Al-Mustaqbal University

College of Technology and Health Sciences

Medical physics Department

Medical Physics

First Semester

3rd stage

Lesson 6

Energy, Work and Power of the body

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Introduction

Our own bodies, like all living organisms, are energy conversion machines. All activities of the body, including thinking involve energy changes. Under resting (basal) conditions, the following percentage of the body's energy is consumed;

- 25% is being used by heart, muscles and skeletal system.
- 19% is being used by the brain.
- 10% is being used by the kidneys.
- 27% is being used by the liver and spleen.

Of course, during vigorous exercise, the energy consumption of the skeletal muscles and heart increase markedly.

The body uses the food energy to;

1. Operate the various organs.
2. Maintain a constant body temperature.
3. Doing external work, such us lifting heavy objects.

Conservation of energy in the body

There are continuous energy changes in the body and the first thermodynamic law that describe this change could be written as;

$$\Delta U = \Delta Q - \Delta W$$

Where; ΔU is the change in stored energy, ΔQ is the heat lost and ΔW is the work done.

Energy changes in the body

In the oxidation process within the body cells, heat is released as energy of metabolism. The rate of this oxidation is called the ***metabolic rate***.

The oxidation equation for 1 mole (180g) of glucose (C6H12O6) is;

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 686kcal$$

1kcal = 4184Joule

Joule = N.m

That means, 180 g of glucose releases 686 kcal. In other words;

$$kilocalories\ of\ energy\ released\ per\ gram\ of\ glucose = \frac{686}{180} = 3.8$$

Similar calculations can be done for different kinds of fuel as follows;

Food	**Kcal/g**
Carbohydrates	4.1
Proteins	4.1
Fats	9.3

In fact, not all the energy calculated is available to the body because part is lost in incomplete combustion. The unburned products are released in feces and urine.

The body is quite efficient at extracting energy from food. For example, the energy remaining in normal feces is only 5% of the total energy.

Basal Metabolic Rate (BMR)

When completely at rest, a person consumes energy at rate of about 92 kcal/hour, or 107W, or about 1 met. This lowest rate is called ***basal metabolic rate (BMR),*** *is the amount of energy needed to perform minimal body functions (such us breathing and pumping blood and so on) under resting condition.*

Athletes have a greater BMR due to this last factor.
Energy consumption is directly proportional to oxygen consumption because the digestive process is basically one of oxidizing food. We can measure the energy people use during various activities by measuring their oxygen use.

The BMR depends primarily upon:

Thyroid function.

A person with an overactive thyroid has higher BMR than a person with normal thyroid function.

Body mass

The energy used for BMR becomes heat which is dissipated from the skin. So, the BMR related to the mass of the body. Figure 1 represents a plot of BMR (kcal/day) for various animals of different mass.

Body temperature

If the body temperature changes by 1 ^{o}C, there is a change of about 10% in the metabolic rate.

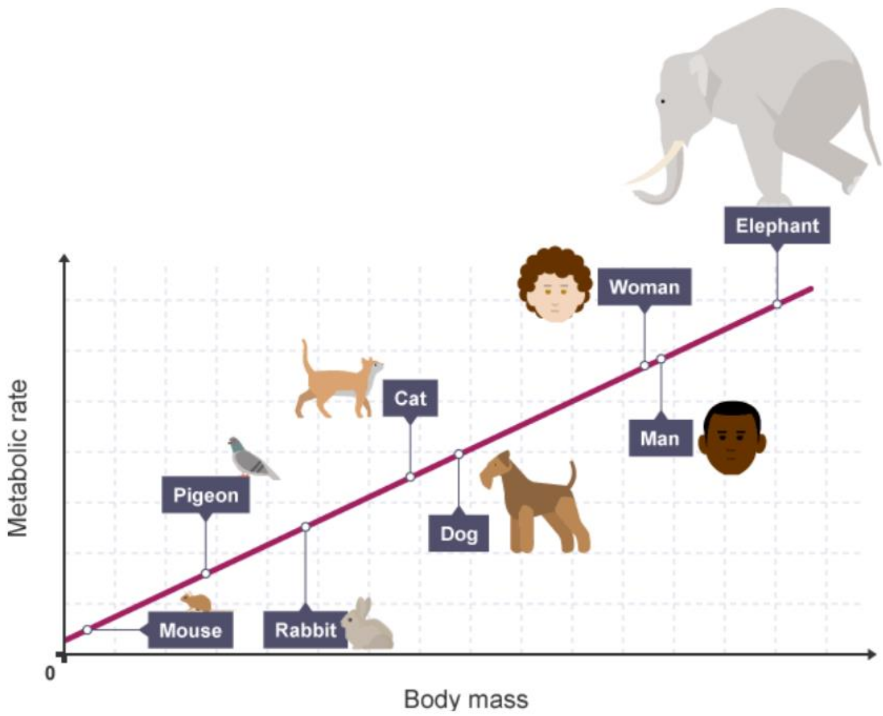


Figure 1. Body mass vs. BMR

Work and Power

The external work ΔW is defined as;

$$\Delta W = F\Delta x$$

Where F is the force and Δx is the distance.

The force and the motion must be in the same direction.

The rate of doing work is the power p.

Thus;

$$p = \frac{\Delta W}{\Delta t} = \frac{F\Delta x}{\Delta t} = Fv$$

Obviously, external work is done when a person is climbing a hill or walking up stairs.

When a man is walking or running at a constant speed on a level surface, most of the forces act in the direction perpendicular to his motion. Thus, the external work done by him is zero.

However, his muscles are doing internal work which appears as heat in the muscle and causes a rise in its temperature.

This additional heat in the muscle is removed by blood flowing through the muscle, by conduction to the skin and by sweating.

The efficiency of human body as a machine can be obtained from the following;

$$\epsilon = \frac{work\ done}{energy\ consumed}$$

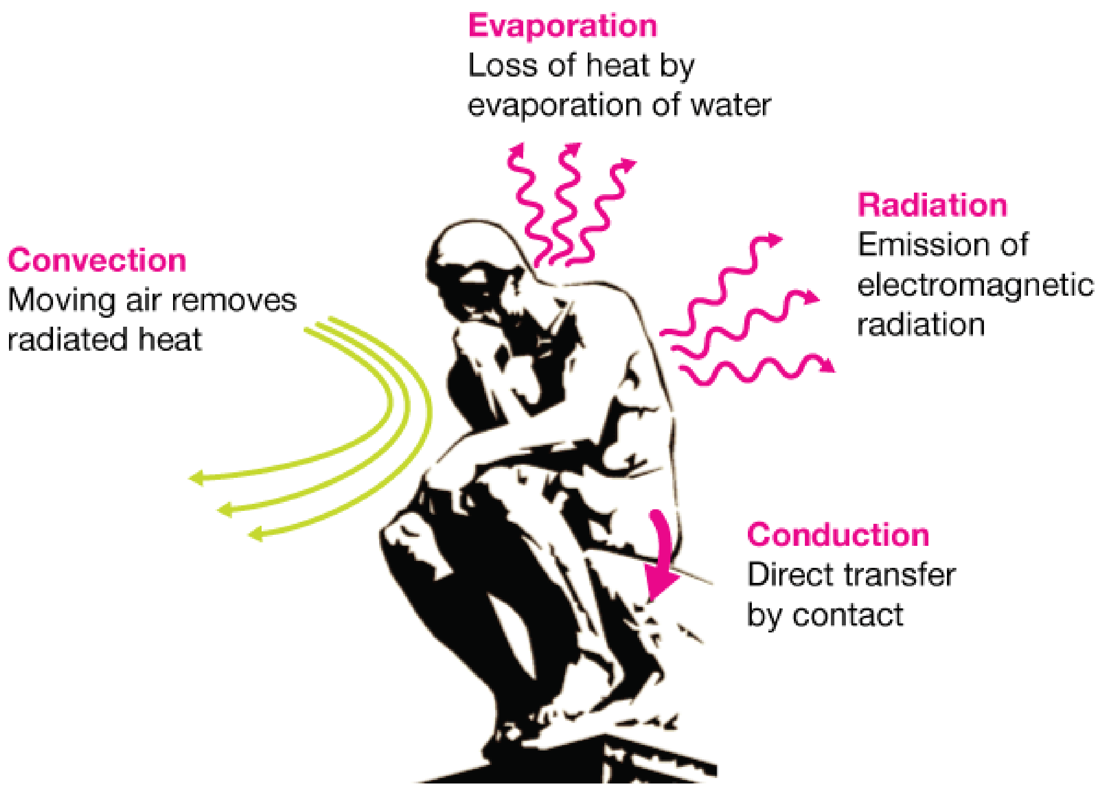
Efficiency is low at low power but can increase to 20% for trained individuals in activities such as cycling and rowing.

Heat losses from the body

Birds and mammals are warm-blooded while other animals are cold-blooded. Birds and mammals have mechanisms to keep their body temperature constant. Constant temperature permit metabolic processes to proceed at constant rate and remain active even in cold climate.

The heat generated in the organs and tissues can be removed by;

- Evaporation
- Convection
- Radiation
- Conduction
- Taking air to the lungs
- Eating or drinking cold food



Exercises

1 **At rest, heart, muscles and skeletal system consume … from the total energy**

(a) 2.5%

(b) 3.5%

(c) 25%

(d) 34%

(e) 50%

2 **First thermodynamic law could be written as**

(a) $\Delta Q = \Delta U - \Delta W$

(b) $\Delta W = \Delta Q - \Delta U$

(c) $\Delta U = \Delta P - \Delta W$

(d) $\Delta P = \Delta Q - \Delta W$

(e) $\Delta U = \Delta Q - \Delta W$

3 **The rate of this oxidation inside human cell is called the**

(a) Metabolic rate

(b) Work rate

(c) Energy consumption rate

(d) Power rate

(e) Heat rate

4 **One gram of proteins can produce energy of ….. kcal**

(a) 40

(b) 30

(c) 20.2

(d) 4.1

(e) 6.1

5 **When a man is walking or running at a constant speed on a level surface, the external work equals**

(a) 100

(b) 1

(c) 0

(d) 2

(e) 200