Heat and low temperature

As molecules of all materials are moving, so they have kinetic energy. The average kinetic energy of an ideal gas can be shown to be directly proportional with temperature. The same thing is for liquids and solids .The movement of gas molecules are more free than liquid and liquid molecules are more free than solid, an increase of temp. of any material means an increase in the energy of molecules of that material.

In order to increase the temp. of a gas, it is necessary to increase the average kinetic energy of its molecules by putting the gas in contact with a flame, the energy transferred from the flame to the gas causing temp. rise is called **heat.**

If enough heat added to a solid, it melts, forming a liquid. The liquid may be changed to a gas by adding more heat. Adding still more heat converts gas to ions.

While adding heat to substance increase its molecular kinetic energy, which increase its temp., the reverse is also true, heat can be removed from a substance to lower the temp., Low temp. referred to as the **cryogenic region** (absolute zero,-273.15°c).

Thermometry and temperature scales

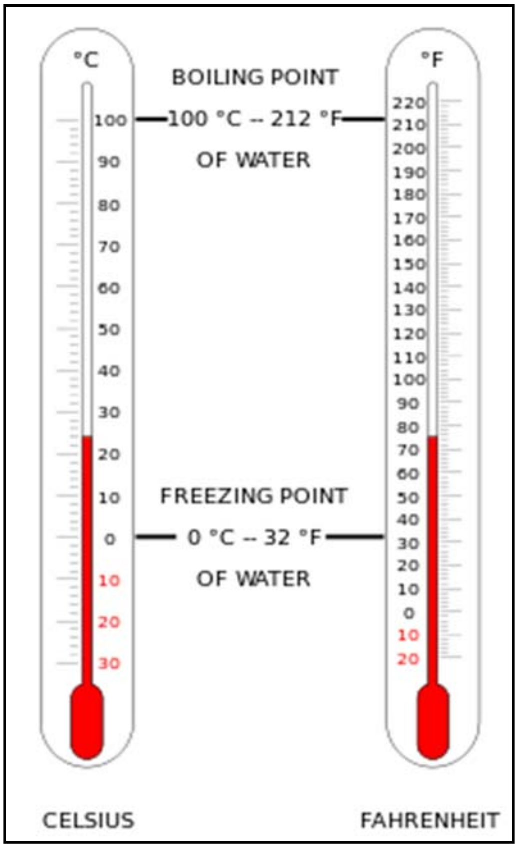
Temperature is difficult to measure directly, so we usually measure it indirectly by measuring one of many physical properties that change with temp. .

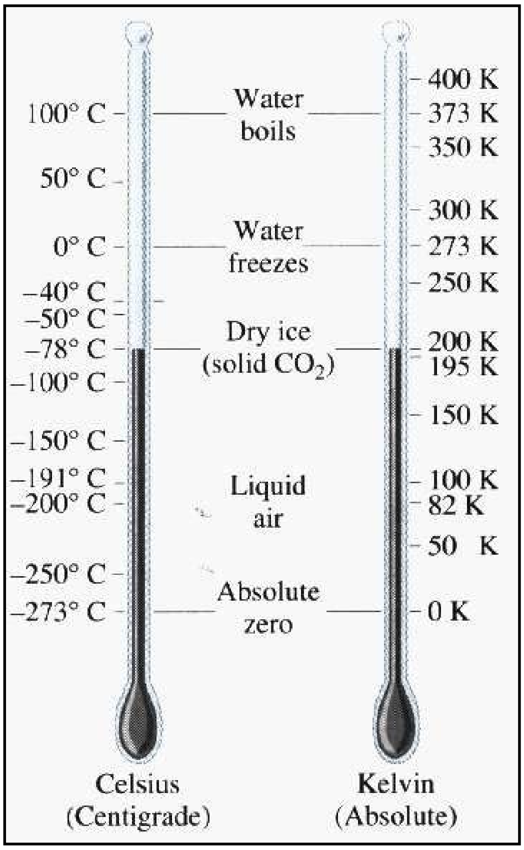
1-Fahrenheit scale(°F):in this scale the freezing temp. is 32°F and boiling point is 212°F ,and normal body temp. is about 98.6°F .

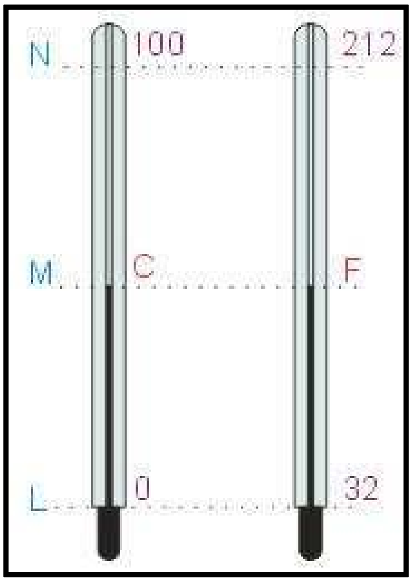
2-The Celsius(°C):the freezing point is 0°C and the boiling point is 100°C ,in between is divided into 100 division.

3-The Kalvin scale(°K):or the absolute scale this scale has the same divisions as the Celsius but takes the 0° K at the absolute zero which is=-273.15°C.

Heat and Cold in Medicine







$$\frac{ML}{NL} = \frac{C-0}{100-0} = \frac{F-32}{212-32}$$

$$\therefore \frac{C}{100} = \frac{F-32}{180}$$

$$F = \frac{9}{5}C + 32$$

To change °C to °F

[°C= (°F-32) 5/9] or [°F=°C (9/5)+32]

Also °C=°K-273 or °K=°C+273

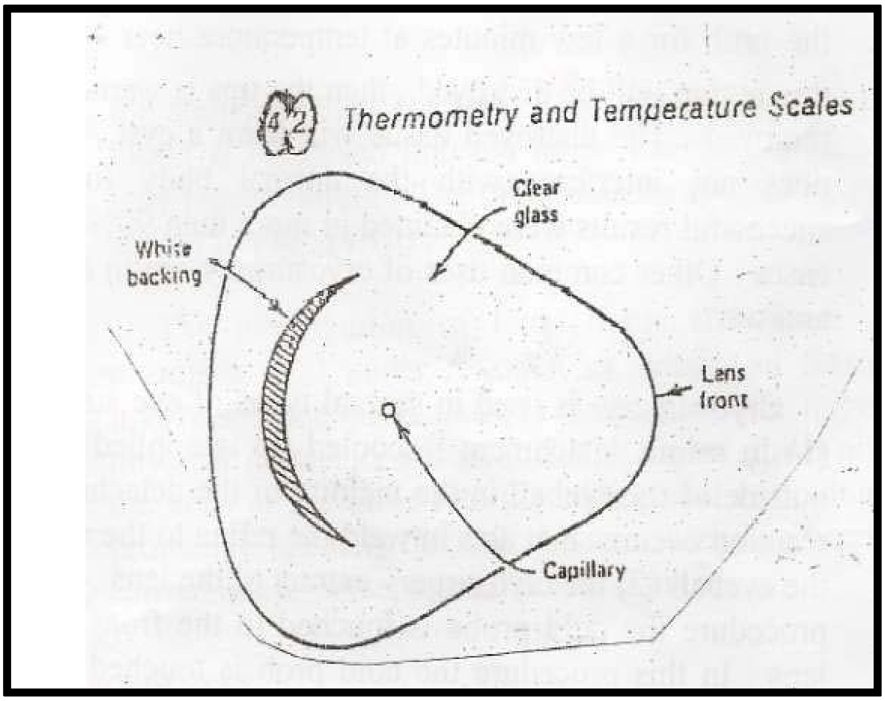
Types of thermometers

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 (0100°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.

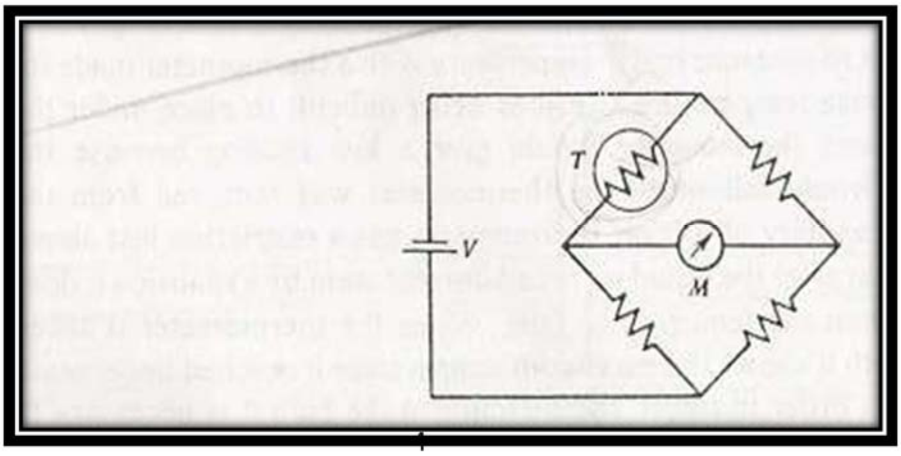
This is unlike the room thermometer if used to check the patient fever it will change as soon as it is taken out from the mouth of the patient, for this reason and others such as the thermometer design not for medical use in addition to its low sensitivity the room thermometer are not used in medicine. 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.



2- Thermistor

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.

Thermistores 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)

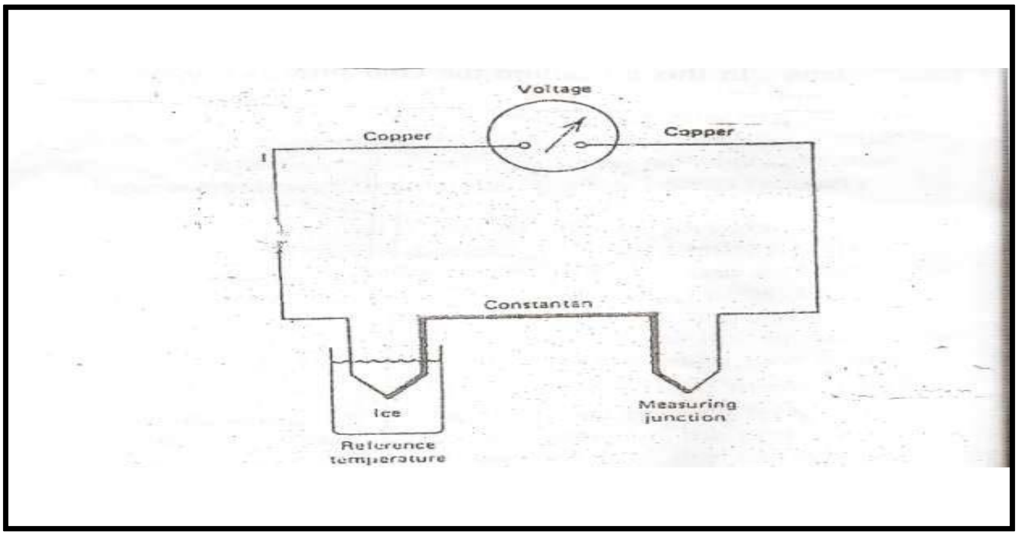


3-Thermocouple

Consist of two junctions of two different metals. If the two junctions are at different temp. , a voltage is produced that depends on the temp. difference. Usually one of the junctions is kept at a reference temp. such as in an ice-water bath.

The copper-constantan thermocouple can be used to temp. from -190 to 300°C. For 100°C temp. difference, the voltage produced is only about 0.004V.

Thermocouple can be made small enough to measure the temp of individual cells.



Thermograph-mapping the body's temperature

The surface of the body temp. is slightly different in different parts. Depending on external physical factors and internal metabolic and blood supply to the skin.

Measurement of surface temp. though to be useful in diagnosis of some diseases, which may change locally the skin temp. All objects regardless on the temp. emit heat radiation. The body heat can give infrared radiation (IR) of long waves, which are not visible unlike the red-hot object, which is visible. By using this principle the thermograph instrument was designed to measure the radiation emitted from a part of the body. fig(4.5) in the book

Heat radiation power can be measured by:

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

Where

T: is the absolute temp. of the body e: is the emissivity depends upon the emitter material and its temp. for radiation from body e is almost 1.

σ: is the Stefan –Boltzmann constant=5.7×10^{-12} $W/cm^2\ °K^4$

Example:

a. what is the power radiated per square centimeters from skin at a temp. of 306°K.?

$W= e\ \sigma T^4= (5.7\times10^{-12})(306)^4= 0.05 W/cm^2$

b. what is the power radiated from a nude body $1.75m^2(1.75\times10^4\ cm^2)$ in area?

$W= (0.05)\ (1.75\times10^4\ cm^2)= 875\ W$

It was found that the most breast cancers has 1°C higher than that the other side(healthy)(since the tumor often increase the blood flow) and it was thought that this will be good procedure for early breast cancer detection.

It was found that one third of thousands women, have abnormal thermo gram of the breast and less than 1% has shown cancer.

X-ray mammography has shown much more successful results to detect breast tumor of less than 1cm in diameter, but they present a radiation hazard to the body.

Thermography usually taken in a rather cold room to increase the temp. difference between region of poor and normal blood supply consequently the contrast improved the machine can detect 0.2°C temp. Difference and record the thermo gram in two seconds. The procedure takes about 20 min at room temp. (20-21 °C).

Thermography is useful in the study of blood circulation in the head, differences in the blood supply between left and right of the patient, which may reflect problems. In diabetic patients the study of blood supply in legs is important. The presence of hot spots in the foot can be determined before of ulcer forms and preventative measure can be taken, studies show a reduction of 20% in limb amputation of diabetic patients.

Heat therapy

Heat was recognized as therapeutic agent several thousand years ago. It has two primary therapeutic effects:

1- An increase in metabolism resulting in relaxation of the blood capillaries (vasodilation).
2- An increase in blood supply to cool down the heated area.

Heat production for therapy

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 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 heat (IR)

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.

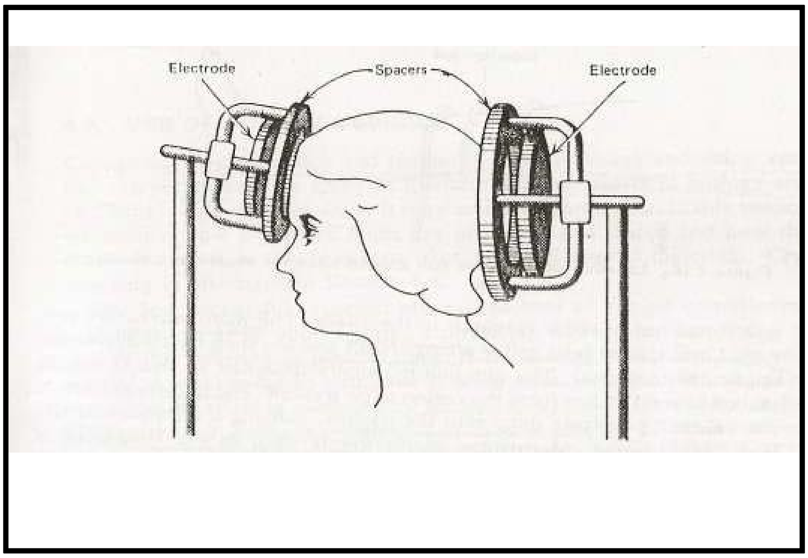
3-Diathermy

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 .

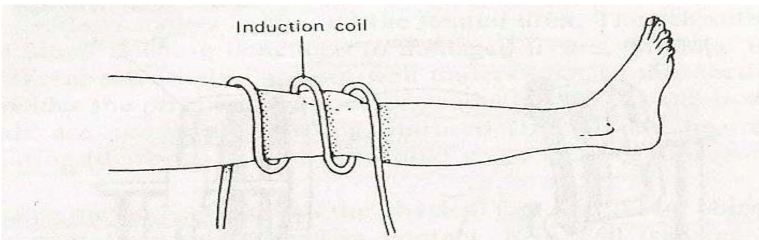
Different methods are used for transferring the electromagnetic energy into the body:

A- The part of the body to be treated is placed between two plates (electrodes) connected with high frequency power supply. The 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 (book fig 4.9).



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 (fig 4.10) 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.



C- Microwave diathermy can be produced in special tube called (magnetron) and emitted from the applicator (antenna) which can be placed several inches from the region to be treated. Microwave can penetrate deeper into the tissue causing heating. It is used in fractures, sprains, strains, bursitis, injuries to tendons. The frequency used is 900MHz, which is found more effective than other frequencies in therapy. It causes more uniform heating around bony region.

4-Ultrasonic waves

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 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.

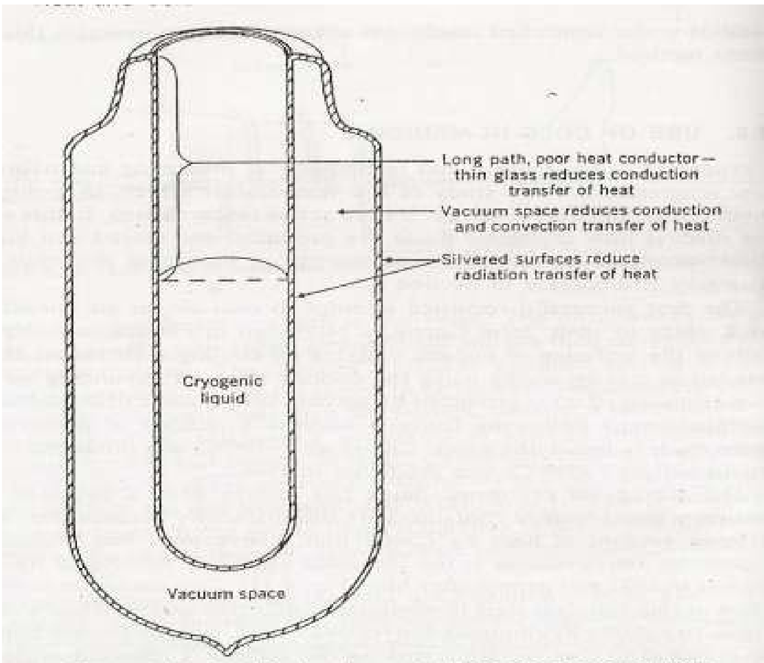
Heat therapy has also been used in cancer treatment in combination with radiotherapy. The tumor is heated about 42°C for approximately 30 minutes, and the radiation treatment is given after heat treatment.

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.

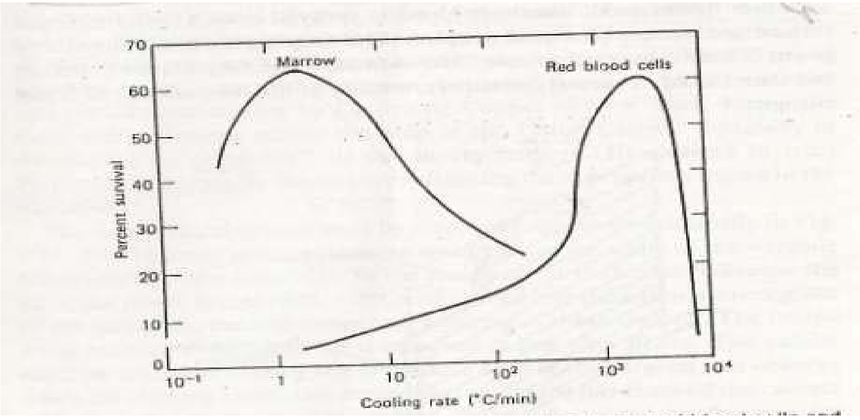
A special container has been designed by Dewar (1892) and its named after his death, this composed from two cylindrical bottles made of glass or stainless steel one inside the other and a vacuum in between .this can prevent heat transfer by conduction and convection the two bottles are both silvered 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 (book fig 4.11).



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.

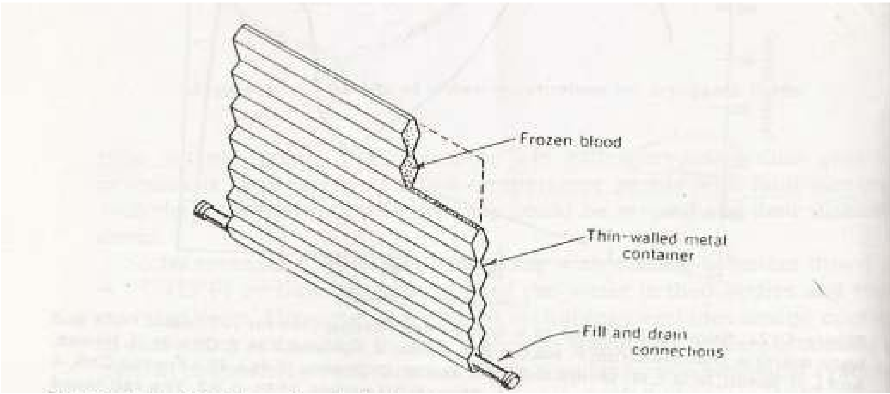
Blood can be preserved for very long periods of time if it frozen rapidly in liquid nitrogen (-196°C).The rate of freezing is very important to revive the cell after thawing them (fig4.12).



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 (book fig 4.13).The container with the blood is immersed into the liquid nitrogen bath making very rapid cooling, the optimum rate of cooling is shown in (book fig 4.12).



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 (book fig.4.14).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.