<u>Principle of the first law of thermodynamic</u> 1:

For closed system or fixed mass the 1st law can be expressed as :

Net energy transfer to (or from) the system as heat or work =net increase (or decrease) in the total energy of the system

$$Q - W = \Delta E \quad ....(1)$$

Where : Q=Net heat transfer across system boundary $\left(\sum Q_{in} - \sum Q_{out}\right)$

W=Net work done in all forms $\left(\sum W_{Out} - \sum W_{in}\right)$

ΔE=net change in total energy of system $\left(E_2 - E_1\right)$

The total energy (E) of system is consist of three parts :

$$\Delta E = \Delta U + \Delta K.E + \Delta P.E \quad ....(2)$$

Where : ΔU :Internal energy

K.E: Kinetic energy

P.E: Potential energy

Substitute this relation in eq.(1) we obtain :

$$Q - W = \Delta U + \Delta K.E + \Delta P.E \quad ....(3)$$

Where $\Delta U = M\left(U_2 - U_1\right)$

$$\Delta K.E = \frac{1}{2} M\left(V_2^2 - V_1^2\right)$$

$$\Delta P.E = mg\left(Z_2 - Z_1\right)$$

For stationary closed system, the change kinetic energy and potential energy are neglected .

That is : $\Delta K.E = \Delta P.E = 0$

The first law of the thermodynamic reduce to :

$$Q - W = \Delta U \quad ....(4)$$

Sometimes it`s convenient to consider the work term in 2 parts $(W_{other} - W_{boundary})$, W_{other} all forms of work except boundary work .

Then the first law will take the following form :

$$Q - W_{other} - W_{boudary} = \Delta E \qquad ....(5)$$

For a cyclic process, the initial and final states are identical, therefore :

$$\Delta E = E_2 - E_1 = 0$$

Then the first law will be :

$$Q - W = 0$$
$$W_{net} = Q_{net}$$

<u>Adiabatic processes</u> : in this process no change in energy . the quantity thermal energy is constant .

$$Q_1 = Q_2$$

when Q is constant .

dQ=zero .

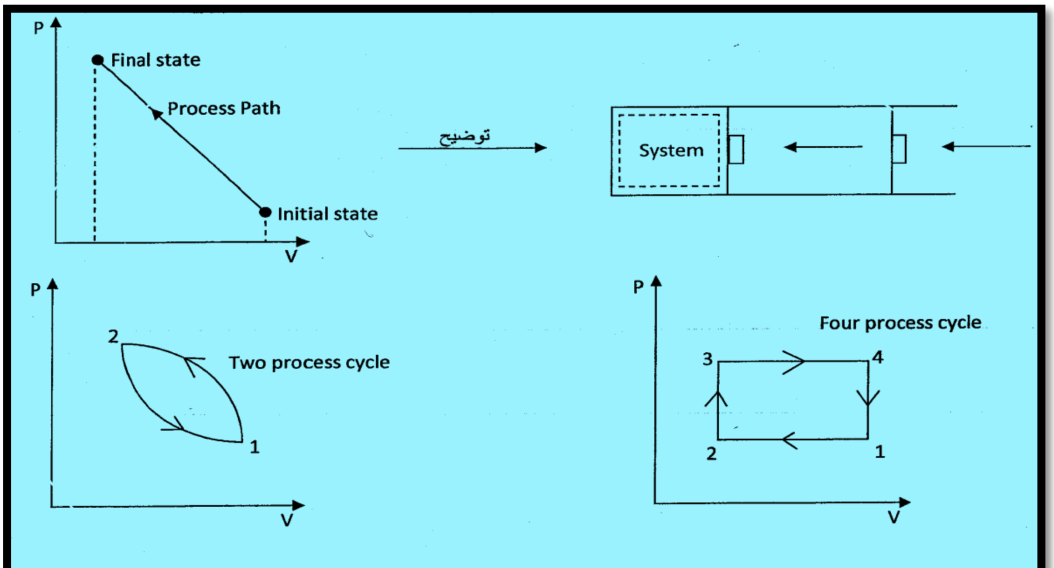

Figure Shows two ideal thermodynamic cycle

Metabolism: Energy, Heat, Work, and Power of the Body

We cannot function without energy. The processes involved in the energy intake, storage, and use by the body are collectively called the **metabolism;** the discipline describing this area is sometimes called *bioenergetics*. More generally, metabolism is any energy usage by the body, and is the sum of all chemical processes performed by the cells in order to keep the body alive. ***For a complete picture we need to include input of food and oxygen to the body, energy storage, and loss of energy by the body through the loss of heat and work done by the body, as is shown in Fig.1.***

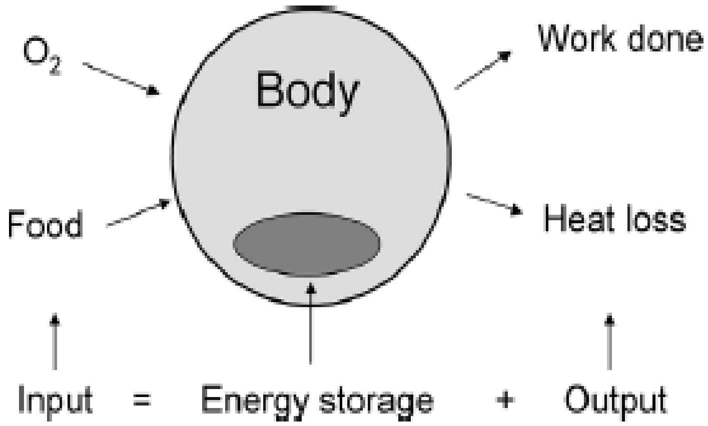

Fig. 6.1. Energy flow into and from the body

Metabolic processes can be divided into catabolic and anabolic reactions. In *catabolic* reactions complex molecules are broken into simple ones, for purposes such as energy usage. In *anabolic* reactions simple molecules are combined to form complex ones, for purposes such as energy storage.

The body uses food to

(1) operate organs .

(2) maintain a constant temperature by using some of the heat that is generated by operating the organs (while the rest is rejected) .

(3) do external work .

(4) build a stored energy supply (fat) for later needs. About 5–10% of the food energy intake is excreted in the feces and urine.

Conservation of Energy and Heat Flow

Let us briefly review some of the basics of the thermodynamics and heat flow physics that we will use in this discussion.

The First Law of Thermodynamics is essentially the conservation of energy in any process. In reference to the body, it can be stated as

$$\Delta U = Q - W, \qquad (1)$$

where ΔU is the change in stored energy, Q is the heat flow to the body, and W is the mechanical work done by the body. The stored energy decreases, $\Delta U < 0$, when there is heat flow from the body, $Q < 0$, and work done by the body, $W > 0$. This type of work is purely mechanical in nature, such as in moving and lifting items. Heat flow includes heat production from the metabolism (Q_{met}) and heat loss (Q_{loss}) from radiation, convection, conduction, and evaporation. We can express :

$$Q = Q_{met} + Q_{loss} ,$$

where metabolic heat production is positive and a negative Q_{loss} indicates heat flow away from the body, so

$$\Delta U = Q_{met} + Q_{loss} - W \qquad (2)$$

Q_{met} is called the metabolic rate (MR).

Relationships in thermodynamics involve amounts of energies changing in a process at equilibrium and not those changing per unit time, i.e., the kinetics of that process, which involves the rates of energy changes or flows. The study of the metabolism usually involves rates and therefore is more appropriate.

$$\frac{dU}{dt} = \frac{dQ_{met}}{dt} + \frac{dQ_{loss}}{dt} - \frac{dW}{dt}$$

{We need to be careful about signs. The body increases its energy with terms such as $\mathbf{d}\boldsymbol{Q}_{\mathrm{met}}/\mathbf{dt}$ that are ***positive*** and loses it with terms such as $\mathbf{d}\boldsymbol{Q}_{\mathrm{loss}}/\mathbf{dt}$ that are ***negative***. The amount of heat flowing from the body is $-\mathbf{d}\boldsymbol{Q}_{\mathrm{loss}}/\mathbf{dt}$, which is a positive quantity.}

All types of energy have the same units, including heat (often expressed in terms of ***calories***) and work (often expressed in terms of ***joules***). One important conversion between units is

1 calorie (cal) = 4.184 joule (J). (4)

1 kilocalorie (1 kcal = 1,000 cal) is sometimes called 1 Cal, which is also known as a food calorie. The energy content of food is always expressed in terms of these Cal (kcal) units.

Units of power

1watt (W) = 1 J/s
100W = 1.43 kcal/min
1 horse power (hp) = 746W = 642 kcal/h
1 kcal/min = 69.7W = 0.094 hp
1 kcal/h = 1.162W

The convenient of unit for expressed the rate of energy consumption of the body is the (met) .

1met=50 Kcal/m^2.hr=58 w/m^2

Q/ Prove 1met=58 w.m^{-2} ?

Ans.

$$1met = 50\,k\,cal.m^{-2}.hr = \frac{50 \times 69.7\,w.m^{-2}}{60\min} = 58\,w.m^{-2}$$

Q/ Prove 1kcal/min =69.7 W ? (H.W)