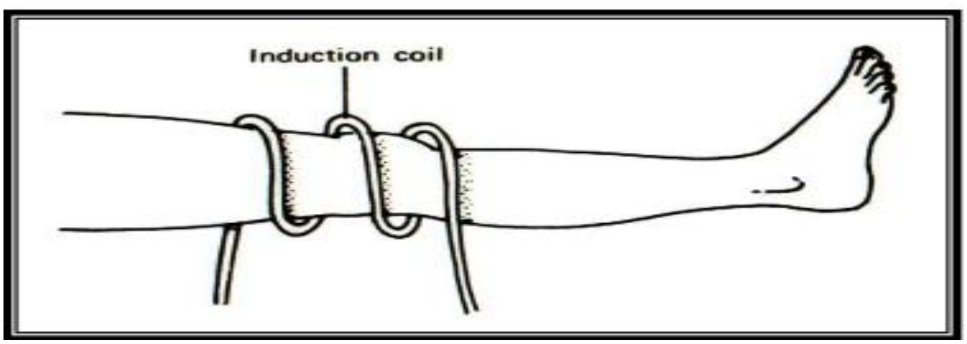



**Figure 8: Inductance method of short wave diathermy**

## Microwave diathermy:-

**Microwave diathermy is another form of electromagnetic energy. These waves are produced in a special tube called a magnetron and then emitted from the applicator(antenna)which is placed at several inches from the region to be treated .These wave penetrate deep into the tissues causing a temperature raised and deep heating. Microwave diathermy is used in the treatment of fractures, strains, bursitis, injuries to tendons, and arthritis. The frequency used is 900 MHz, which is found more effective than other frequencies in the therapy. It causes more uniform heating around bonny region.**

## Ultrasonic Wave:

**These waves are different from electromagnetic waves. It produces mechanical vibration inside tissue. It is the same as the sound waves but it has much higher frequencies about 1MHz with power of several watts per centimeter. It can move the tissue particles backward and forward with high frequency, in doing so it can increase the kinetic energy consequently it heats the tissue. Ultrasound can be produced by special transducers placed in direct contact with the skin. It is used for reliving tightness and 13 scarring occurring in joint disease. It can dispose more heat in bones, as bones are better absorber for ultrasonic energy than soft tissue. It is also used in deep therapy. Heat therapy has also been used in cancer treatment in combination with radiotherapy. The tumor is heated about 42°C for approximately 30 minutes, and the radiation treatment is given after heat treatment.**

## Cryogenics

**Cryogenics is the science of very low temp., it is used in biology and called cryobiology. Low temp. can be produced by liquefying gases. It was succeeded to produce liquid air (-196 °C) in 1877 and liquid helium (-269°C) in 1908.For solid carbon dioxide it is (-79°C)and liquid nitrogen(-196°C).These cold liquids have many medical and biological advantages. The storages of liquefied gases is rather difficult because it can take heat rapidly from the environment by conduction, convection, and radiation. A special container has been designed by Dewar (1892) and its named after his death, this composed from two cylindrical bottles made of glass or stainless steel one inside the other and a vacuum in between .this can prevent heat transfer by conduction and convection the two bottles are both silvered so that radiation striking the surface is reflected rather than absorbed, they are as good reflector and poor radiation for heat, the contact between them is made only at the top to minimize heat losses by conduction**

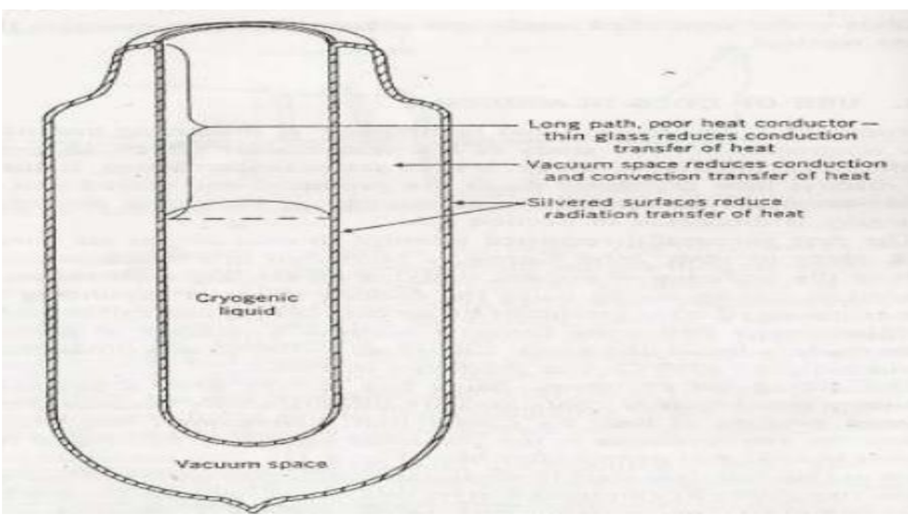



**Figure (9)**

Moderately low temp. were used successfully to cool down hamsters to (-5°C) freezing 50 to60 % of the water in their bodies, and then reviving them., for short term preservation moderate low temp. was successful in some types of tissue blood and semen, low temp. have been used for long term preservation of blood, sperm, bone marrow, and tissue. It has been found that for long-term, survival the tissue should be stored at very low temp. , since the biochemical and physical processes that sustain life are temp. dependent, lowering the temp. reduce the rates of the processes, liquid nitrogen (-196 °C) proved to be much better for preservation than solid carbon dioxide (-79°C). For conventional blood storage it can be stored with anticoagulant at 4°C, about 1% of the red blood cells hemolyze (break) each day so the blood will not be suitable for use after 21 day, for rare blood types should be stored for longer periods, other procedures were used. Blood can be preserved for very long periods of time if it frozen rapidly in liquid nitrogen (-196°C).The rate of freezing is very important to revive the cell after thawing them

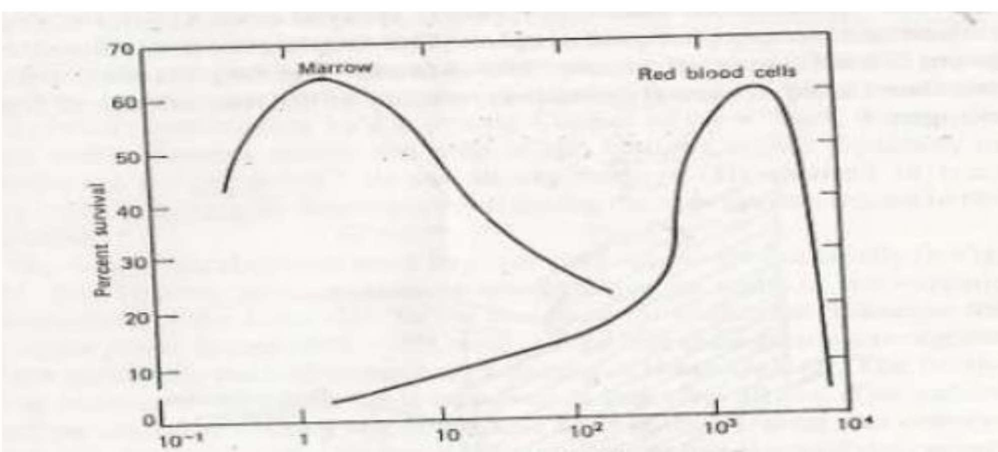



**Figure (10)**

**Also some preservation materials(protective agents) added such as glycerol improve the cell survival. Sometimes and especially in blood these materials can present a problem to remove them from the blood. There are two ways to freeze the blood to (-196°C):**

**1-The blood sand on the surface of liquid nitrogen surface and then it will be frozen in small droplets in very short time forming sand like particles, then stored at liquid nitrogen temp.**

**2-The blood is kept in a thin wall highly heat conductive with large surface area metal container and the spacing between the walls of the container is small to maintain a small thickness of blood inside the container .The container with the blood is immersed into the liquid nitrogen bath making very rapid cooling, the optimum rate of cooling is shown in Figure.**

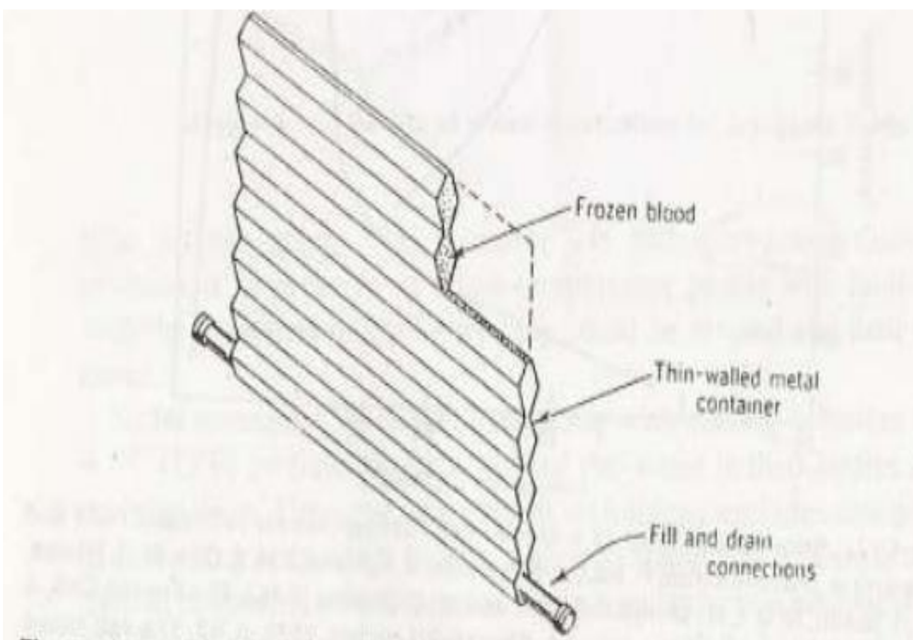



**Figure (11)**

**The preservation of large tissue like bone, muscles is still under searches as storage of them involves some problems: 1- Because of its large physical dimensions it is difficult to cool down all the cells at the same rate. 2- Adding and removing protective agents is difficult. Some work has been carried out to preserve cornea and skin.**

## Cryosurgery

**The cryogenic methods are used to destroy cells called cryosurgery. It has several advantages:**

**1-Cause a little bleeding**

**2-The volume of the tissue destroyed can be controlled**

**3-Little pain because low temp. desensitize the nerves**

**4-Very short recovery**

**One of the first uses of cryosurgery is in the treatment of Parkinson's disease,(shaking palsy).This disease causes uncontrolled tremors in the arms and legs. It is possible to stop it by destroying parts of the thalamus of the brain that controls nerve impulse to the other part of the nerve system. The instrument is shown in figure .The treatment undergoes while the patient in conscious, the probe at (-10°C) moved into the appropriate parts of the thalamus causing temporary freezing, the frozen area can recover if the probe tip is removed in less than 30 sec, while the surgeon is moving the probe and when the tremors stops he will keep the probe a few minutes at temp. near -85°C this region will be destroyed ,then the tips is warmed and removed, the destroyed tissue will form a cyst, which does not interferes with the normal**

**body function, successful results were obtained in more than 90% of cases. Other common uses of cryosurgery are in tumors and warts.**

**Cryosurgery is used in several types of eye surgery:**

**1-In retinal detachment, a cooled tip is applied to the outside of the eyeball in the vicinity of the detachment a reaction occurs that acts in weld the retina to the wall of the eyeball**

**2-Extraction of the lens, remove the darkened lens, in this procedure the cold probe is touched to the front of the lens, the probe sticks to the lens making the lens easy to remove.**