9.1

Why We Need to Eat

On average, humans eat three times a day. If you spend 1 h eating each meal, that means you will spend 3 h, or 12.5 % of each day, eating. Eating is also a part of our social life. Many of our social interactions revolve around eating. We eat as a family, or we invite friends over or meet at a restaurant for a meal (**Figure 1**). Although eating may provide beneficial social interactions, the primary reasons for eating are to provide materials for growth and maintenance of our bodies, and to provide energy for all of our biological processes and activities.

Figure 1 Eating, an important part of our family and social lives, is also necessary for life.

Food for Growth and Maintenance

nutrient a chemical that must be obtained by an organism from its environment in order to survive; nutrients provide the raw material for growth and repair and may be a source of energy

We obtain the raw materials for growth and maintenance of our bodies from nutrients in food. **Nutrients** are the chemicals that an organism needs in order to grow, build, and repair tissues, and to produce energy. The nutrients that are important for keeping our bodies healthy are carbohydrates, proteins, lipids (fats), water, minerals, and vitamins. You will learn more about these nutrients in the next section. Once in the body, most nutrients are broken down into simpler molecules that are then used to build bone, muscle, and other types of cells and tissue. Damaged cells are repaired, dead cells are replaced, and, in growing organisms, new cells are produced.

Food for Energy

Nutrients provide the energy that fuels all biological processes. As you learned in your previous science studies, most of this energy begins as light energy from the Sun, which is converted into chemical energy by plants during the process of photosynthesis. Unlike light energy, chemical energy can be stored in cells and then released when needed. All organisms require chemical energy to perform basic life functions.

Animals eat in order to obtain chemical energy. The chemical energy produced by plants is transferred to herbivores and omnivores. Humans obtain the chemical energy carried in animal- and plant-based food. Cells in the body use chemical energy to fuel biological processes and physical activities, such as growth and movement. In endothermic (warm-blooded) animals, some of this energy is used to maintain a fairly constant body temperature, but eventually, the energy is converted into thermal energy and is transferred back to the environment. Normally, the temperature of the human body is higher than that of its surroundings, which means that we are continuously transferring thermal energy to the environment (**Figure 2**).

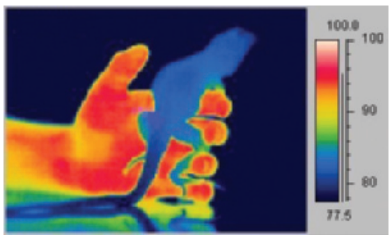

Figure 2 All animals lose thermal energy, some more than others. Note that the reptile is much cooler than the human. Why is that?

If you are sitting reading this book, you may think that you are not using much energy. However, there are many processes going on inside your body—your heart is beating, you are breathing, your brain is processing information, your muscles are holding you upright in your chair, and you are transferring thermal energy to the air around you. All of these processes require energy.

Factors That Affect Energy Requirements

Some living things require much more food than others. Endothermic animals—mammals and birds—need a great deal of energy to keep their bodies warm and therefore must consume a greater quantity of food than ectothermic (cold-blooded) animals of equal size. A shrew, for example, needs to eat more than two-thirds of its body mass in food every day in order to have enough energy to stay warm (**Figure 3(a)**). Ectothermic animals, on the other hand, survive on much less food. A similar sized frog, for example, could easily survive for a month on the same amount of food as a shrew needs to eat every day (**Figure 3(b)**).

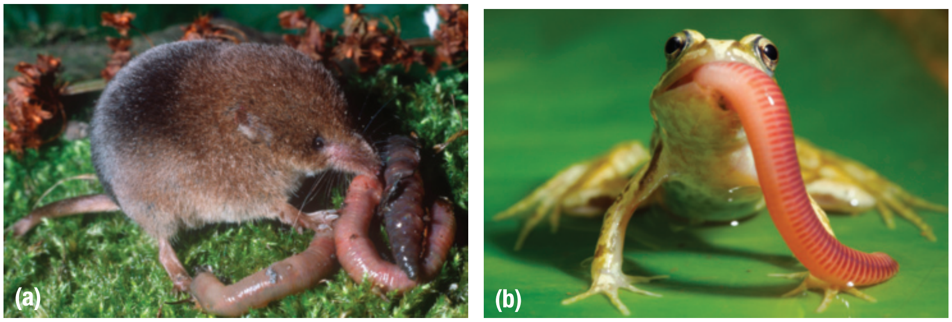

Figure 3 (a) This shrew must consume a large amount of food every day. (b) This frog can survive for weeks on one good meal.

Size is also a factor in determining how much an animal needs to eat. Larger animals generally eat more food than smaller ones. However, in the case of endothermic animals, the relationship is a bit more complex. Small endothermic animals need to eat more food for their size than large endothermic animals. For example, a 5000 kg elephant might eat 250 kg of food a day—5 % of its body mass. A 5 g shrew might have to eat 4 g of food a day—80 % of its body mass!

In order to stay alive, your body performs many different chemical reactions. All of these chemical reactions are collectively referred to as your **metabolism**. One part of metabolism, called **catabolism**, involves the breakdown of materials in an organism. The chemical and physical breakdown of nutrients during digestion is an example of catabolism. Another part of metabolism, called **anabolism**, involves the building of larger, more complex molecules from smaller, simpler molecules. An example of anabolism is the use of materials and energy provided by catabolic processes to build the complex materials needed for growth and repair.

The rate at which the body converts stored energy into working energy is called **metabolic rate**. Everyone's metabolic rate is different. This is because metabolic rate depends on a number of factors. Generally, the following trends apply:

- Body size: The larger the body, the more energy is required to stay alive.
- Physical activity: Muscle burns more energy than fat, so physical activity requires more energy.
- Sex: Males are typically larger in size and have a greater proportion of muscle mass than females of the same size, age, and fitness level.
- Age: Metabolic rate decreases with age (in part due to decreased physical activity and the loss of muscle mass).
- Hereditary factors: Some individuals have a naturally high metabolic rate. In these individuals, the chemical energy obtained from food is very quickly converted into other forms of energy.

As these trends indicate, someone who is smaller in size may still require more energy than a larger person if he or she has a higher level of physical activity. Similarly, a person in her sixties who leads a very active lifestyle may still have a lower metabolic rate than a person in her teens who is only moderately active. There is no steadfast rule that can be applied to metabolic rate; these are trends.

metabolism the set of chemical reactions that occur in living organisms that are necessary to maintain life

catabolism the metabolic reactions that break down larger molecules into smaller subunits

anabolism the metabolic reactions that use energy to produce larger molecules from smaller subunits

metabolic rate the rate at which the body converts stored energy into working energy

Measuring Energy

Energy is measured using an SI unit: the joule (J). Since the joule is a relatively small unit of energy, we often use the kilojoule (kJ) to refer to the energy requirements of people or the energy stored in foods (1 kJ = 1000 J).

Recall from previous grades that a calorie (small *c*) is the amount of energy required to raise the temperature of 1 g of water by 1 °C. When referring to food energy, another unit—the Calorie—is often used. One Calorie (with a capital *C*) equals 1000 calories, or 4180 J. The energy in food is often described in terms of Calories. Nutrition labels, for example, provide the energy value of food in Calories.

The rate at which energy is used by an organism when it is at rest is referred to as the **basal metabolic rate** (BMR). This is the amount of energy you would use per day if you stayed in bed all day, with your body performing only vital processes (such as breathing and heartbeat). The BMR for a person can be accurately calculated based on the consumption of oxygen, but it is a complex process and not practical for everyday use. The BMR is generally estimated using a calculation that takes into account four variables: height, weight, age, and sex. Males tend to have a higher BMR than females by about 10 %. Your energy requirements also depend on your activity level.

LEARNING **TIP**

Muscle-to-Fat Ratio
The limitation of the BMR calculation is that it does not take into account the ratio of muscle to fat in the body. While it is a good guideline for most people, it does not provide an accurate value for very muscular or very overweight individuals.

basal metabolic rate the minimum amount of energy required to keep you alive

Mini **Investigation**

How Much Energy Do You Need?

Skills: Observing, Analyzing — SKILLS HANDBOOK A2.1, A6.2

In 1918, J. Arthur Harris and Francis G. Benedict, nutrition researchers at the Nutrition Laboratory of the Carnegie Institute of Washington, published a paper based on their study of basal metabolism. The data from their research allowed them to derive a formula that is still the most commonly used method of estimating basal metabolic rate and energy expenditure.

Your BMR is unique to you. It depends on your sex, size (height and mass), and age. The Harris–Benedict formulas for estimating your BMR are as follows:

female

$$\text{BMR} = [655 + (9.6 \times \text{mass in kilograms}) + (1.8 \times \text{height in centimetres}) - (4.7 \times \text{age in years})] \times 4.18$$

male

$$\text{BMR} = [66 + (13.7 \times \text{mass in kilograms}) + (5.0 \times \text{height in centimetres}) - (6.8 \times \text{age in years})] \times 4.18$$

Example:
Tom is a 16-year-old student who is 175 cm tall with a mass of 75 kg. Estimate his BMR.

Solution:
Use the formula for males and substitute the values as follows:

$$\text{BMR} = [66 + (13.7 \times 75) + (5.0 \times 175) - (6.8 \times 16)] \times 4.18$$

$$\text{BMR} = 7773.5 \text{ rounded to } 7800 \text{ kJ}$$

The Harris–Benedict formula uses the following activity factors in conjunction with the BMR to estimate the average individual daily energy requirement.

- little or no exercise — BMR × 1.2
- light exercise or sports 1–3 days/week — BMR × 1.375
- moderate exercise or sports 3–5 days/week — BMR × 1.55
- vigorous exercise or sports 6–7 days/week — BMR × 1.725
- very hard exercise daily or sports & physical job or 2 × training daily — BMR × 1.9

For example, Tom is a fairly active student who plays sports most weekdays. Therefore his average daily energy requirement will be 7800 kJ × 1.55 = 12 090 kJ rounded to 12 000 kJ.

1. Use the appropriate formula to estimate your BMR.

A. Analyze your lifestyle in terms of your level of activity. Multiply your BMR by the appropriate activity factor to estimate your daily energy requirement. T/I A

Your energy requirement is not the same each day; it varies with the type and amount of physical activity that you do. You can more accurately estimate your energy requirement by analyzing your activities each day and adding up the amounts of energy required for each activity. **Table 1** (next page) shows the energy requirements for various activities. Note that the units are in kJ/kg/h. This is the energy (kJ) that you need for each kilogram of body mass, to perform the activity for 1 h.

Table 1 Average Energy Requirements for Various Activities

Type of activity	Energy required (kJ/kg/h)	Type of activity	Energy required (kJ/kg/h)
sleeping	4.1	walking (6.4 km/h)	20.6
sitting	5.2	badminton	21.5
writing	6.0	mowing lawn	23.0
standing	6.3	cycling (15.3 km/h)	25.8
singing	7.1	hiking, fast dancing	27.0
using a computer keyboard, playing cards	9.0	tennis, downhill skiing	36.2
washing the car, cooking	10.5	climbing stairs, running (8.8 km/h)	37.5
playing the piano	11.2	cycling (20.9 km/h)	40.5
walking (3.2 km/h)	11.6	cross-country skiing	42.0
cycling (13 km/h)	15.8	running (12.9 km/h)	62.0
walking (4.8 km/h)	16.2	competitive cross-country skiing	73.6

9.1 Summary

- All animals must eat to obtain materials for growth and repair and to obtain energy for all life processes.
- All of the chemical reactions that occur in an organism are referred to as the organism's metabolism. These reactions include the breakdown of materials to provide energy and the construction of materials for growth and repair.
- The basal metabolic rate (BMR) is the minimum amount of energy required to keep an organism alive. It can be estimated using a formula that takes into account the individual's sex, age, height, and mass.
- Your daily energy requirement depends on your BMR and level of physical activity.

UNIT TASK BOOKMARK

Consider what you have learned about basal metabolic rate and energy requirements. How will this information be useful to you in Parts A and B of the Unit Task?

9.1 Questions

1. What are two factors that determine how much an animal needs to eat? K/U
2. How and why is our energy requirement affected by each of the following factors: physical activity, body size, sex? K/U A
3. Using the values in Table 1 (above), estimate how much energy you will need for the current 24 h period, starting at midnight last night. Include a complete list of your activities (both completed and planned) and the estimated time and energy requirement for each activity. T/I A
4. Paul and his friends ate at a fast-food restaurant. Paul, who has a mass of 70 kg, had a cheeseburger, fries, and a large drink. These items provide a total of 2500 kJ of energy. T/I
   (a) How long would Paul have to play a computer game in order to use this much energy?
   (b) How long would he have to run to use this much energy?
   (c) If Paul walked at 6.4 km/h for 2 h, do you think he would use up all the energy from his meal? Explain, showing your calculations.
5. Compare the workday energy requirements of an office worker and a letter carrier. (Assume that these individuals are both of the same sex and body size.) K/U A
6. Use the Internet and other sources to find values for the average daily energy requirements for people of different ages and levels of activity. Using this information, what would be the daily energy requirement for
   (a) an active 5-year-old girl?
   (b) an inactive 65-year-old man?
   (c) a very active 16-year-old male?
   (d) a very active 16-year-old female? T/I

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