Physiology

● Sheet ○ Slide

number 2

Done by Abdel-Mu'ez Siyam

Correction Nura Alramahi

Doctor Mohammad Iyas Kawas

Metabolic rate

The main source of energy for human beings is food. We ingest variable types of food containing carbohydrates, lipids and proteins. Our body then oxidizes these molecules in the presence of oxygen (so it is combustion) to yield carbon dioxide CO_2, water H_2O and energy. The metabolism of the body simply means all the chemical reactions in all the cells of the body

This energy is then used either to perform external work or be important internally (to maintain the general health of the body). All the physical activity that we do is considered as the energy important externally (the energy that we use to perform external physical work), like when you move an object (perform external work), you lose some of your energy (you actually store it in this object). The other form of energy that we lose (actually the majority of our energy) is heat. So as an estimate, if we measure the heat produced by the body, we can estimate the metabolic level in the body. So the metabolic rate is normally expressed in terms of the rate of heat liberation during chemical reactions.

Note: *when I measure the heat, I exclude the energy lost as external work.
*No more than 27 percent of all the energy from food is finally used by the functional systems. Even when 27 percent of the energy reaches the functional systems of the cells, most of this energy eventually becomes heat.

Measurement of the metabolic rate is called calorimetry. [calorie: amount of energy required to increase temperature of 1 g of water 1 by degree C, while a Calorie (with big C, same as Kilocalorie): amount of energy needed to raise 1 Kg instead of 1 g by 1 degree]. So calorimetry is measurement of amount of **energy,** and mostly it is in the form of heat.

**Calorimetry:

1-Direct: direct measurement of **heat**, by putting the individual in an insulated room, the body will liberate heat (the individual must **not** perform any physical activity) and heat the air in the chamber, then we make water flow. The water after going out from the room is hotter (because you release heat) than when it first came in. From the difference in water temperature, the specific heat of water and the duration I can know how much heat it gained, thus how much heat the body emitted. I multiply the 3 variables together to get the amount of heat.
Side note: An implication on the fact that your body liberates heat is that you cover yourself in winter. You are not heated by the coat, it just limits heat dissipation around you so you feel warmer.

2- Indirect: by measuring CO2 production or O2 consumption (because 95% of energy produced is in presence of oxygen). If we are measuring oxygen, it was found that for each **1L O2 consumed, you liberate 4.825 Calorie** {IMPORTANT, memorize}.

This is called the average oxygen equivalent, which differs according to what you eat. When you depend on fat, it is 4.7 Calorie/L of O2, and on protein, it is 4.6 Calorie/L of O2 and with glucose, it is 5.01, and with starch, it is 5.06 Calorie/L of O2, so on average (mixed diet) it is 4.825 Calorie/L of O2.

Sometimes we measure CO2 released rather than O2 consumed. We use the Respiratory Quotient (**RQ**) to estimate one if we know the other. RQ = CO2 eliminated/O2 consumed. It is a known value for mixed food; around 0.82-0.84 (**so 0.83--memorize)** and differs according to certain food [for glucose it is 1, for fat it is 0.7, and for protein it is 0.81].

For calculations, we need:

#Volume of oxygen:

1- directly provided.
2- calculated from respiratory quotient : (Volume of eliminated CO2/ RQ)

 # Oxygen equivalent: - 4.825 Calories per litre of oxygen (on average).

 # Time.

What we have now is the metabolic rate for the duration of the test. We then can calculate the metabolic rate for 24 hours. It can also be reported per hour, and can be standardized **for ease of comparison** by dividing it over the surface area of the test subject. So it is usually reported as (Kcal/hr/m2). The surface area can be obtained from charts using weight height and gender.

Calculation example: During a 30 minute indirect calorimetry test a 70 kg resting male produced 6 litres of CO2, calculate the metabolic rate for 24 hours assuming the same level of activity. (Oxygen equivalent: 4.825 Kcal/LO2 , RQ: 0.83 LCO2/LO2).

Note: Sometimes the type of calorimetry used won't be mentioned in the question, but it'll be clear.

Answer: Volume of oxygen used = 6/0.83 = 7.23 litres.

Energy released = 7.23 * 4.825 = 35 Kcal.

Energy released in 24 hours = metabolic rate in 24 hours = 1680 Kcal/24 hours.

MOST PROBABLY FOR THIS LAB, THE QUESTION IN THE FINAL IS CALCULATION.

*Note: after calculating the energy produced over a period of time, if we want to compare between individuals we have to add another factor into consideration which is the surface area of the body (we can get it from special tables according to the person's height and weight) then divide the rate over the surface area. So the unit is Calorie/hour/m².

The indirect calorimetry can be done through either:

opened system (a bag is used for collection of expired air during the physical activity. By knowing the concentration of oxygen in the atmosphere and in collected air, we can know how much oxygen was consumed and then we can calculate oxygen consumption and the metabolic rate).

or closed system By using a certain device that the person respirates through (filling it with pure oxygen and adding in the way of expired air a substance to adsorb the CO_2 produced), then we can measure how much oxygen was consumed and estimate the metabolic rate).

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The basal metabolic rate (BMR):

It is the minimal energy expenditure by the body to exist. (for the brain to function, for the heart to beat, for the kidneys to function and for maintenance of your core temperature). The BMR normally averages about 65 to 70 Calories per hour in an average 70- kilogram man.

We use around 65-70 % of all the energy we get from food for the BMR. Skeletal muscle, even under resting conditions, accounts for 20 to 30 percent of the BMR. For this reason, BMR is usually corrected for differences in body size by expressing it as Calories per hour per square meter of body surface area, calculated from height and weight. Therefore, if someone wants to lose weight, already about 65% of his energy is used to maintain the BMR, so to increase his metabolic rate, he must increase the physical activity or decrease food intake.

We measure BMR by direct/indirect calorimetry, but under certain conditions, which include:

1. The person must not have eaten food for at least 12 hours.
2. The BMR is determined after a night of restful sleep.
3. No strenuous activity is performed for at least 1 hour before the test.
4. All psychic and physical factors that cause excitement must be eliminated.
5. The temperature of the air must be comfortable and between 68°F and 80°F.
6. No physical activity is permitted during the test

Note: Sleeping decreases the metabolic rate, and we call it *sleeping metabolic rate*.

*Factors affecting BMR:

1- Thyroid hormone: hyperthyroidism increases BMR (thin persons), while hypothyroidism decreases BMR (fatigue, gain of weight).
2- Male sex hormones: increase BMR.
3- Growth hormone: increase BMR.
4- Fever: increase BMR.
5- Malnutrition: decrease BMR.

Good Luck