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## ***Energy***

It is a physical concept related to the ability to do work
All the activities in the body including thinking involve energy changes.
The body basic energy (fuel) source is food.
The food is generally not in a form suitable for direct energy conversion.
It must be chemically changed into molecules that can combine with Oxygen in the body cells, this happens in a process called ***Krebs cycle***.

Under resting (basal) conditions the energy used by the body organs is as follow:

| The organ | % of the used energy |
|---|---|
| Skeletal muscle and heart | 25 |
| Brain | 19 |
| Kidney | 10 |
| Liver and spleen | 27 |

There are two main kinds of energy:-

***1-The potential energy:*** it is associated with the potential of the body to do work under the action of force. In order to a body to have a potential energy it must be subjected to an external force (field).

***P.E (Joules) = mgh***
m= mass of the body (kg), g = 9.8 N/Kg
h= distance (height) (m)

***2- The kinetic energy*:** It is associated with the motion of a body. Newton second law tells as that when a body subjected to a constant force, it will be accelerated at a fixed rate.
The kinetic energy (K.E) of a body of mass (m) traveling at velocity (v) is:

***K.E (joules)=1/2 $mv^2$***

***Conservation of energy in the body***

We can consider the body to be as an ***energy converter*** that is subject to the law of conservation of energy.
Conservation of energy in the body can be expressed by the first ***law of thermodynamics*** in the following equation:

***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***

***Or we can write the first law of thermodynamics as:***
$\Delta U = \Delta Q \pm \Delta W$
***If:*** $\Delta W = 0$
***The body temp. is constant***
***The body continues to lose heat to its surrounding***
$\Delta Q$ ***is (–)ve and*** $\Delta U$ ***is (–)ve***
***That is indicating a decrease in the stored energy***

***The first law of thermodynamics can be also written as:***

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} \pm \frac{\Delta W}{\Delta t}$$

*Where*: $\Delta U / \Delta t$ is the rate of change of stored energy
$\Delta Q / \Delta t$ is the rate of heat loss or gain
$\Delta W / \Delta t$ is the rate of doing work which is the ***dynamic Power***

***Energy changes in the body***

The most widely accepted physics unit for ***energy*** is the (***Joule***); and for ***power*** is ***joule/sec*** or (***Watt***).
In the body:
The unit of ***food energy*** that is used by the physiologist is ***Kilocalories*** (kcal).
And the unit of the ***rate of heat production*** is **kcal/min**.

***The met:*** **It is a convenient unit for expressing the *rate of energy consumption* of the body.**
The ***met*** is defined as ***50 kcal/m$^2$ of body surface area per hour.***
For a normal person ***1 met*** is about equal to the energy consumption under resting conditions

A typical man has about 1.85 m$^2$ of surface area, thus for typical man:
1 met = 1.85 m$^2$ x 50 Kcal /m$^2$·hr = 92 kcal/hr

***Note***: The surface area for a woman is 1.4 m$^2$

1 kcal = 4184 J = 4.2 X 10$^3$ J
1 J = 10$^7$ ergs
1kcal/min = 69.7 1 met = 50 kcal/ m$^2$hr = 58W/m$^2$

***The Metabolic Rate:***
In the oxidation process within the body heat is released as energy of metabolism, **the rate of oxidation is called the *metabolic rate*.**
We will discuss the oxidation of 1 mole of glucose (C6H12O6)

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 + 686\ Kcal$$

Where:
the molecular weight of glucose is180 gm
1 mole of a gas at normal temp. And pressure has a volume of 22.4 liters.
- Kcals of energy released per gm of glucose =
686/ 180= 3.8
- Kcals released per liter of O2 used =
686/ 22.4 x 6 = 5.1
- Liters of O2 per gm of glucose =
6 x 22.4/ 180 = 0.75
- Liters of Co2 per gm of glucose =
6 x 22.4/ 180 = 0.75

$$\textbf{The respiratory ratio} = \frac{\textbf{Liters of } O_2 \textbf{ used}}{\textbf{Liters of } CO_2 \textbf{ Produced}}$$

**Typical Energy Relationship for some Foods and Fuels**

| Food or Fuel | Energy Released per liter of $O_2$ used (kcal/ Liter) | Caloric Value (kcal/ gm) |
|---|---|---|
| **Carbohydrates** | **5.3** | **4.1** |
| **Proteins** | **4.3** | **4.1** |
| **Fats** | **4.7** | **9.3** |
| **Typical Diet** | **4.8 - 5** | **-** |

## The Basal Metabolic Rate:

*BMR*: It is the amount of energy needed to perform minimal body functions ( such as breathing and pumping the blood through the arteries).

### *The BMR depends on:*

- The Temp.
- The thyroid function.
- The mass of the body fig (5.1).

## *The work and Power:*

The work is defined as a force (F) moved through a distance ($\Delta x$)

$$\Delta W\ (J) = F\ \Delta x \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

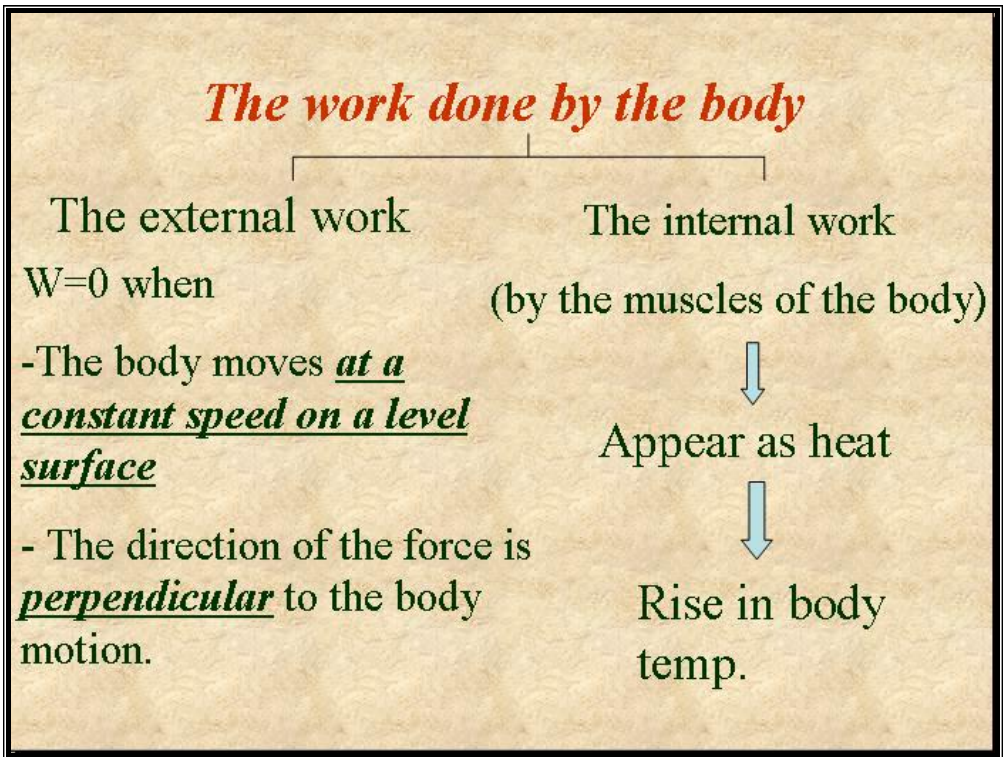
Where F = the force in (Neutron)
$\Delta x$ = the distance in (meter)

**The work, w (J) = m g h**

Where m = the mass in (Kg)
g = 9.8 N/ Kg
h = the vertical height in (m)

**In the body: The stored energy converts into mechanical work**

***When does the work of the body equal zero?***




We can measure the external work done and the power by an ***Ergometer***.

The ergometer is a fixed bicycle that can be adjusted to vary the amount of resistance to the turning of the pedals.

The oxygen consumed can also be measured during this activity. The total food energy can be calculated since 4.8 – 5 Kcal for each liter of oxygen consumed.

## ***<u>The Efficiency:</u>***

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

$$\textbf{Efficiency} = \frac{\textbf{The work done (output)}}{\textbf{The energy consumed (input)}} \times 100$$

***Cycling*** is one of our most efficient activities, for a trained cyclist the efficiency approaches <u>20%</u> with an external power production of <u>370W</u> and a metabolic rate of <u>1850W</u> (table 5.4)

# *Aerobic and anaerobic phases of work*

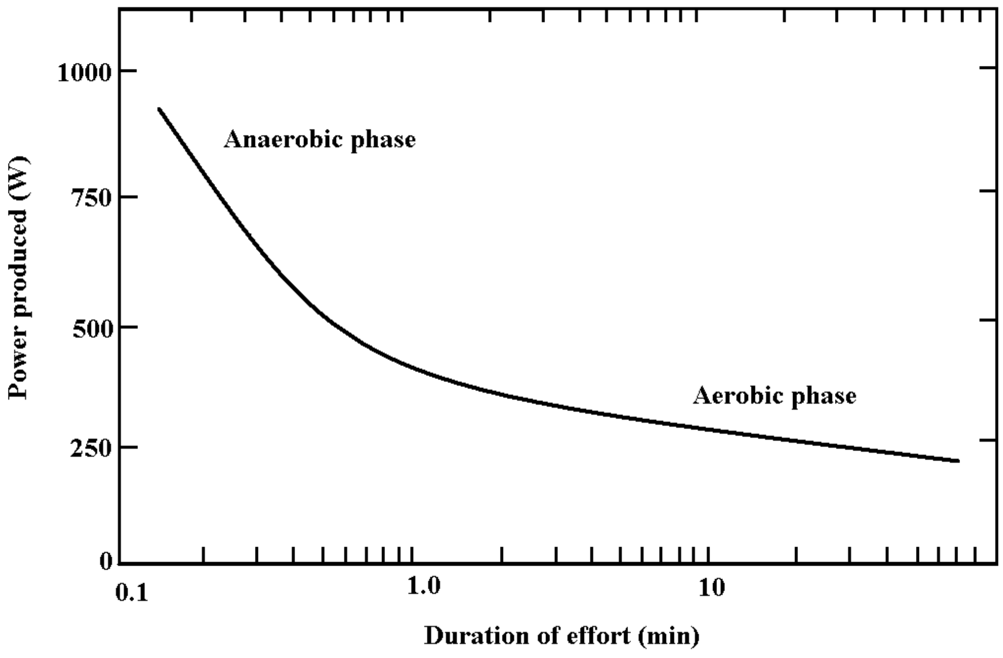
## For long term effort

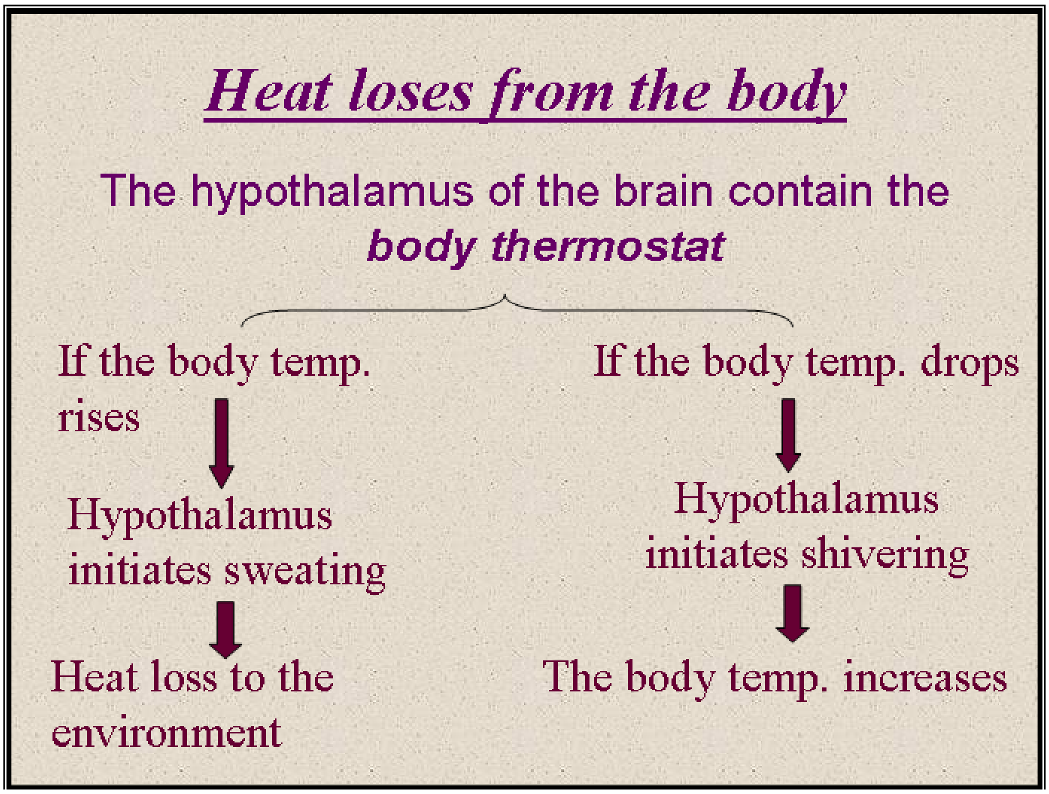
Long term power is proportional to the max. rate of O2 consumption in the working muscles. For a healthy man this consumption is typically 50ml/Kg of body weight each minute ***(aerobic work)***

## For short term effort

The body supplies instantaneous energy by splitting energy – rich phosphates and glycogen leaving an oxygen deficit in the body, this process lasts about 1 min. ***(anaerobic work)***

**Heat losses from the body**






## *The main heat loss mechanisms in the body are:*

1- Radiation.
2- Convection.
3- Respiration, and
4- Evaporation (perspiration)

The actual amount of heat lost by these four mechanisms is depending on:
- Temperature of surroundings
- Motion of air
- Humidity
- Physical activity of the body
- Amount of body (surface area) exposed to air
- Amount of body insulated (clothes and fat)

### *1- Heat loss by Radiation:*

**a. The amount of energy emitted by the body is proportional to the Temperature raised to power four. [ W $\alpha$ $T^4$ ]**

**The power (W) $\alpha$ Absolute temperature ($T^4$)]…............................... ( 1 )**

**b. The difference between energy radiated by the body skin and the absorbed by the surrounding walls:**

**$H_r = K_r A_r\, e\, (T_s – T_w)$……………………..................................... ( 2 )**

**K = constant = 5 kcal/m$^2$ hr. ºC**

### *2- Heat loss by Convection:*

Heat loss due to convection is given by:

$H_c = K_c A_c (T_s – T_a)$

$K_c$ = it is a constant depends upon the movement of air

$T_a$ = Temp. of air

$T_s$ = Temp. of skin

$A_c$ = the surface area

### *3- Heat loss by Evaporation:*

***i. Heat loss by evaporation of sweat:***

a. Under extreme conditions of heat and exercise, a man may sweat more than 1 liter of liquid/hr.

b. The a mount of evaporation depend upon

1. Air movement
2. Humidity

c. There is some heat loss due to perspiration even when the body doesn't feel sweaty; it is about 7% of the body heat loss

***ii. Heat loss by moisture in the lungs***

a. When we breathe in air, it becomes saturated with water.

b. The additional water in the expired air carries the same amount of heat as it evaporated from the skin.

c. Under typical conditions, the total respiratory heat loss is ≈ 14% of the body heat loss.