Ministry of Higher Education and Scientific Research

College of Health and medical techniques \ Kufa

Department of Aesthetic and Laser technique

Learning package in field of

Medical Physics

Presented to the 1st class students

Designed by

Dr. Hawraa Hadi Chyad

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Lecture 1\\ Physics of the Skeleton

Skeleton comes from a Greek word meaning **dried up body**. Bone appears dead and dried up, but it is **not**! Bone is **living tissue.**

Parts of the skeletal system

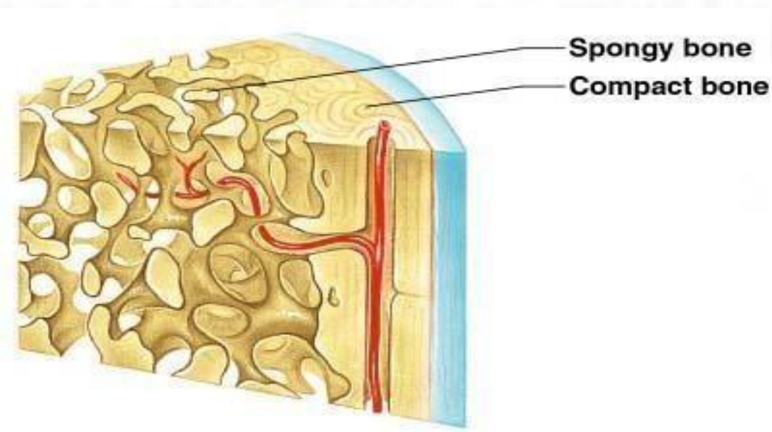
- **Bones (skeleton)**
- **Joints**
- **Cartilages**
- **Ligaments (bone to bone) (tendon=bone to muscle)**

Functions of Bones

1. **Support** of the body (framework)
2. **Protection** of soft organs
3. Serve as **levers** (with help from muscles)
4. **Storage** of minerals and fats (calcium)
5. Blood cell **formation**

There are **two** basic types of **bone tissue** in the human body.

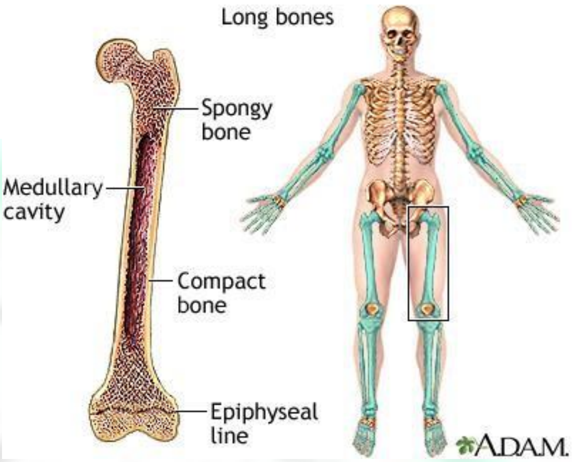
1. **Compact bone** {**dense** and **hard**)
2. **Spongy bone** {Cancellous and Many open spaces}



Classification of Bones

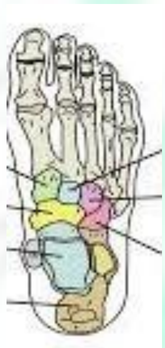
1. Long bones

- Typically, longer than wide.
- Have a shaft with heads at both ends.
- Contain mostly compact bone.
- Found in legs and arms.
  - Examples: Femur, humerus.



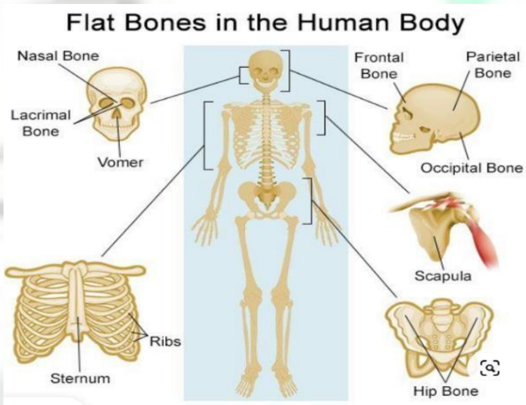
2. Short bones

- Generally, cube-shape and small.
- Contain mostly spongy bone.
- Found in wrist, ankles, and toes.
- Examples: Carpals, tarsals



3. Flat bones

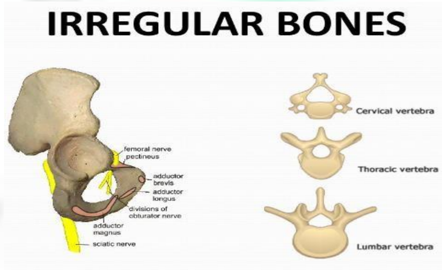
- Thin and flattened Usually curved
- Cover organs and provide surface for leg muscle
- Thin layers of compact bone around a layer of spongy bone
- Examples: Skull, ribs, sternum



3. **Sesamoid Bones**

- The sesamoid bones get their name for resembling a sesame seed.

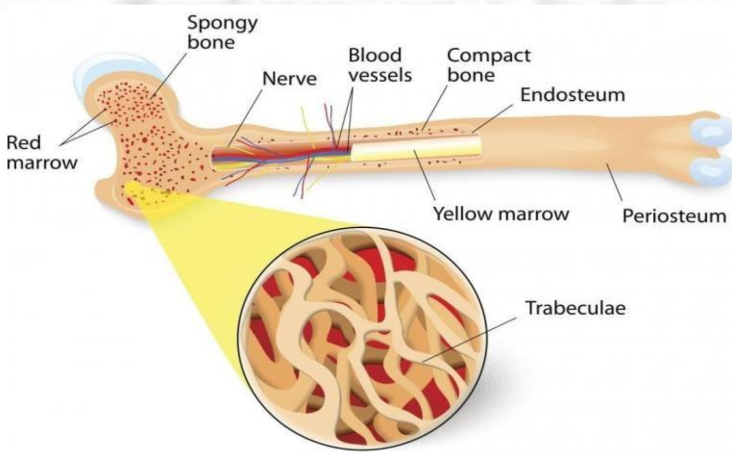
4. **Irregular bones**



- The irregular bones get their name for their odd shapes that do not fit the other categories of long, short, flat, or sesamoid.

What Are Bones Made of?

- **Periosteum**: The outer surface of the bone; a thin, dense membrane that contains **nerves** and **blood vessels** that nourish the bone!
- **Compact**: This is the next layer; it is very **smooth** and very **hard**. It is the part you see when you look at a skeleton!
- **Cancellous**: Many layers within the compact bone; these look like sponges! Not as hard as compact bone, but it is still very hard. In many bones, the **cancellous** bone **protects** the **innermost** part of the bone.
- The **bone marrow**: It is sort of like a thick jelly, and its job is to make blood cells.



Composition of compact bone: Table 1 where Large percentage of **calcium** with heavier **nucleus (**high x-ray absorption**).**

Table 1 . Composition of Compact Bone"

Element	Compact Bone, Femur (%)
H	3.4
C	15.5
N	4.0
O	44.0
Mg	0.2
P	10.2
S	0.3
Ca	22.2
Miscellaneous	0.2

Generally, Bone = collagen + bone mineral + water

- **Collagen**

Collagen which is the major organic fraction, 40% of the weight of solid bone and 60% of its volume. {**flexible and bends easily, large tensile strength**. Produced by **osteoblastic** cells.

- **Bone mineral**

Bone mineral: inorganic component 60% of weight 40% of its volume. Formed on the collagen. Made up of calcium hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$. Very large surface area of $4\times10^5\ m^2 \Rightarrow$ rapid interaction with chemicals in the blood and other body fluids.

Lecture 2\\ Physics of the Skeleton (part 2)

How Strong Are Your Bones?

We mentioned in the previous lecture that there are two types of bones. so, what are the advantages of sponge (trabecular) bone over compact bone?

1. Where a bone is subjected primarily to compressive force, such as at the ends of the long bones and the trabecular bone give the strength necessary with less material than compact bone.

2. Also because the trabecular is relatively flexible trabecular bone can absorb more energy when large forces are involved such as in walking, running, and jumping.

Mechanical properties of bones

1. **Density**

   The density of compact bones is constant = 1.9 gm/cm^3 (or 1.9 times as dense as water). It is independent of age.

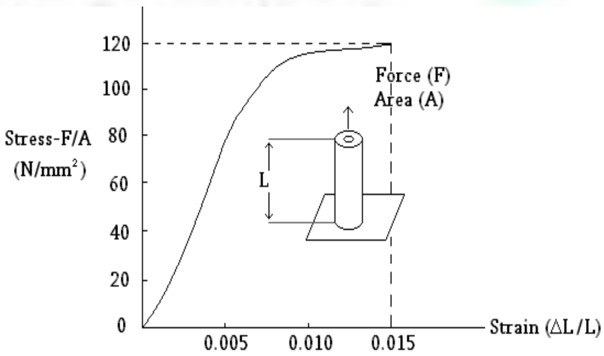
   In old age, the bone becomes more porous and thinner due to reduced strength.

2. **Bone elongation under tension and shortening under compression*:***

   According to Hook's law below a sample (e.g bone) under a tensional force (F) will increase in length (ΔL) as the force increases, and the bone breaks at a stress of about (120 N/ mm2) Healthy compact bone is able to with stand a compressive stress of about 170 (N/mm2), as in the Fig below.

Hooke's law:

$\sigma = Y \xi$, *(stress-strain)*



Young's Modulus of Elasticity of compact bone = 1.8×10^{10} N/m^2

How can derive Young's Modulus ?

According to the definitions for : **Stress** (the force (F) per unite area (A) of the sample)

$$\sigma = F / A$$

- **Tension**: pulling it apart
- **Compression**: pushing it together

Strain fractional change in **length** due to **stress** (the ratio of the change in the length (ΔL) of the sample (e.g bone) to the original length (L_O))

$$\xi = \Delta L / L$$

Young's modulus: is the relationship between stress and strain

$$Y = \sigma / \xi = LF / A\Delta L$$

EX: Assume 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 body weight 0f (700 N) is supported on the leg? (Y.M=$1.8x10^{10}$ N/m^2).

Solution:

$L_O = 1.2$ m , $A = 3$ cm^2, $F = 700$ N, ΔL =?

$A = 3$ $cm^2 \rightarrow 3 \times 10^{-4}$ m^2

$$Y = LF / A\Delta L$$

$= (1.2 \times 700) / (3 \times 10^{-4} \times 1.8 \times 10^{10})$

$\Delta L = 0.000155$ m

H.W Calculate the change in length of a bone the original length is (40 cm) exposed to a limited stress (2.33×10^3 N/m^2)? Knowing that (Y.M.=$1.8x10^{10}$ N/m^2).

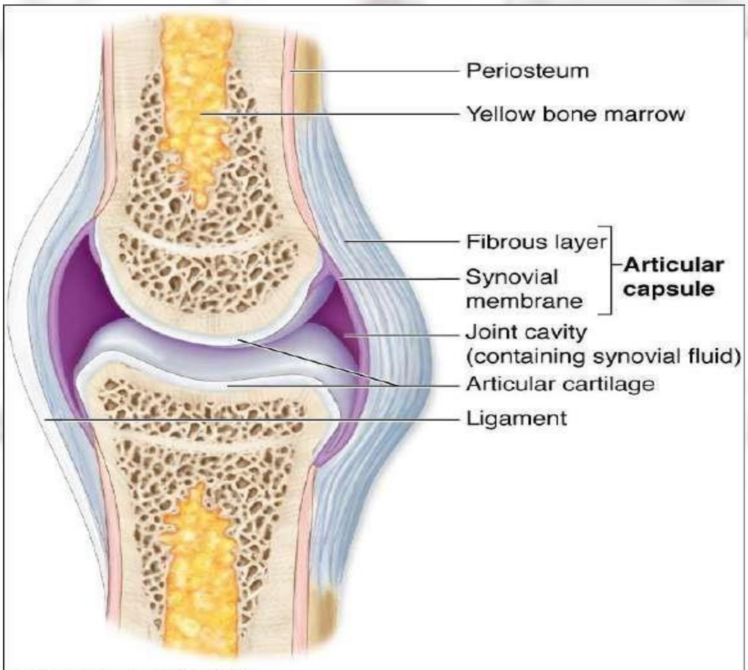
Lubrication of Bone Joints

Joints are places in the body where two bones come together. Each bone ended with synovial fluid, and the joints made most of the body movement The surface of the articulate cartilage does not smooth the roughens of the cartilage but plays a useful role in joint lubrication by trapping some of the synovial fluid and because of its porous nature, another lubricating material is squeezed into the joint when it is under great test stress when it needs the most lubrication.

When the pressure increases on the joint, the lubrication threads squeeze out of the cartilage into the joint in one end each lubricating thread remains in the cartilage, and as the pressure is reduced the threads pull back into their holes. The viscosity of the synovial fluid decreases under the large shear stresses found in the joint.

The coefficient of friction of a healthy joint was found to be 0.01.

Viscosity α 1 / Lubrication



a Typical synovial joint

Measurement of bone mineral

A few years ago, osteoporosis was difficult to detect until a patient appeared with broken hip or crushed vertebra. At that time it was too late to use preventive therapy. The strength of bone depends on the mass of bone mineral present. The physical techniques for studying bones are:

1- x-ray image: to measure the bone mineral , its an old one. There are some problems of using x-ray, these are : x-ray beam has different energies and the absorption of x-ray by Ca varies rapidly with energy, scattered radiation when it reaches the film, the film is a poor detector for making quantitative measurements

•The three problems are eliminated by using

1- Mono energetic x-ray or gamma ray source.
2- a narrow beam to minimize scatter
3- a scintillation detector that detects all photons

2- photon absorptiometry technique: the determination of bone mineral mass by using

MB=K Log (I^o/I)

MB: bone mineral , I^o: initial intensity , I : final intensity , k: constant

3- Activation technique: take the fact that nearly all of calcium in the body is in the bones. The whole body is irradiated with energetic neutrons that convert a small amount of calcium and some other elements into radioactive forms that given off gamma rays, and the emitted gamma rays then detected and counted,the gamma rays from radioactive calcium can be identified by their unique energy

Lecture 3\\ Energy, Work and Power of the body

Energy (E): Is the quantitative property that must be transferred to an object in order to perform work on, or to heat, the object. The SI unit of energy is the **Joule(J).** Common forms of energy include the kinetic energy , potential energy, the chemical energy, the radiant energy carried by light, and the thermal energy due to an object's temperature.

Work (W): Is defined as product of the force (F) and the distance (x) over which the force is applied. **Work** is done when a force is applied to an object and the object is moved through a distance, the unite is (1N.m= J).

$$\mathbf{W = Force \times Distance}$$

Power (P): Is the rate of doing work (W) or transferring heat, the amount of energy transferred or converted (E) per unit tim (t) . The SI unit of power is the joule per second (J/s), known as the Watt .

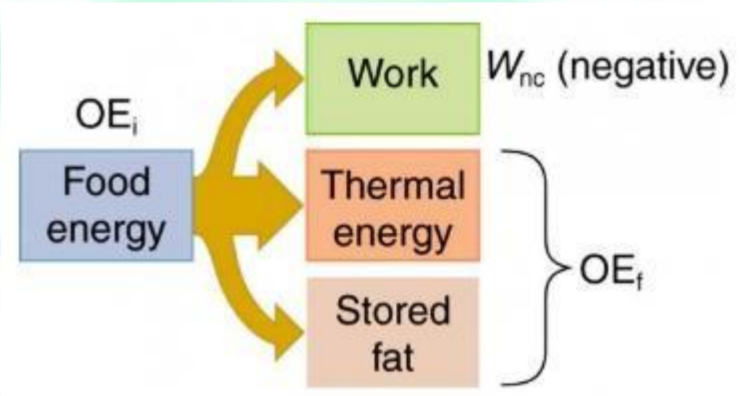
$$\mathbf{(P = W/t)}.$$

The Energy in Human Body

All body activities including thinking, doing work, or keeping the body temperature (temp.). 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 feces and urine. Extra food energy will be stored mainly as fat. External heat energy from environment can help maintain the body temp., but it has no use in body function.

The body uses the food energy to:-

1. Operate body various organs.
2. Maintain a constant body temperature.
3. Do external work for example lifting.



Energy consumed by humans is converted to work, thermal energy, and stored fat. By far the largest fraction goes to thermal energy, although the fraction varies depending on the type of physical activity.

Conservation of energy in the body

The conservation of energy in the body is expressed by the first law of thermodynamics: The change in stored energy in the body (food energy, body fat, and body heat) = The heat lost or gained from the body ± Work done

$$\Delta U = \Delta Q \pm \Delta W \text{ .... (1)}$$

Where:

ΔU: is the change in stored energy. ΔW: is the work done by the body.

ΔQ: is the heat lost or gained (will discussed the heat concept in coming lectures).

The rate of change of energy is given by:

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} \pm \frac{\Delta W}{\Delta t} \text{ .... (2)}$$

Where:

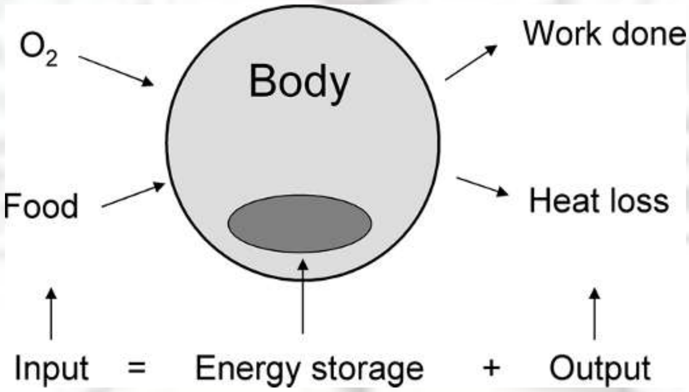
$\frac{\Delta U}{\Delta t}$: Rate of change of stored energy.

$\frac{\Delta Q}{\Delta t}$: Rate of heat loss or gain.

$\frac{\Delta W}{\Delta t}$: Rate of doing work.

Equation (2) tells us that energy is conserved in all processes, but it does not tell us whether or not a process can occur.

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. Figure below



Energy flow into and from the body

All types of energy have the same units, including heat (often expressed in terms of calories) and work (often expressed in terms of joules). One important conversion between units is

1 calorie (cal) = 4.184 joule (J).

Energy Content of Body Fuel

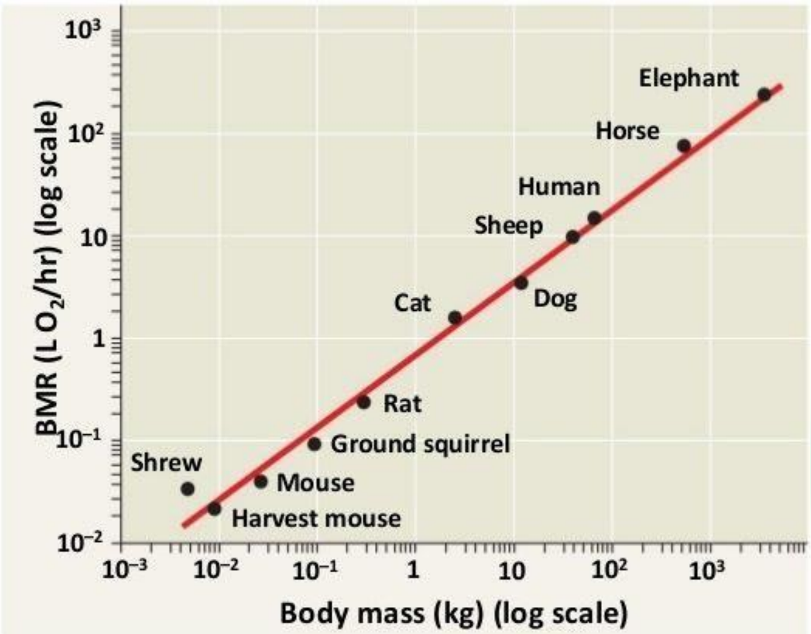
There is some similarity between metabolic **oxidation** and combustion, even though the body does not "burn" its fuels in oxygen. It is useful to learn about the combustion of these fuels because combustion tells you the maximum amount of energy that is available from breaking and rearranging bonds.

What do you mean oxidation?

A chemical process in which oxygen is used to make energy from carbohydrates (sugars). Also called metabolism. The oxidation process within the body, heat is produced as energy of metabolism**.**

The Basal Metabolic Rate (BMR)

BMR: It is the amount of energy needed to perform minimal body functions (such as breathing and pumping the blood through the arteries). BMR depends primarily upon thyroid function. A person of an over active thyroid has a higher BMR than a person with normal thyroid function. Since the energy used for basal metabolism becomes heat and dissipated from the skin, so BMR is related to the surface area, or the mass of the body. The metabolic rate depends on temperature of the body, and on sex, age, height, and weight. In Figure below the graph represents the change between BMR (kcal/day) and the mass of different beings, the slope of the graph indicates that the BMR is proportional to mass.



Relationship between BMR and body mass for different beings

Mechanical Work and Power

The first law of thermodynamics equation (1) shows that stored energy can be used to supply heat or work. For people, this is mechanical work.

Mechanical work is the force you apply to an object (F) × the distance you push or pull it (x) and it can be also written as:

$$\Delta w = F.\Delta x \quad \text{.......... ....} \quad (3)$$

Or with accurate meaning:

$$\Delta w = F\,\Delta x \cos(\theta) \quad \text{.......... .....} \quad (4)$$

where θ is the angle between F and the direction of movement.

The power is work per unit time.

$$P = \frac{\Delta w}{\Delta t}$$

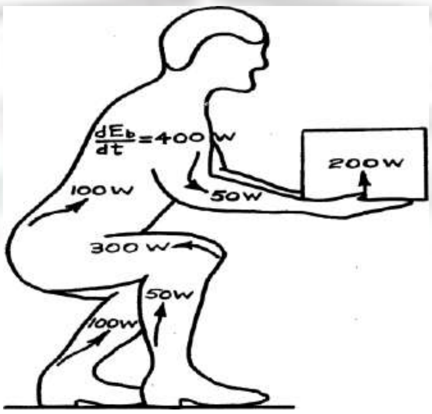
$$= F\frac{\Delta x}{\Delta t}\ ; \qquad \frac{\Delta x}{\Delta t} = v$$

$$P = F\,v \quad \ldots\ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots.\ (5)$$

where v is the velocity. When the force is perpendicular to the displacement ($\theta=90^0$) 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 given in the equation below

$$w = mgh \qquad \text{where: } g=9.8\ m/sec^2$$

we can call external work, work is also done about the joints of the body to lift the center of mass of the body itself, which is internal work. Also, concentric muscle contractions are said to do positive (mechanical) work, while eccentric contractions do negative work. Walking on level ground requires equal amounts of positive and negative work. Walking uphill requires relatively more positive work, while walking downhill requires relatively more negative work Figure below. The work efficiencies of positive and negative work are different.



"Internal" vs. "external" work in lifting an object.

The efficiency of human body can be obtained from the law:

$$Efficiency\ (\mathcal{E}) = \frac{\text{The work done (output)}}{\text{The energy consumed (input)}} \quad \text{.......................... (6)}$$

$$\mathcal{E} = \frac{w=mgh}{E} \quad \text{.......................... (7)}$$

Energy consumed = Metabolic Rate

Example:

Person raising a box of mass (15 kg) to a table is (2 m) from the ground, Calculate the necessary energy in the units of calories, assuming that the efficiency of this person is (25%) and acceleration of the gravitational is (g=9.8 m/sec^2).

Solution

$$\mathcal{E} = \frac{mgh}{E} \rightarrow E = \frac{mgh}{\mathcal{E}}$$

$$E = \frac{15 * 9.8 * 2}{0.25} \rightarrow E = 1176\,J$$

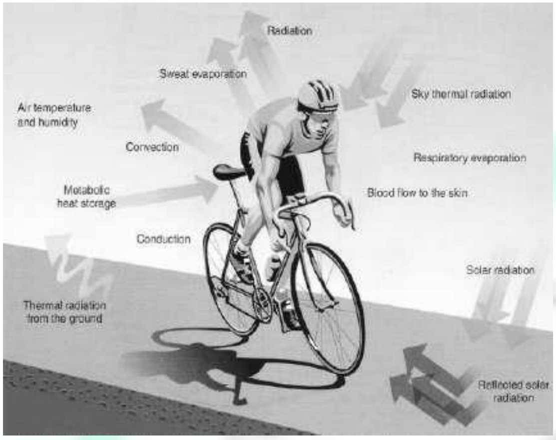
1 cal = 4.184 J

$$E = \frac{1176\,J}{4.184\,J/cal} \rightarrow E = 281.07\,cal$$

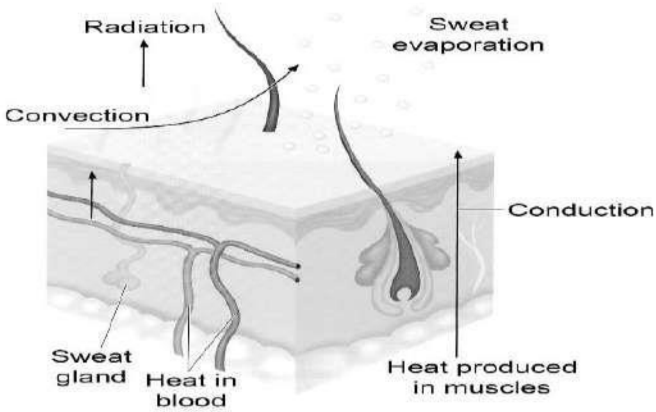
Modes of Heat Loss

There are four modes of heat loss. -Figures (below).

1. Radiation loss.
2. Convection and Conduction of air from the body .
3. The Evaporation of sweat .
4. The Evaporation of water through breathing



Overall body modes of loss of heat



More microscopic view of modes of heat loss by removal from the skin.

(H.W) Calculate the power of a man who has completed a work of (7.2×10^3 Joule) within a period of time estimated at 20 minutes.

solution

Lecture 4\\ Heat and Cold in Medicine

Definition of Heat

Heat is a form of energy associated with the movement of atoms and molecules in a substance. It is the energy that is transferred between systems or objects with different temperatures. The transfer of heat always occurs from a region of higher temperature to a region of lower temperature until thermal equilibrium is achieved.

Energy Transfer: Heat is not a substance but a mode of energy transfer due to temperature difference.

Units of Measurement:

SI Unit: Joule (J)
Common Units: Calorie (cal)

The effect of heat on the material

As molecules of all materials are moving, so they have kinetic energy (K.E). 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.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, We can represent this word with the following expression :

$$\textbf{Solid + heat} \Rightarrow \textbf{liquid}$$

$$\textbf{Liquid + heat} \Rightarrow \textbf{gas}$$

$$\textbf{Gas + heat} \Rightarrow \textbf{ions}$$

- **Definition of Temperature (Temp.)**

Is a physical quantity expressing hot and cold. It is measured with a thermometer calibrated in one or more temperature scales. We'll discuss the temperature scale types in the coming lecture.

- **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. All objects regardless on the temp. emit heat radiation. The body heat can give infrared radiation (IR) of long waves, which are not visible. By using this principle the thermograph instrument was designed to measure the radiation emitted from a part of the body, The total radiation power per surface area (P) is is ***given by Stefan – Bultzman Law : The power radiated (P) from a black body is directly proportional to the fourth power of the black body's thermodynamic temperature T (P α T⁴):***

$$P= e\,\sigma T^4 \quad \text{.......................} (1)$$

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} Watt/cm^2 °K^4.

Example:- What is the power radiated per square centimeter from skin at a temperature of 306°K (33°C)? 2.What is the power radiated from area 1.75m ^{2} (1.75×10^4 cm ^{2}) of a body?

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

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

- **Heat production for therapy.**

Heating of tissue may be beneficial to damaged tissues. So that heat has two therapeutic effects:

1. Increase in metabolism resulting relaxation in capillary system(vasodilatation)
2. Increase in blood flow when blood moves to cool the heated area

1- **Conductive heating:**

Which transferred by conduction from the warmer object to the cooler one. (Hot bath, hot pack,electric heating pad, etc.)

The total heat transferred will depends upon:

a) Contact area
b) Time of contact
c) Temperature different
d) The thermal conductivity of materials

2- **Radiant (IR) heating:**

Heat radiation can be achieved by using infrared radiation (IR), it penetrates about (3mm) in the skin. It is considered to be more effective than conductive heating because it can penetrate deeper.

3- **Electromagnetic (E.M) wave (Diathermy)**

The energy (E) of electromagnetic waves is expressed in the following relationship:

$$E=h\upsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where h is Blank's constant ($h= 6.626\times10^{-34}$ J/s , υ the frequency ($\upsilon=1/\lambda$)

So the classified according to energy $E\rightarrow\upsilon\rightarrow\lambda$:

A- Short-wave Diathermy with (λ = 10nm and υ =30 MHz) - (MHz =10^6 Hz)

B- Long Wave Diathermy with υ = 10 kHz

Heat from diathermy penetrates deeper into the body than radiant and conductive heat, thus it is useful for internal heating. It used in treatment of inflammation of the skeleton , bursitis , neuralgia ,Muscle spasm, pain from protruded intervertebral discs , degenerative joint disease.

- ## Body absorption of radiation

In physics, absorption of electromagnetic radiation is the way in which the energy of a photon is taken up by matter, typically the electrons of an atom. Thus, the electromagnetic energy is transformed into internal energy of the absorber, for example thermal energy.

In the body if the **radiation intensity** at the surface is **(I_o)** penetrates the tissue with **thickness (D)**, then **the radiation intensity (I)** at **depth (x)** is:

$$I = I_o \exp(- x / D) \quad \text{.....................................(3)}$$

4- **Microwave diathermy:**

Microwave diathermy utilizes electromagnetic radio waves used in treatment of fractures, sprains and strains, bursitis, injuries to tendons. we use microwaves diathermy for deep area covered with fatty layers.

Absorption of Microwave beam depend on :

1. The amount of water in the tissue. Because the energy is deposited more effectively in tissue with high water content, microwave energy is absorbed better in muscle tissue rather than in fatty tissue which have less water.

2. The frequency of microwaves: The energy is absorbed is very high at frequency ~ 20 GHz (GHz = 10^9Hz). It's poorly absorbed at lower frequency nearly 100 MHz and at very high frequency >1000 GHz.

5- Ultrasonic diathermy:

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.

Heat in medicine

Heat in medicine exemplifies the integration of physics and biology to promote healing and relieve discomfort, where heat is a critical concept with diverse applications in therapy, diagnostics, and research. It is used both for its therapeutic properties and as a diagnostic tool. in this lecture will discuss some of the main uses and considerations of heat in medicine.

1. Therapeutic Applications of Heat

Heat therapy (thermotherapy) is widely used to relieve pain, promote healing, and improve circulation.

a. Pain Relief and Muscle Relaxation where heat increases blood flow, reduces muscle stiffness, and enhances tissue elasticity.

b. Improving Circulation where heat dilates blood vessels, improving oxygen and nutrient delivery to tissues, aiding in recovery from injuries or surgeries.

c. Hyperthermia Therapy for Cancer where tumors are more heat-sensitive than normal tissues to make them more susceptible to treatments like chemotherapy or radiation.

d. Wound Healing where heat promotes the repair of damaged tissue by improving circulation and stimulating cellular processes

e. Fever Therapy (Pyrotherapy) Historically, fever was induced to combat infections or diseases, such as syphilis, before antibiotics became available.

2. Diagnostic Applications

Heat plays a role in various diagnostic techniques, particularly involving thermal imaging.

a. Thermography is a non-invasive imaging technique that measures the heat emitted by the body. Uses for detecting inflammation or abnormal blood flow (e.g., in arthritis or vascular disorders).

b. Heat-Responsive Imaging in Research Thermal probes are used in medical research to study metabolic activity and tissue responses to temperature changes.

3. Risks and Contraindications of Heat Therapy

- Burns: Excessive heat or prolonged exposure may damage skin or tissues.
- Worsened Inflammation: Heat can exacerbate swelling in acute injuries.

Conditions to Avoid Heat:

- Open wounds or infections.
- Areas with poor circulation or numbness.
- Active bleeding or hemorrhage.

Lecture 5 **Heat and Cold in Medicine**

Cold in Medicine

Cold plays a significant role in medicine, both as a therapeutic tool and in preserving biological materials. Below is some of uses and effects of cold in medical contexts:

Therapeutic Applications of Cold

Cold therapy, also known as cryotherapy, is widely used in medical and therapeutic settings to treat injuries, reduce pain, and manage inflammation.

Mechanism: Cold reduces blood flow (vasoconstriction) to the affected area, which helps minimize swelling and numbs nerve endings, reducing pain.

Local Anesthesia

Cold-Induced Numbing: Cooling sprays or ice packs are sometimes used as a temporary numbing agent before minor procedures, such as injections or superficial surgeries.

Cryogenics

Is the science of very low temp., it is used in biology and called cryobiology. Low temp. can be produced by liquefying gases. The storages of liquefied gases is rather difficult because it can take heat rapidly from the environment by conduction, convection, and radiation.

Moderately 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).

There are two ways to freeze the blood to (-196°C):

1- In this method , the blood sprayed on the surface of liquid nitrogen and then it will frozen in small droplets in very short time forming sand like particles . The stored at liquid nitrogen temperature.

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 preservation of large tissue like bone, muscles is still under searches as storage of them involves some problems:

A- Because of its large physical dimensions, it is difficult to cool down all the cells at the same rate.

B- 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.

- **Uses of Cryosurgery**

In treatment of

1. Parkinson's disease , Disease Shaking Palsy . It is a disease that associated with the basal ganglion of the brain which causes un controlled tremor in the arms and legs, Treatment is done by destroying the part of the thalamus in the brain that controls the transmission of nerve impulses to other parts of nervous system .

2. Tumors and warts.

3. Eye surgery :
   - Repair of detached retina.
   - Cataract surgery removal of a darkened lens.

Physiological Effects of Cold on the Body

a. Vasoconstriction

- Cold causes blood vessels to constrict, reducing blood flow to the area.
- Benefits: Minimizes swelling and bruising.
- Risks: Prolonged exposure can lead to bn / tissue damage.

b. Nerve Response

- Cold slows nerve conduction velocity, reducing pain perception and muscle spasms.

- Overuse can lead to temporary or permanent nerve damage in severe cases.

c. Metabolic Rate Reduction

- Cold lowers the metabolic activity of cells, which is beneficial in reducing inflammation and preserving tissues.

d. Hypothermia

- Medical Hypothermia: Deliberate cooling of the body to reduce metabolic demand and protect organs during surgeries or after cardiac arrest.

Lecture 6 Thermometer and it's kinds, Heat Transfer
Specific heat, heat capacity, latent heat,

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., For example, the Mercury expansion property at high temperature. There are three for temperature scales

1. **Fahrenheit scale (°F):** In this scale the freezing temp. is 32°F and boiling point is 212°F.
2. **The Celsius (°C):** The freezing point is 0°C and the boiling point is 100°C
3. **The Kelvin 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.

To convert from...	Use this equation...
Celsius to Fahrenheit	$T_F = \frac{9}{5}T_C + 32$
Fahrenheit to Celsius	$T_C = \frac{5}{9}(T_F - 32)$
Celsius to Kelvin	$T_K = T_C + 273.15$
Kelvin to Celsius	$T_C = T_K - 273.15$
Fahrenheit to Kelvin	$T_K = \frac{5}{9}(T_F - 32) + 273.15$
Kelvin to Fahrenheit	$T_F = \frac{9}{5}(T_K - 273.15) + 32$

Table 1.1 Temperature Conversions

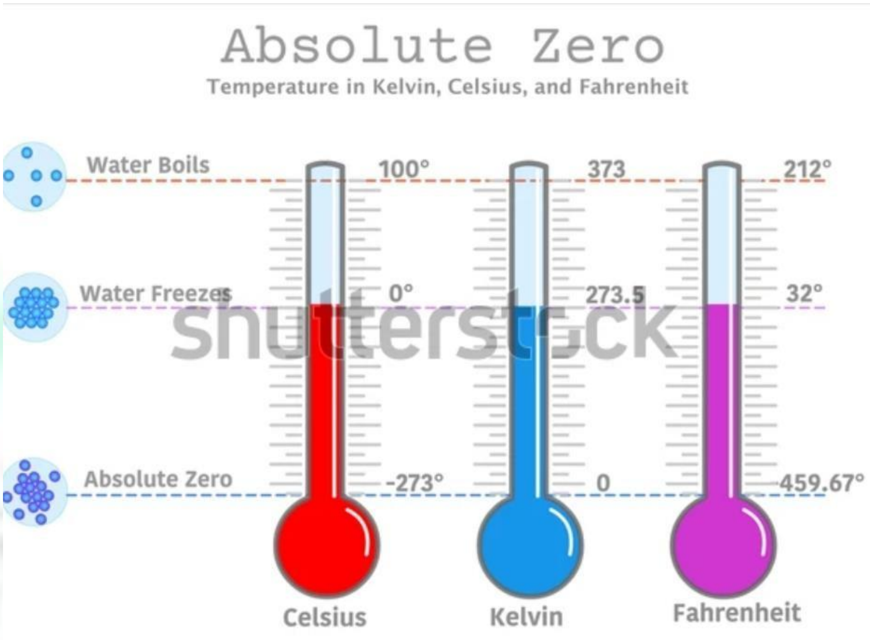


Fig. (1): Temperature Scales

• Types of Thermometers

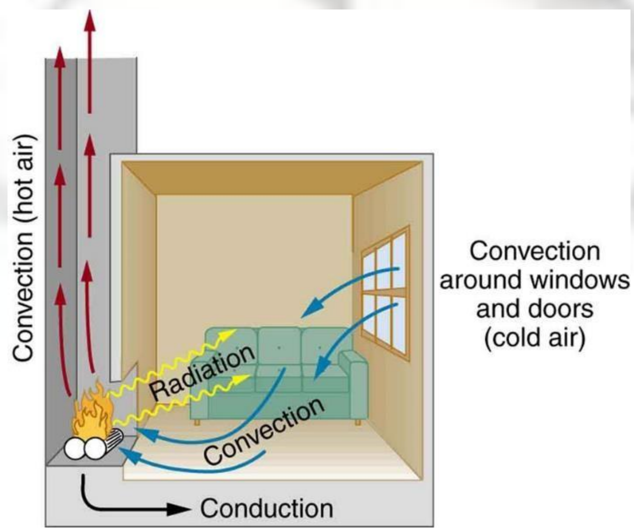
Thermometer, instrument for measuring the temperature of a system. Temperature measurement is important to many fields including manufacturing, meteorology, scientific research, and medicine, etc.

A thermometer contains two essential elements: a sensor that detects a change in temperature and a device that communicates that temperature to the person reading it. Thermometers work by utilizing the physical properties of various substances. For example, liquids and solids expand as they heat up and contract when they cool down. Similarly, gases increase in pressure as they heat up and decrease as they cool down. Using known temperatures of a substance (such as the freezing and boiling points of a liquid), you can make a thermometer that translates these physical changes into a number that we understand as temperature. On this basis, thermometers are classified to:

- The liquid thermometer: The thermometric property is the volume.
- The gas thermometer: The thermometric property is the pressure at a constant volume.
- Electric resistance thermometer: The thermometric property is the electric resistance for small coil of wire
- Thermocouple: The thermometric property is the electromotive force.

Heat Transfer

Whenever there is a temperature difference, heat transfer occurs. Heat transfer may happen rapidly, such as through a cooking pan, or slowly, such as through the walls of an insulated cooler. There are three different heat transfer methods: conduction, convection, and radiation. At times, all three may happen simultaneously. See Figure below



Conduction is heat transfer through stationary matter by physical contact. (The matter is stationary on a macroscopic scale—we know there is thermal motion of the atoms and molecules at any temperature above absolute zero.) Heat transferred between the electric burner of a stove and the bottom of a pan is transferred by conduction.

Convection is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced-air furnace and in weather systems, for example.

Heat transfer by radiation occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of the Earth by the Sun. A less obvious example is thermal radiation from the human body.

Definition Heat Capacity

The amount of energy (or more specifically, the heat (Q)) that must be added to an object to raise its temperature by one degree is known as the heat capacity (Hcap) of that object), then it is given in calories/0 C or in Joules/0 C.

Mathematical expression of Heat Capacity (Hcap):

Change in thermal energy = (Heat capacity) x (Change in Temperature)

$Q = H\ cap \times \Delta T$

$Hcap = Q/\Delta T$

where Q = heat added or subtracted (calories or joules) , H_{cap} = heat capacity (calories/ °C or joules/ °C) ,ΔT = change in temperature = $T_{final} - T_{initial}$ (Celsius degrees).

Example 1

What is the heat capacity of (100 g) of iron if (9000 J) of thermal energy are required to increase the temperature of the iron by (20 ^{o} C)?

Solution:

H_{cap} =? , Q=9000 J, ΔT =20 ^oC

$$Hcap = \frac{Q}{\Delta T}$$

$$Hcap = \frac{9000}{20}$$

$\therefore H_{cap}$ =450 $J/^0C$

The heat capacity of an object depends both on its mass and its chemical composition, suppose m is mass of a system, then the heat capacity per unit mass is called the specific heat capacity we shall denote it by the letter C:

$$C = \frac{\text{Heat capacity (H)}}{m} = \frac{Q}{m\Delta T}$$

$$Q = mC\Delta T$$

We can also express the heat capacity by the number of moles which called molar heat capacity (Cm):

$$C_m = \frac{Q}{n\Delta T}$$

$$Q = nC_m\Delta T$$

The specific heat can be measured under conditions either constant pressure C_p or constant volume C_V.

The unit of specific heat is (Jgm^{-1} deg^{-1}) and the unit of molar heat capacity is ($Jmol^{-1}$ deg^{-1}). The unit of heat is joule and we have another unit that is called Calorie (Cal). 1 Cal =4.186 J It has been found that specific heat capacity for solid material decreases when the temperature decreases and reached to zero when temperature approaches the zero Kelvin.

Then the specific heat does not depend on the size or shape of an object, but only on the material from which it is made. Table (1) Water has a large specific heat of (1 calorie per gram per degree Celsius) or (4.186 Joules per Kilogram degree Celsius). Ice floats because the volume of water increases when it freezes. This is connected to the change in the specific heat of water near 0 ^oC.

Object (Substance)	**Specific Heat (cal/g°C)**
Water	1
Ice	0.480
Soil	0.2 to 0.8, depending on water content
Average for human body	0.83
Aluminum	0.214
Protein	0.4

TABLE(1) Specific Heat for Some objects

- **Note: The heat capacity is an extensive property of a given object, while the specific heat is an intensive property of an object.**

Example 2:

A. **How much thermal energy is needed to raise (200 g) of iron by (10 ^oC)? The specific heat of iron is (0.450 J/g ^oC).**

Solution:

$$Q = C \times m \times \Delta T$$

$$= 0.450 \times 200 \times 10$$

$$Q = 900\ J$$

B. **What is the heat capacity of this object? (H.W)**

Example 3:

How much energy (in calories) is needed to warm up (300 kg) of water from (10 ^{0}C) to a comfortable (37 ^{0}C)? (Use the specific heat of the water is 1(cal/g ^{0}C).

Solution:

$1Kg=1000g=10^3g$, $m=300\times10^3=$

3×10^5 g $T_1=10\ ^0C$, $T_2=37\ ^0C$,

$\Delta T = T_2-T_1= 37-10=27\ ^0C$

$Q = C \times m \times \Delta T$

$=3\times10^5\times1\times27$

$Q =81\times10^5$ cal

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