LECTURE 5

TOPIC: THE THERMODYNAMICS OF THE HUMAN BODY AND THE BIOPHYSICAL FEATURES OF THE THERMAL ENERGY
TIME: 2 HOURS

BASICS OF THERMAL ENERGY, THERMODYNAMICS AND TEMPERATURE
heat - is a form of energy called thermal energy (energy of the inert molecules and the atomic interactions). In the physical attitude this is the connection of the kinetic fractions energy with their potential energy.

Heat always flows from a hot body to a colder one. According to the first law of thermodynamics the change in the internal energy of a substance is equal to the amount of heat absorbed by the substance minus the amount of work done by the substance:
$\delta U = \delta Q - \delta W$
This is really just conservation of energy. Heat is commonly measured in calories, where
1 cal = 4.186 J [Joules]

1 cal - is a needed energy to heat the 1 cm3 of the water to 1 degree in Celsius, in fact from 14.5 degree to 15.5 degree in Celsius.

The amount of random motion of the particles (usually atoms and molecules) of a substance is related to the temperature of that substance. A temperature scale is usually defined by two fixed points and an assumed linear change of some property of a substance like the lenght of a substance or the resistance of that substance. For the Fahrenheit scale, the normal freezing point of water is 32 degree F and the normal boiling point is 212 degree F. For the Celsius scale, these same two points are 0 degree C and 100 degree C. In the Kelvin or absolute temperature scale, they are 273.15 K and 373.15 K.

NORMAL BODY TEMPERATURES
Core temperature and skin temperature
The temperature of the deep tissues of the body - the "core" - remains almost exactly constant, within + or - 1 degree F (+ or - 0.6 degree C), day in and day out except when a person develops a febrile illness. Indeed, a nude person can be exposed to temperatures as low as 55 degree F or as high as 130 degree F in dry air and still maintain an almost constant internal body temperature.
The skin temperature, in contrast to the core temperature, rises and falls with the temperature of the surrounding. This is the temperature that is important when we refer to the ability of the skin to lose heat to the surroundings.
The average normal temperature is generally considered to be between 98 degree F and 98.6 degree F when measured orally and about 1 degree F higher when measured rectally.
Body temperature is controlled by balacing heat production against heat loss. When the rate of heat production in the body is greater than the rate at which heat is being lost, heat builds up in the body and the body temperature rises. Conversely, when heat loss is greater, both body heat and body temperature decrease.
HEAT PRODUCTION
Heat production is a principal by - product of metabolism. The most important factors that determine the rate of heat production are: basal rate of metabolism of all the cells of the body, extra rate of metabolism caused by muscle activity including muscle contractions caused by shivering, extra metabolism caused by the effect of thyroxine hormone and testosterone on

the cells, extra metabolism caused by the effect of epinephrine, norepinephrine, sympathetic stimulation on the cells and extra metabolism caused by increased chemical activity in the cells themselves, especially when the cell temperature increases.

HEAT LOSS

Most of the heat produced in the body is generated in the deep organs, especially in the liver, brain, heart and the skeletal muscles during exercise. Then this heat is transferred from the deeper organs and tissues to the skin, where it is lost to the air and other surroundings. Therefore, the rate at which heat is lost is determined almost entirely by two factors: first, how rapidly heat can be conducted from where it is produced in the body core to the skin and how rapidly heat can then be transferred from the skin to the surroundings.

The complete energy exchange between the organism and the environment is presented as:

$$S = M + \text{or} - C_v + \text{or} - C_d + \text{or} - R - E$$

M - a metabolic warm production

C_v, C_d, R - dismissed or taken energy under the influence of C_v - a convection, C_d - a conduction, R - a radiation

E - an eliminated warm under the influence of the evaporation

In physiology, a naked person in the room temperature conditions (about 21 degrees in Celsius) loses the thermal energy, because of the radiation - 60%, the evaporation - 25%, the conduction - 8% and the convection - 7%.

RADIATION

Loss of heat by radiation means loss in the form of infrared heat rays, a type of electromagnetic wave. Most infrared heat rays that radiate from the body have wavelengths of 5 to 20 micrometers, 10 to 30 times the wavelengths of lights rays. All objects that are not at absolute zero temperature radiate such rays. The human body radiates heat rays in all directions. Heat rays are also being radiated from the walls and other objects towardsthe body. If the temperature of the body is greater than the temperature of the surroundings, a greater quantity of heat is radiated from the body than is radiated to the body.

CONDUCTION

Only one minute quantities of heat are normally lost from the body by direct conduction from the surface of the body to other objects, such a chair or a bed. On the other hand, loss of heat by conduction to air does represent a sizable proportion of the body’s heat loss even under normal conditions. It will be recalled that heat is actually the kinetic energy of molecular motion and the molecules of the skin are continually undergoing vibratory motion. Much of the energy of this motion can be transferred to the air if the air is colder than the skin, thus increasing the velocity of motion of the air molecules. Once the temperature of the air immendiately adjacent to the skin equals the temperature of the skin, no further loss of heat occurs because now an equal amount of heat is conducted from the air to the body. Therefore, conduction of heat from the body to the air is self - limited unless the heated air moves away from the skin, so that new, unheated air is continually brought in contact with the skin.

TISSUE ENERGY CONDUCTION

TYPE OF TISSUE	**COEFFICIENT OF ENERGY CONDUCTING**
skin congestion	0.0035
normal skin	0.0012
muscle congestion	0.0015
normal muscle	0.0012

As a result of the most important factor is a tissue blood flow.

CONVECTION

The removal of heat from the body by convection air currents is commonly called heat loss by convection. Actually the heat must first be conducted to the air and then carried away. A small amount of convection almost always occurs around the body because of the tendency for the air adjacent to the skin to rise as it becomes heated.

EVAPORATION

It is mainly reserved for sweat glands. If human body temperature is on normal level (under 37 degree C) the evaporation of 1 liter sweat loses about 2.4 MJ (580 kcal) from organism. Even when a person is not sweating, water still evaporates insensibly from the skin and lungs at a rate of about 450 to 600 ml per day. This causes continual heat loss at a rate of 12 to 16 cal per hour.

BASAL METABOLIC RATE (BMR) - is a velocity of the organism metabolism, which remains in the physical and psychological comfort and also in the temperature, after at least 12 hours for the last physical effort and after 8 hours sleeping.

It is an energy needed to survive and to protect the basal living functions. The basal metabolic rate is intented for the systems work.

- 1/4 of all for the nervous system
- 1/5 of all for the liver
- 1/15 of all for the kidneys
- 1/15 of all for heart
- the rest energy for the muscles work

The medium day demand for the energy is about 2000 - 3000 kcal. The energy consuption depends on the person lifestyle. Here are examples:

- an athlete (7000 - 10000 kcal a day)
- a coal miner (6000 kcal a day)

THE ENERGY COST OF VARIOUS ACTIVITIES

TYPE OF ACTIVITY	ENERGY COST (kJ/min)
standing	6 - 10
sitting	3 - 7
walking	5 - 22
driving a car	4 - 5
cleaning	23 - 26
volleyball	14 - 39
jogging	25 - 44
skiing	16 - 31

The impact of the thermal energy on the human body

The local activity of the cold factor

The first phase based on the blood vessels spasm situated in the skin (a paleness effect). Next is the second phase, which insists on opening the superficial blood vessels and in fact the hyperaemia reaction. The presented process is known in physiology as hunting response or the Lewis' waves.

The local activity of the warm factor

At the first moment the skin blood vessels are opened. After the arterial hyperaemia the skin tissue begins to become a cyanotic reaction.

The impact of the cold factors on the circulatory system

- a hypovolaemia (a decrease of the circulatory blood volume)
- a bradycardia (a decrease of the functional heart parameters: a cardiac output and ejection volume)
- a decrease of the peripheralvascular resistance
- a blood pressure rise

The impact of the warm factors on the circulatory system

- a hypervolaemia (an increase of the circulatory blood volume)
- a tachycardia (an increase of the functional heart parameters: a cardiac output and ejection volume)
- a decrease of the peripheral vascular resistance
- a blood pressure fall

The impact of the cold factors on the respiratory system

- an increase of the pulmonary minute ventilation
- a respiratory acidosis

The impact of the warm factors on the respiratory system

- an increase (300 - 400%) of the pulmonary minute ventilation
- a hyperventilation
- a respiratory alkalosis

The impact of the thermal factors (both warm and cold) on the metabolism

- a gastric hypersecrection
- a hyperperistalsis in the alimertary tract

The impact of the cold factors on the urinary system
- a hyperuresis (if is a short - time impulse)
- an oliguresis (if is a long - time impulse)

The impact of the warm factors on the urinary system
- a hyperuresis

The impact of the cold factors on the endocrine system
- an increase of the adrenaline, noradrenaline, histamine, rhenine and tyroxinosis level

The impact of the warm factors on the endocrine system
- an increase of the acetylocholine and adenile acid level

In medicine we can use various thermal factors. One of many branches of the physical medicine is a thermotherapy. It is distinguished a few thermal factors, but I would like to present two important ones:

First is a infra - red radiation (irr)

an IRR - is an invisible radiation in the electromagnetic spectrum between the red visible radiation and the microwaves (the wavelenght 770 - 15000 nm)

The radiation is applied by special lamps, the Sollux for instance. The distance between the generator and the skin is about 40 - 50 cm. The emission is caused by the professional light bulbs (power 60 - 1500 W). These bulbs are required in the carbonic fibre, which is able to produce the IR. The strongest bulbs (power 1000 - 1500 W) are equiped in tungsten, which is a thermal resistant.

Next is a microwave diathermy, which insists on tissue overheating. It is used the high frequency elecromagnetic field. It is applied a few kinds of impulses.

DIATHERMY IMPULSES

THE WAVELENGHT	THE FREQUENCY
22.12 m	13.56 MHz
11.02 m	27.12 MHz
7.38 m	40.68 MHz

In physical medicine is also a cryotherapy, which based on the cold factors. It is used many measures like cold packs, ice massage, ice towels, ice slush, cryo air etc.

LITERATURE
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