Energy, Heat, Work
and
Power of the Body

By

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Energy

- Energy is a property of objects which can be transferred to other objects or converted into different forms, but cannot be created or destroyed.
- All activities of the body, including thinking, involve energy consumption.
- When resting body's energy consumption-
  - Skeletal Muscles and the Heart – 25%
  - The Brain – 19%
  - The Kidneys – 10%
  - Liver and spleen – 27%
  - A small percent of food energy excrete in feces and urine- 5%

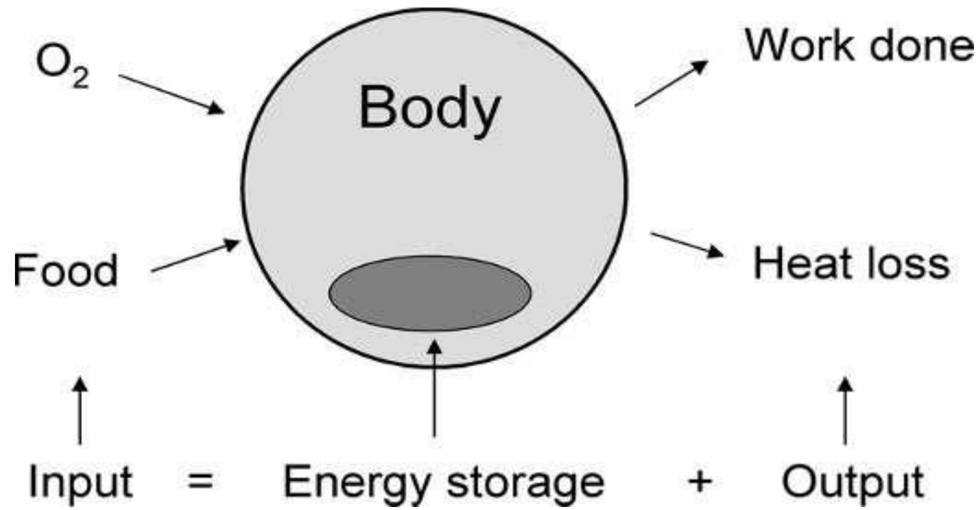
Metabolism

- **Food is the basic source of energy (fuel) for the body.**

- **Body works as a converter to change food chemically by making molecules which combine with Oxygen in cells.**

- **The processes involved in the energy intake, storage, and use by the body are collectively called the Metabolism.**
- **Extra food energy will be stored as fat.**
- **External heat energy from environment can help maintain the body temp., but it has no use in body function.**

Conservation of Energy



Change in stored energy in the body (i.e., food energy, body fat, body heat) → heat lost from body+Work Done

- This is similar to the first law of thermodynamic:-

$$\Delta Q = \Delta u + \Delta w$$

Where

ΔQ is the change of quantity of heat of the system.

- Δu is the change in the internal or stored energy.
- Δw is the work done.

This can be written as

$$\Delta u = \Delta Q - \Delta w$$

A body doing no work ($\Delta w=0$) and at constant temp. continues to lose heat to its surroundings, and ΔQ is negative. Therefore, Δu is also negative, indicating a decrease in stored energy.

The rate of change of their variables is just taken per unit time (by dividing on Δt) .

$$\Delta u / \Delta t = \Delta Q/\Delta t - \Delta w/\Delta t$$

Energy change in the body

1cal= 4.184J or 1Kcal=4184J

The power is defined as energy or work per unit time =J/s=watt.

- In the oxidation process within the body, heat is produced as energy of metabolism
- The rate of oxidation is called metabolic rate

For example

the oxidation of one mole of glucose can be shown as:

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

1 mole	6 mole	6 mole	6 mole	
180g	192g	108g	264g	

Co2 and O2 are gases (1 mole of a gas at normal temp. and pressure has a volume 22.4 liters)

From the above equation we can calculate useful quantities for glucose metabolism:

- Kcal of energy released/g of fuel (glucose) =686/180=3.8
- Kcal of energy released/L of O_2used=686/ (22.4×6) =5.1
- Liters of O_2 used/g of fuel glucose = (22.4×6)/180=0.75
- Liters of CO_2 produced /g of fuel glucose= (22.4×6)/180=0.75

So the ratio of moles of CO_2 produced to moles of O_2 used, called the (respiratory quotient) R=1→ No. of moles of CO_2/No. of moles of O_2 =1

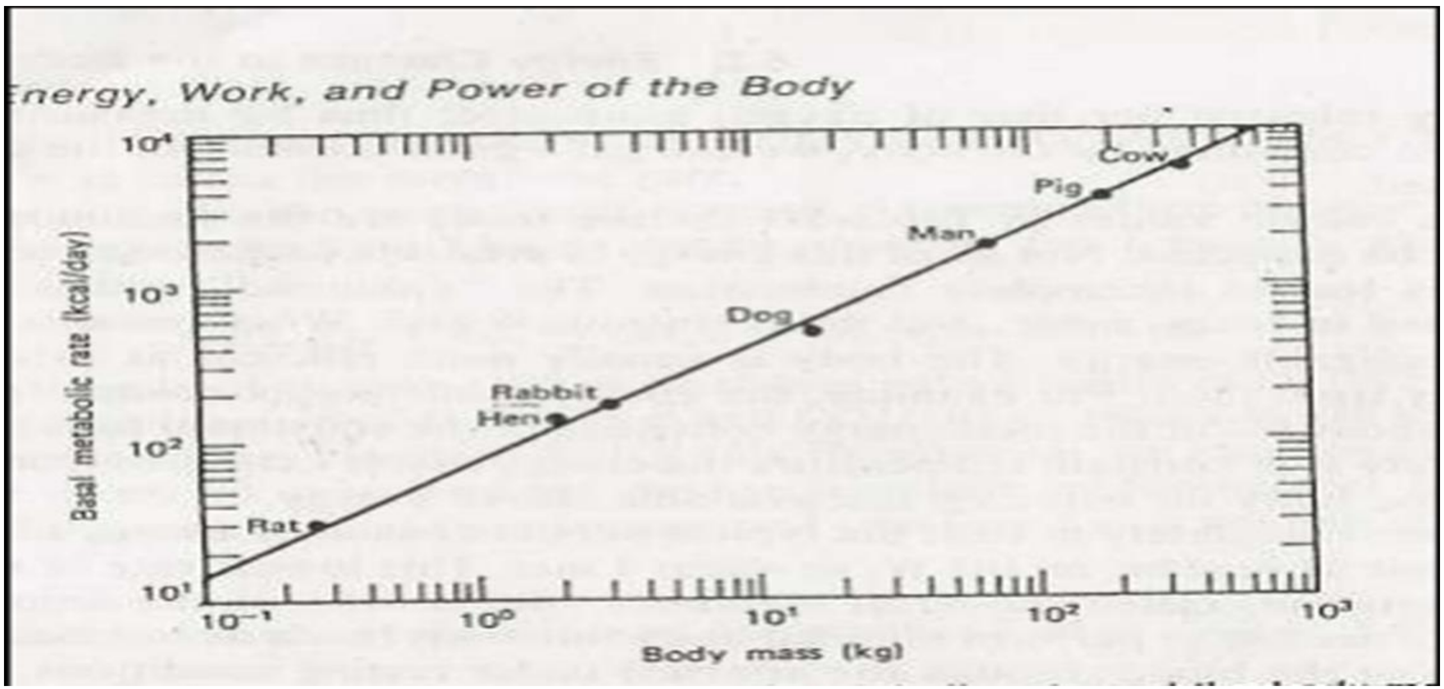
Similar calculation can be done for fats, proteins, and other Carbohydrates.

- When the body is completely at rest, it will have the lowest rate of energy consumption this is called the basal metabolic Rate (BMR)
- BMR is the amount of energy needed to perform minimal body functions (such as breathing and pumping the blood through the arteries)

Table 5.1. Typical Energy Relationships for Some Foods and Fuels

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

- under resting conditions, and for typical person 92 Kcal/hr ≈ 107w or about 1 met (met is 50 Kcal/m2 hr). m2: body surface area
- BMR depends on sex, age, height, and weight; it depends primarily on thyroid function, overactive thyroid gives higher BMR.
- BMR related to the surface area or to the mass of the body.



- BMR depends to large extent on body temp.

- **A man who is taking food energy equivalent to his BMR plus his other physical activities will keep on constant weight.**

● Less food will cause weight lose 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

Example: Suppose you wish to lose 4.54kg either through physical activity or by dieting.

1-How long would you have to work at an activity of 15Kcal/min to lose 4.54kg of fat?

From (table (5.1) page 90 Ch.5 in Medical physics by John R. Cameron) maximum of 9.3kcal/g of fat, if you worked for T minutes, then

T(15kcal/min)=(4.54x103g)(9.3kcal/g)

=4.2x104kcal

T=2800 min≈47hr

2- It is much easier to lose weight by reducing your food intake. If you normally use 2500kcal/day, how long must you diet at 2000kcal/day to lose 4.54kg of fat?

T= (energy of 4.54kg fat/energy deficit per day)

4.2X104kcal / 5x102kcal/day ≈84 days

Work and power

- Chemical energy stored in the body is converted into external mechanical work
- 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 Θ is the angle between F and the direction of movement

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

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 shortd period of time the body can perform at very high power levels,(like running very fast but it is more limited for longer periods)
- 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