ENERGY, WORK, AND POWER OF THE BODY

Energy is a property of objects which can be transferred to other objects or converted into different forms but never created or destroyed.

Work, in physics, measure of energy transfer that occurs when an object is moved over a distance by an external force at least part of which is applied in the direction of the displacement.

$$\text{Work} = \text{force} * \text{distance}.$$

Power is the rate of doing work, the amount of energy transferred per unit time. Having no direction, it is a scalar quantity. In the International System of Units, the unit of power is the joule per second (J/s), known as the watt

$$\text{Power} = \frac{work}{time}$$

All activities of the body including thinking, involve energy changes.
The conversion of the energy into work occurs continuously in the body.

Under resting conditions the body energy is being used as follows.

1. 27% by the liver and spleen.
2. 25% by the skeletal muscles.
3. 19% by the brain.
4. 10% by the kidney.

The body's basic energy (fuel) source is **food;** the food must be chemically changed by the body molecules that can combine with oxygen in the body.

Extra food energy will be stored mainly as **fat.**

The body uses the food energy to:-

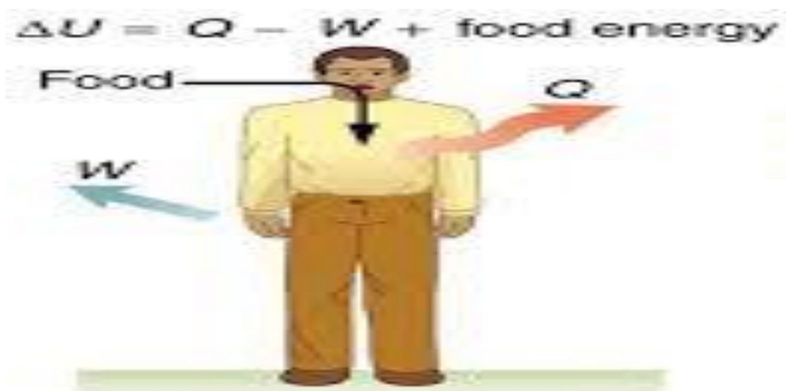
1. Operate its various organs.
2. Maintain a constant body temperature.
3. Do external work e.g. lifting.

Conservation of energy in the body

There are continuous energy changes in the body both, when it is doing work and when it is not.
We can write the first law of thermodynamics as:

$$\Delta U = \Delta Q - \Delta W \cdots\cdots \quad (1)$$

Where:
ΔU: is the change in stored energy.
ΔQ: is the heat lost or gained.
ΔW: is the work done by the body.



If a body has no work ($\Delta W=0$) and at constant temperature continues to lose heat to its surrounding, and ΔQ is negative. Therefore, ΔU is also is negative, indication a decrease in stored energy.

The rate of change of energy is given by:

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} - \frac{\Delta W}{\Delta t} \ldots\ldots\ldots 2$$

Where:
ΔU/Δt: Rate of change of stored energy.
ΔQ/Δt: Rate of heat loss or gain.
ΔW/Δt: Rate of doing work.

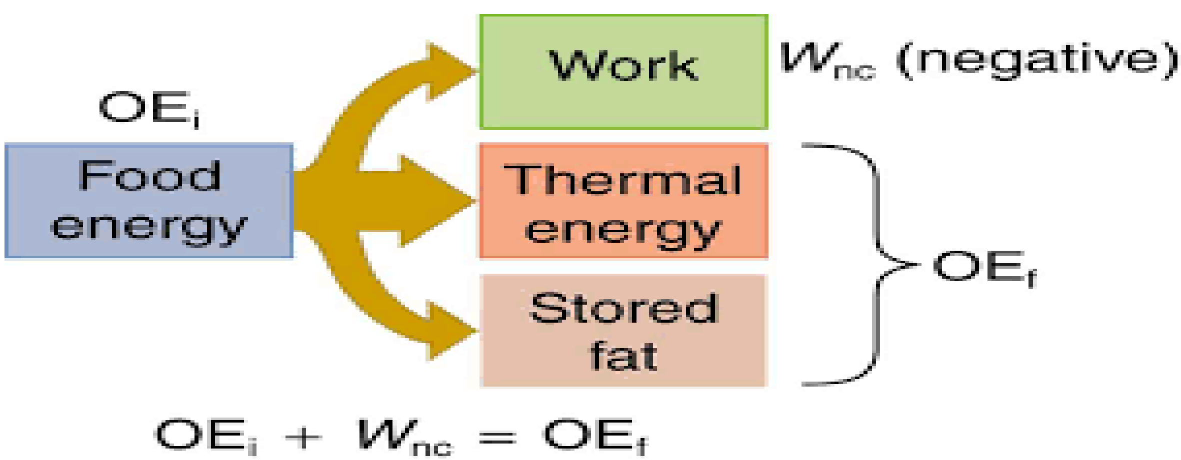
<u>The body's basic source of energy is the food energy;</u> it must be chemically changed by the body to make molecules that can combine with oxygen in the body's cells.

Energy changes in the body

The energy value of food referred to by nutritionists as a Calorie is actually akilocalorie; thus a diet of 2500 C/day is 2500 Kcal/day.

- Energy unit is joule or erg.
- Power is given in joule per second or watts (W).

A convenient unit for expressing the rate of energy consumption of the body **met.**
Met: is called the metabolic rate (MR) it equal to 50 Kcal/m² of body surface per hour.
<u>For a normal person 1 met is about equal to the energy consumption under resting condition.</u>



A typical man has <u>about 1.85m²</u> of surface area (woman has about <u>1.4m²)</u> and thus for a typical man <u>1 met ≈ 92 Kcal/hr. or 107 W</u>. and in woman 1 <u>met ≈70 Kcal/hr</u>.

1 Kcal =4184j.
1 J =10^{7} ergs.
1 met =50 Kcal/m² hr.

➢ OXYGEN CONSUMPTION:-

Food is oxidized; in oxidation by combustion heat is released. In the oxidation process within the body released as energy of metabolism. The rate oxidation is called the metabolic rate.

Let us consider the oxidation of glucose, a common form of sugar used for intravenous feeding.

The oxidation equation for 1 mole of glucose is:-

$C_6 H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 686$ Kcal
1 mole 6 mole 6 mole 6 mole releasing (heat energy)
1 (180 g) 6 (32 g) 6 (18 g) 6 (44 g)

1 mole of a gas at normal temperature and pressure has a volume of 22.4 liter.

This table for typical energy relationships for some foods.

Food or fuel	energy released per liter Of O_2 used (Kcal/liter)	Caloric value (Kcal/g)
Carbohydrates	**5.3**	**4.1**
Proteins	**4.3**	**4.1**
Fats	**4.7**	**9.3**
Typical diet	**4.8-5.0**	—
Gasoline	—	**11.4**
Coal	—	**8.0**
Wood (pine)	—	**4.5**

When the body is completely at rest, it will have the lowest rate of energy consumption this is called the basal metabolic rate (BMR), which is the amount of energy needed to perform minimal body functions (such as breathing and pumping the blood through the arteries) under resting conditions, and for typical person 92 Kcal/hr.

BMR depends on sex, age, height, and weight; it depends primarily on *thyroid function*, overactive thyroid gives higher BMR.

Since the energy used for basal metabolism becomes heat which is mainly dissipated from the skin, so the basal rate is related to the surface area or to the mass of the body. The **BMR depends** to large extent on the body temp., for an increase of 1°C it will change by 10% in the metabolic rate, so for 3°C the change will be 30% greater than normal. Similarly, if the body temp. drops 3°C below normal, the metabolic rate decreases by about 30%. For this reason hibernating body at low body temp. will reduce the metabolic rate very much.

- A person who is taking food energy equivalent to his BMR plus his other physical activities will keep on constant weight.
- Less food will cause weight loss and for longer time cause starvation.
- Excess food of body needs will cause food storage and increase in weight.
- BMR is sometimes determined from oxygen consumption when resting, we can also estimate the food energy used in various physical activities by measuring the oxygen consumption, table (2) shows some typical values for various activities.

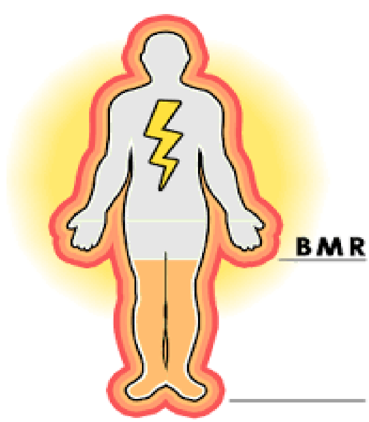


Table 5.2. Oxygen Cost of Everyday Activities for a Man with a Surface Area of 1.75 m^2, Height of 175 cm, and Mass of 76 kg[a]

Activity	O_2 Consumption (liters/min)	Equivalent Heat Production kcal/min	Equivalent Heat Production W	Energy Consumption (mets—50 kcal/m² hr)
Sleeping	0.24	1.2	83	0.82
Sitting at rest	0.34	1.7	120	1.15
Standing relaxed	0.36	1.8	125	1.25
Riding in automobile	0.40	2.0	140	1.35
Sitting at lecture (awake)	0.60	3.0	210	2.05
Walking slow (4.8 km/hr)	0.76	3.8	265	2.60
Cycling at 13–17.7 km/hr	1.14	5.7	400	3.90
Playing tennis	1.26	6.3	440	4.30
Swimming breaststroke (1.6 km/hr)	1.36	6.8	475	4.65
Skating at 14.5 km/hr	1.56	7.8	545	5.35
Climbing stairs at 116 steps/min	1.96	9.8	685	6.70
Cycling at 21.3 km/hr	2.00	10.0	700	6.85
Playing basketball	2.28	11.4	800	7.80
Harvard Step Test[b]	3.22	16.1	1120	11.05

[a] Adapted from P. Webb, in J. F. Parker and V. R. West (Eds.), *Bioastronautics Data Book*, National Aeronautics and Space Administration, Washington, D.C., 1973, pp. 859–861.
[b] A test in which the subject steps up and down a 40 cm step 30 times/min for 5 min.

Work and power

Chemical energy stored in the body is converted into external mechanical work as well as into life-preserving functions.

Mechanical work is usually defined by

$$\Delta w = F . \Delta x$$

Where F : is the force on the same line of displacement x, or it can be also written as:

$$(\Delta w = F\ \Delta x \cos \Theta)$$

Where Ө : is the angle between F and the direction of movement, the power is work per unit time.

$$P = \Delta w / \Delta t = F\ \Delta x / \Delta t = F\ v$$

Where v is the velocity

When the force is perpendicular to the displacement 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 = mgh, the efficiency of human body is

E = work done/ energy consumed

Efficiency is usually lowest at low power but can increase to 20% for trained individuals in activities such as cycling and rowing

The maximum work capacity of the body is variable, for short period of time the body can perform at very high power levels, (like that long term power is proportional to the maximum rate of oxygen consumption in the working muscles). It is found that long term power is proportional to the maximum rate of oxygen consumption in the working muscles.

For healthy man this consumption is 50ml/kg m of body weight each minute. The body can supply an instantaneous energy for short term power needs, this can be done by splitting energy rich-phosphates and glycogen leaving an oxygen deficit in the body. This process can only last about a minute and is called ***anaerobic*** (without oxygen) .For longer term work requires oxygen **aerobic.**

Heat loses from the body

The body losses heat mainly ***by radiation, convection, and evaporation***, all these processes can take place in the skin temp. The evaporation of perspiration from the skin can cool down the skin by absorbing the latent heat of evaporation from it.

<u>Evaporation</u> takes place also in breathing causing cooling effect. If the air is cold it will also cool down the body. Eating and drinking cold or hot food can also decrease or increase the body temp. The body temp. is kept constant for this reason the hypothalamus in the brain can control the body temp

. The heat loses from the body depends on many factors:

1- The temp. of the surroundings.

2-Humidity

3-Motion of the air

4-The physical activity of the body

5-The amount of the body exposed

6-The amount of the insulation of the body (like clothes and fat).