Chapter 2

How your bodies function (Mechanisms and functions of your body)

Learning objectives

You will be able to gain proper understanding and explain:

- The mechanisms and functions of a body that supports life.
- The regulatory mechanisms of the human body in supporting daily activities, in relation to your own daily activities.

In this chapter, you will learn about the basic structure (structure and morphology of organs) and functions (roles and functions of organs) of the human body; organs and tissues functioning while interacting with each other; and functions of the body that maintain a stable internal environment.

1. Structure and functions of the human body

The human body carries out various functions. These functions are broadly grouped into those that sustain life and those that actively use life for motion and regulation. Examples of functions that sustain life include eating food to obtain nutrition, breathing to take in air, and circulating blood throughout the

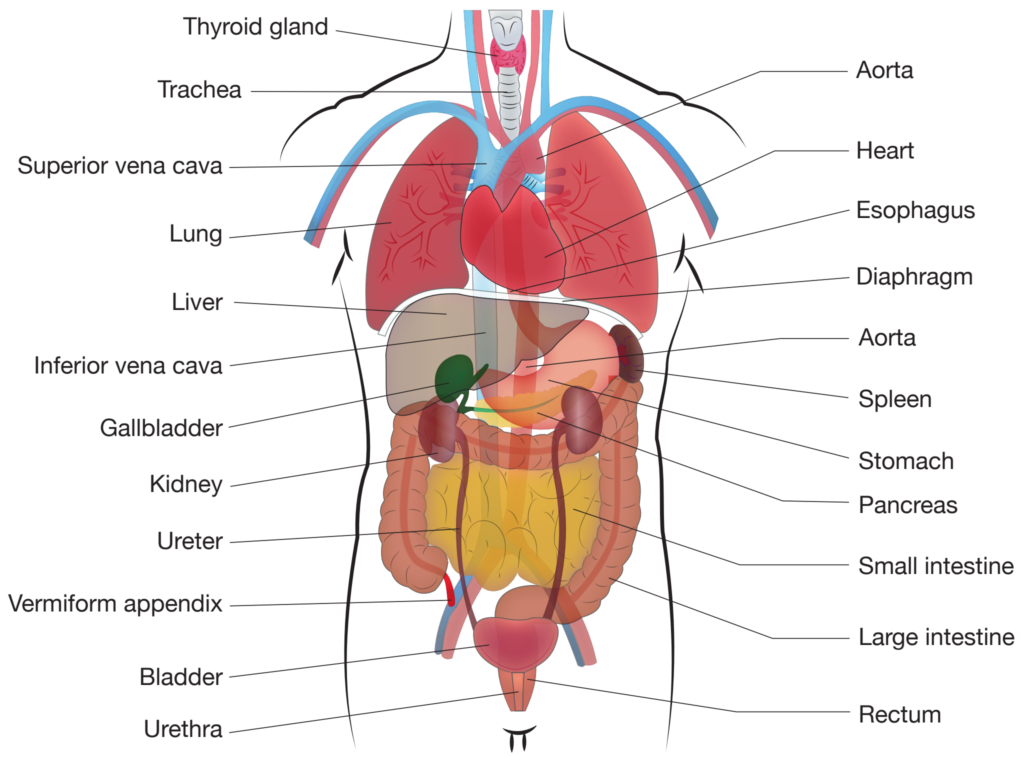

Figure 2.1 Anatomy of the human body (Organs)

body (**Figure 2.1**). Functions for motion and regulation include seeing, hearing, and moving joints. Organs inside and outside the body are involved in these functions.

1) Basic structure of the human body (cells, genes, tissues, and organs)

The human body is made up of **cells** as minimum units. A cell is composed of a **cell nucleus** and the **cytoplasm** surrounding it. The cell's basic function is to produce proteins based on the information possessed by the cell nucleus. Each cell nucleus contains 23 pairs of **chromosomes** (46 in total), and one chromosome contains hundreds to thousands of **genes**. Genes correspond to the blueprint of the human body and form a part (region) of **deoxyribonucleic acids** (DNAs), which holds specific genetic information such as "what kind of protein to make. DNA is a chain of small units called nucleotides composed of sugar, a nitrogenous base, and a phosphate group. It usually has a double-helix structure in which two strands of nucleotides running in opposite directions are bound to each other. Long-pitch filamentous double-helix DNA is connected to histones (protein) to form chromosomes, and is located in the nucleus of a cell. There are four types of DNA bases, namely adenine (A), guanine (G), thymine (T), and cytosine (C), where A binds to T and G binds to C (**Figure 2.2**). Sequences in which the four types of bases are arranged (base sequence) provide encoded (symbolized) genetic information. There are many areas in DNA whose functions have yet to be understood.

There are many types of cells in the body, such as heart, liver, and muscle cells. They vary in size and shape by their functions. For example, red blood cells (erythrocytes) are disc-shaped and are able to change shape easily. This allows them to squeeze through narrow blood vessels and transport oxygen throughout the body. Derived from a single fertilized egg, all cells essentially have the same DNA. However, different genes are expressed in different cells (or at different times in the same cell), which is why cells are able to acquire diverse appearances and functions.

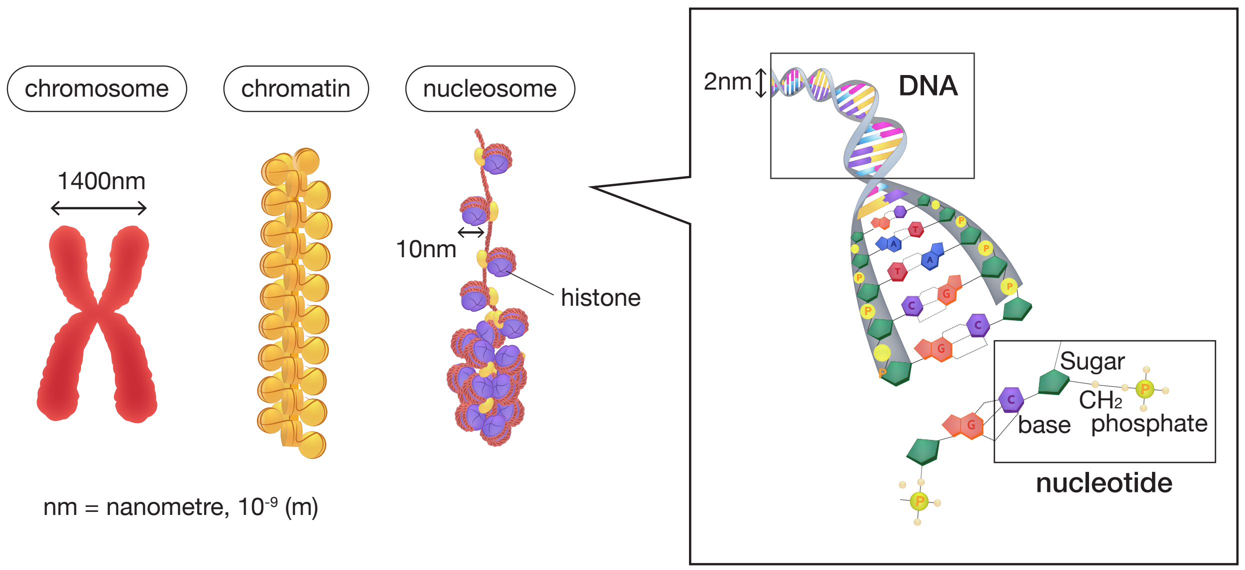

Figure 2.2 DNA structure

A collection of specifically differentiated cells is called a **tissue**. Tissues work together to create an **organ** that performs a specific function. A group of organs with similar functions is called an **organ system**, which can be classified as shown in Table 2.1:

Table 2.1 Main functions and types of organ systems

Organ system	Main functions	Main organs
Motor system (Bone, and muscle)	Bones form the skeleton (strut) that supports the body. The body is able to move simply by moving bones with joints. Bones also protect internal organs and the hematopoietic function.	Bones, cartilage, joints, muscles
	Skeletal muscles are able to contract and change their length to move each part of the body.	
Cardiovascular system	The cardiovascular system consists of the heart (acting as a pump to circulate blood) and blood vessels (acting as pipes for supplying blood), and functions to deliver the required nutrients and oxygen to cells throughout the body, as well as carry carbon dioxide and other waste products away for disposal.	Heart, blood vessels (arteries, veins), blood, lymph vessels
Respiratory system	The respiratory system takes in oxygen necessary for activities into the body and discharges carbon dioxide. It also functions to produce sound waves (pharynx) and resonate in the oral cavity to produce voice.	Nose, pharynx, trachea, lungs
Nervous system	The nervous system can be divided into the central nervous system (which processes collected information and sends out instructions) and the peripheral nervous system (which conveys instructions from the central nervous system to various parts of the body and conveys systemic information to the central nervous system).	Brain, spinal cord (central nervous system)
		Autonomic nerve, somatic nerve (peripheral nervous system)
Digestive system	The digestive system functions to chew, swallow, digest, and absorb the beneficial parts of food into the body.	Oral cavity, esophagus, stomach, small intestine, large intestine, rectum, liver, pancreas
Urinary system	The urinary system excretes unnecessary substances in the blood as urine. It adjusts the amount and composition of urine to maintain the constant composition and osmotic pressure of body fluids.	Kidney, urinary tract, bladder, urethra
Endocrine system	The endocrine system secretes substances (hormones) that circulate throughout the body along with the blood flow and work on specific organs. It regulates the functions of those organs.	Pituitary gland, thyroid gland, adrenal gland, pancreas, gonads
Sensory system	The sensory system mainly collects information outside the body to regulate and control the body's activity.	Eyes, ears, tongue, nose, skin
Reproductive system	The reproductive system produces sperms and eggs and functions to preserve species (create future generations), from the binding (fertilization) of sperms and eggs to delivery.	[Male] Testis, seminal duct
		[Female] Ovary, uterus
Immune system	The immune system functions to eliminate foreign substances invading the body and abnormal cells in the body. The body is affected if its function deteriorates or reacts excessively.	Lymphatic vessels, bone marrow, spleen, thymus, blood, skin, tonsils

2. Structures and functions of organs

1) Motor system

The motor system consists of the bones (making up the skeleton), muscles, joints, ligaments, cartilage, and other connective tissues. It functions to move and support the body.

(1) Skeleton

The skeleton is the base tissue shaping the human body. It includes a total of about 200 bones (cranial 23, spinal column 26, thorax 25, upper limbs 64, lower limbs 62), with five types of bone shapes (long, short, flat, irregular, and pneumatized bones). Pneumatized bones (hollow bones) are filled with space for air.

The roles of bones are as follows: (1) supporting the head, internal organs, and trunk, (2) supporting movement, (3) protecting key organs, (4) storing minerals (calcium, phosphorus), and (4) creating blood in the bone marrow (red blood cells, white blood cells, and platelets).

(2) Muscle

Muscles can be grouped into **skeletal, cardiac, and smooth (visceral) muscles** based on their differences in shape and function. Skeletal muscle can be consciously moved through the somatic nerve (**voluntary muscle**). Its roles include (1) moving the body by contraction and relaxation of skeletal muscle, (2) maintaining posture, and (3) producing body heat. Through muscle contraction, the skeleton moves at joints. The axis and range of joint movement are mainly determined by the shape of the joint. During movement, the muscles that mainly work are called **prime mover** (**agonist muscles**), the muscles that work together to move the body are called **synergist muscles**, and the muscles that perform opposite movements are called **antagonist muscles**. For example, both flexors and extensors are **antagonistic muscles** (Figure 2.3).

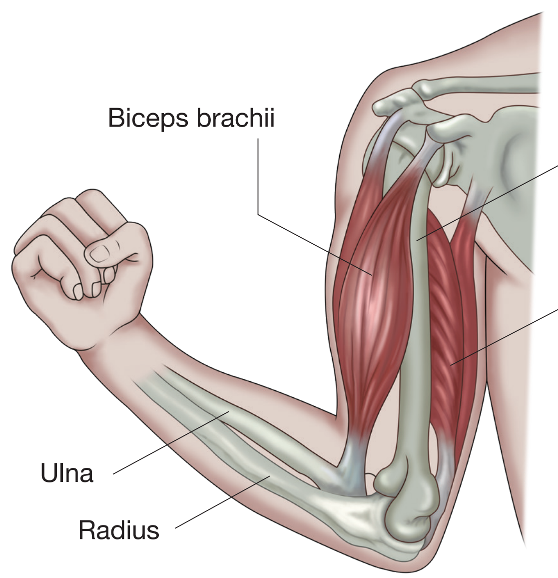

Figure 2.3 Muscle structure (agonist and antagonist muscles)

The myocardium is the muscle forming the heart wall. It is the same striated muscle as the skeletal muscle, but unlike the skeletal muscle, it cannot be moved consciously and is regulated by the autonomic nerves (**involuntary muscle**). It differs from the skeletal muscle in that it does not get fatigued no matter how much it continues moving, and in that myocardial cells do not have the ability to divide, which means that these cells will not be regenerated once they are damaged or undergo necrosis, for example, due to events such as myocardial infarction.

Smooth muscles are also involuntary muscles, which are controlled by the autonomic nerves in the same way as myocardium. They serve as the internal organ walls and blood vessel walls of the digestive tract, airways, etc. Their ability to contract is not as strong as skeletal or heart muscles, but they can continue to move without getting tired.

Column: Why do elderly people fall easily? (Aging of bones and muscles)[1]

With aging come many changes in the skeleton and muscles. For example, sarcopenia, a phenomenon in which muscle mass decreases with age, begins around 30 years of age and progresses throughout life. During this process, the amount of muscle tissue and the number and size of muscle fibers gradually decrease. As a result, muscle mass and strength gradually decrease. This mild weakness increases the load on some joints (e.g., knee joints), thereby increasing susceptibility to arthritis and falls. Although physical inactivity (lack of exercise) is assumed to be the main cause, its mechanism has yet to be fully understood.

2) Circulatory system

The **circulatory system** consists of the heart, blood vessels, blood, and lymphatic vessels. It sends oxygen and nutrients to cells throughout the body and takes back carbon dioxide and waste products that are no longer needed by the cells.

(1) Circulation

The **heart** acts like a pump and is slightly larger than the fist (weighs about 250–300 g in adults). It is located slightly to the left of the center of the chest in the mediastinum space in the thoracic cavity, surrounded on its right and left sides by the lungs, and connected to the diaphragm at the bottom.

The heart is composed of four chambers (**left ventricle**, **left atrium**, **right ventricle**, and **right atrium**). The **atriums** receive blood to the heart, and the **ventricles** pump out blood from the heart (Figure 2.4). Blood from the left ventricle flows throughout the body to supply oxygen and nutrients to somatic cells, receives waste from those cells, and returns to the right atrium. This circulation is called **systemic circulation**. On the other hand, blood from the right ventricle passes through the lungs, where it undergoes **gas exchange** (exchange of oxygen and carbon dioxide), and then returns to the left atrium. This is called **pulmonary circulation**.

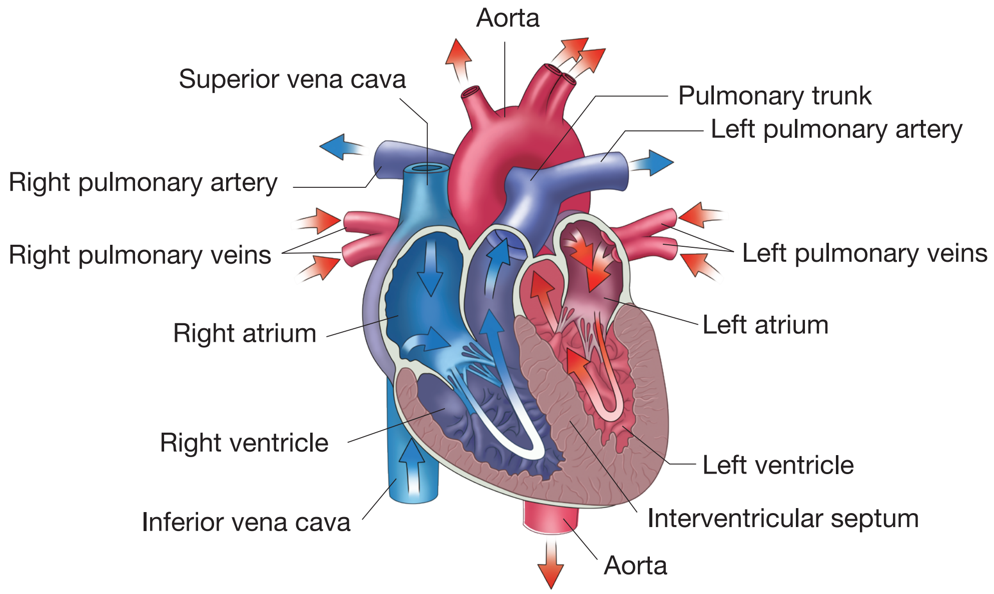

Figure 2.4 Heart structure and blood flow

(2) Blood pressure regulation

The pressure of blood on the walls of blood vessels is called **blood pressure**. The blood pumped by contraction of the ventricles generates blood pressure. Blood pressure decreases as distance from the left ventricle increases or elasticity of the vascular wall (vascular resistance) changes while blood moves in the vasculature from arteries through arterioles, capillaries, and venules to veins (Figure 2.5).

Vascular resistance is defined by: (1) inner diameter of the blood vessels, (2) viscosity of blood, and (3) total length of the vessels. The smaller the inner diameter of the blood vessel, the greater the resistance to blood flow. Generally, physiological changes in the vessel diameter of the arterioles affect blood pressure. Blood pressure lowers during vasodilation and rises during vasoconstriction. Blood pressure rises when the viscosity of blood, which is regulated by the amount of red blood cells and plasma, increases, and falls when it falls. Blood pressure is maintained relatively constant at rest. In adults, normal values are approximately 120 mmHg for systolic blood pressure and 80 mmHg for diastolic blood pressure.

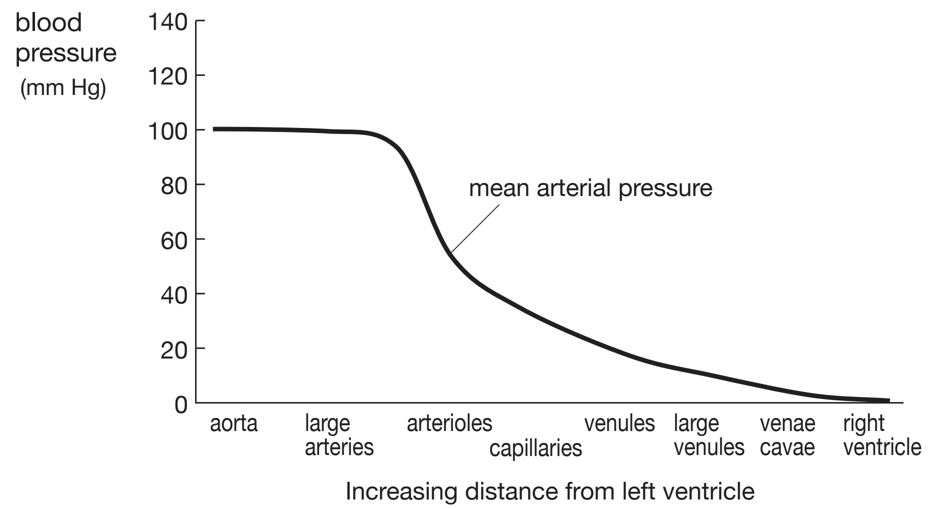

Figure 2.5 Changes in blood pressure along systemic circulation[2]

3) Respiratory system

The **respiratory system** consists of the **upper respiratory tract** (nasal cavity, pharyngeal pharynx, larynx), **lower respiratory tract** (trachea and bronchus), and **lungs**. It works to take into the body necessary oxygen and excrete carbon dioxide outside of the body (**Figure 2.6**).

The function of taking oxygen (O_2) from the air (outside air) into the blood and excreting the carbon dioxide (CO_2) generated in the body from the blood to outside the body is called **external respiration**. The O_2 and CO_2 that enter and leave the body through breathing are collectively called **respiratory gases**, and O_2 and CO_2 gas exchange is performed in the **alveolis**.

After emitting CO_2 and taking in O_2 by external respiration, the blood returns to the heart as **arterial blood**, and is pumped out from the left ventricle to the entire body. This blood reaches the periphery, enters the capillaries, and exchanges gas with body tissues. The direction of inflow and outflow of respiratory gas at this stage is opposite to those in external respiration in the lungs, i.e. O_2 is released from the blood and taken in by tissue cells, while CO_2 generated by cell metabolism is released from cells and moves into blood. Such gas exchange at peripheral tissues is called **internal respiration**.

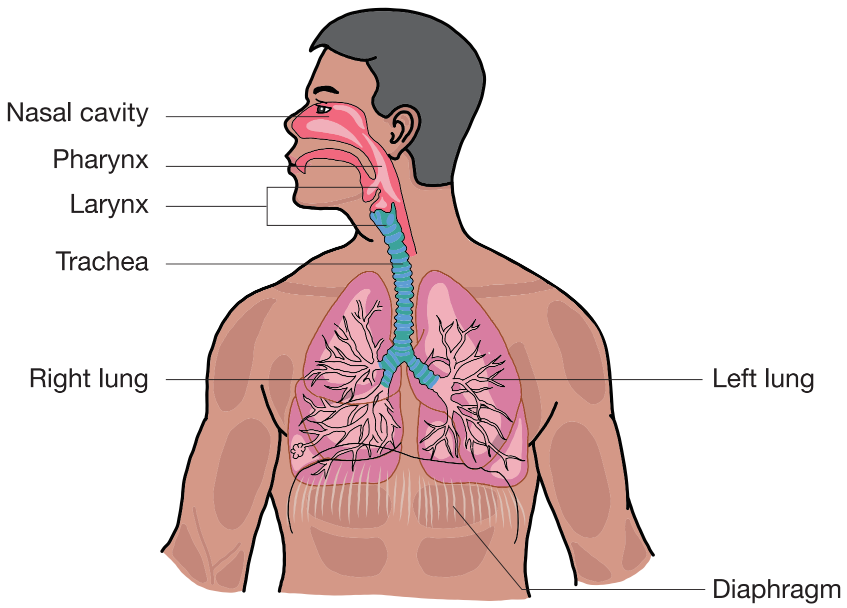

Figure 2.6 Respiratory organs

4) Nervous system

Neurons are the basic developmental, morphological, and functional units of the nervous system. They are excited by stimuli, and the excitement is transmitted to other neurons by synapses. Neuronal excitement generated by the stimulation of receptors in various parts of the body is transmitted to the central nervous system by ascending neurons, while excitement of the central nervous system is transmitted to peripheral effectors by descending neurons. The nervous system covers the entire body like a mesh and controls the functions of organs and tissues through the conduction of excitement generated by impulses of nerve fibers and conduction of excitement to effectors and other neurons.

The nervous system can be divided into the **central nervous system** (brain and spinal cord, the center of functions of the nervous system) and the **peripheral nervous system** (**somatic** and **autonomic nervous systems**). Peripheral nerves cover every corner of the body and play a key role in connecting each part of the body to the central nervous system (**Figure 2.7**).

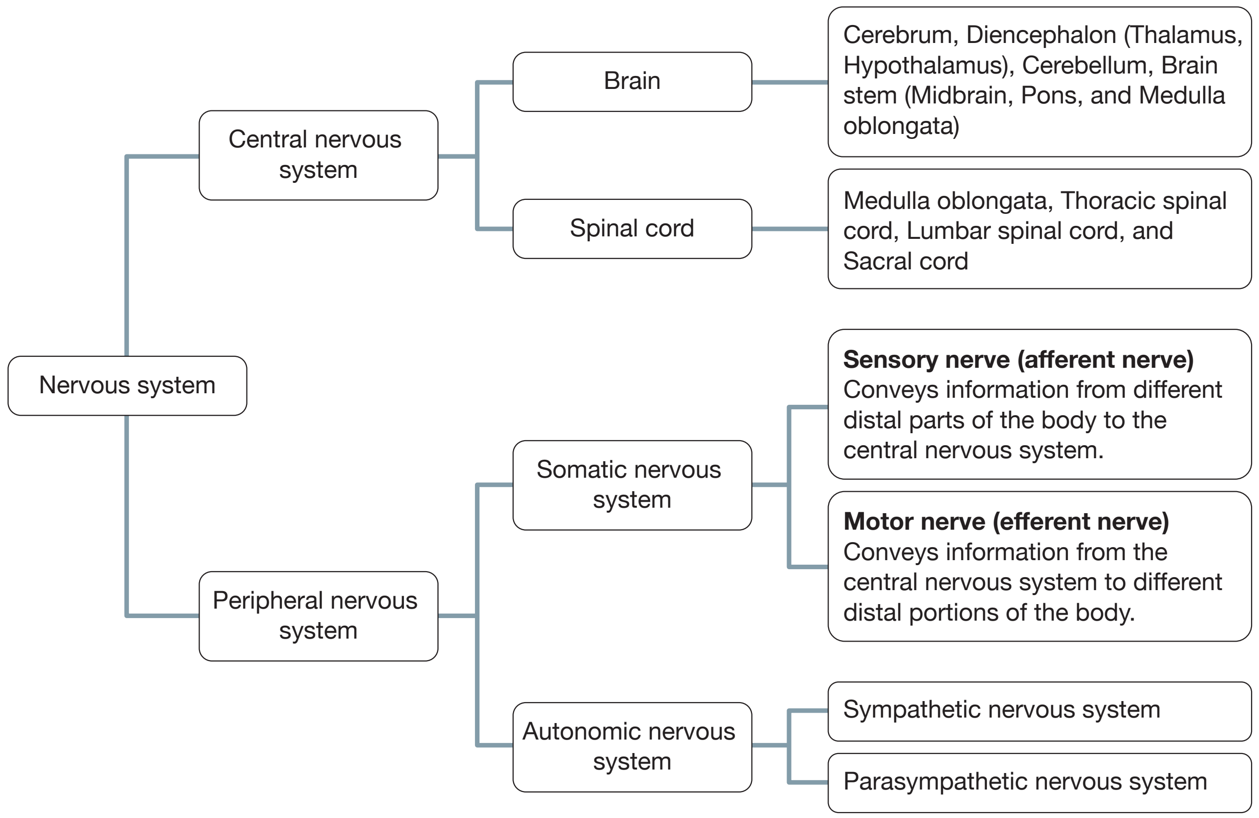

Figure 2.7 Structure of nervous system classification

(1) Central nervous system[3, 4]

The central nervous system comprises the brain and spinal cord. Located in the cranial cavity, the brain weighs approximately 1,300–1,400 g in adults. It can be divided into four main parts (cerebrum, diencephalon, cerebellum, and brain stem). The **cerebrum** is the most developed part of the brain and occupies 80% of the whole brain volume. Its functions include identifying information and instructing movements accordingly (primary functions), as well as advanced mental functions such as memory, emotion, motivation, and cognition (higher functions). Under the cerebrum lies the **cerebellum** (motor regulation). Between the left and right sides of the brain is the **diencephalon** (sensory information processing, and integration of the autonomic nervous system). The **brain stem** is the center of the functions supporting life, namely respiration, circulation, digestion, and thermoregulation. The **medulla oblongata** at its lower rear is connected to the **spinal cord**. The spinal cord is located in the spinal canal and is approximately 40–45 cm long in adults. Each nerve of the peripheral nervous system runs from the central system and branches repeatedly toward the target organs under its control. If the spinal cord loses its function, all sensations will be lost, and you will become numb. Furthermore, motor functions are also lost, and you will not be able to move.

(2) Peripheral nervous system (somatic nervous system and autonomic nervous system)

Somatic nerves control the skin and muscles. The sensory information can reach consciousness easily, and often motor commands are consciously sent from the cerebrum.

The autonomic nervous system controls most of the complex communication networks that regulate body functions. It works without human consciousness, and you almost never notice that it is functioning. Substances called **neurotransmitters** transport messages in different parts of the nervous system, or between the nervous system and other organs. There are two types of autonomic nervous systems: **sympathetic nervous system** and **parasympathetic nervous system**. They control processes such as blood pressure, heart rate, body temperature, digestion, metabolism, sweating, excretion, and sexual response. Many organs are regulated by both sympathetic and parasympathetic nerves. These two types of nerves work antagonistically. For example, signal input to the sympathetic nerve increases the heart rate, while signal input to the parasympathetic nerve decreases it (Figure 2.8). They also play a major role in regulating blood pressure via hormones.

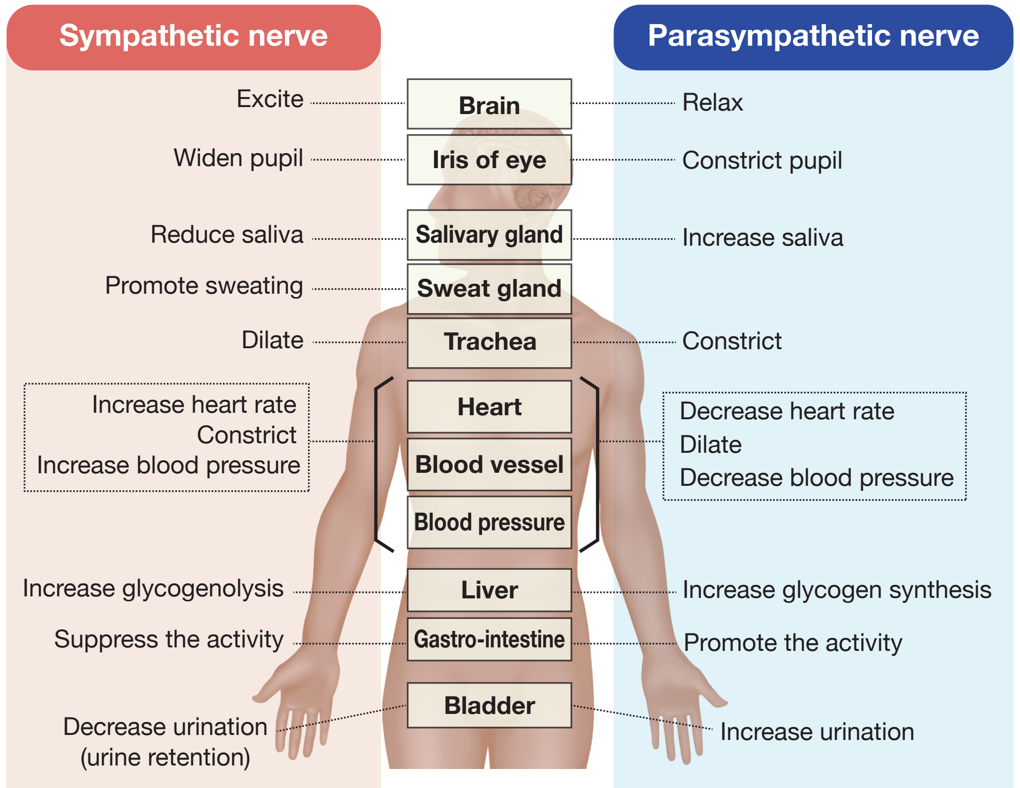

Figure 2.8 Actions of sympathetic and parasympathetic nervous systems

Column: Autonomic nerves referred to as "fight or flight" and "rest and digest"[4]

Generally, the sympathetic nervous system works when you are stressed or taken by surprise. For this reason, it is referred to as "fight or flight," as sympathetic nerves work to either counteract (fight) against or escape (flight) from the situation in order to adapt to the circumstances. This explains, for example, why when you are taken by surprise, your heart beats intensely, your pupils dilate, your breathing becomes fast and deep, your palms get sweaty, and you get thirsty. These are due to hyperactivity of the sympathetic nervous system. On the other hand, the parasympathetic nervous system works when relaxed to encourage you to rest for storing energy. The parasympathetic nervous system also plays an important role in regulating the function of the digestive system, which together makes its function referred to as "rest and digest."

5) Digestive system

The **digestive system** has four roles: food intake and digestion, nutrient absorption, and excretion of unwanted substances. It is composed of a single gastrointestinal tract, which extends 9 m from the mouth to the anus, and several organs attached to it (Figure 2.9). Specifically, these organs include the **mouth (oral cavity) , pharynx, esophagus, stomach, small intestine, large intestine, and anus** for moving and absorbing food, as well as the **pancreas, liver, and gallbladder**, which are responsible for making digestive enzymes, removing toxins, and storing substances needed for digestion.

Food taken from the mouth is digested by the actions of **digestive enzymes** in the digestive juice secreted into the digestive tract while the food is transferred to the stomach and small intestine. The digestive juice is secreted not only from the cells in the digestive tract such as the stomach and small intestine, but also by the salivary glands, pancreas, and liver.

Digested nutrients, water, and various electrolytes are mainly absorbed from the wall of the small intestine into the cell, then into the blood. Most of the absorbed nutrients are sent to the liver. There, they are synthesized, decomposed and detoxified, and converted into a form that can be used by cells throughout the body. What is not absorbed is subjected to water absorption in the large intestine and then is excreted as stool. Gastrointestinal motility and secretory functions are regulated by autonomic nerves, intestinal plexus, and gastrointestinal hormones secreted into the blood from the gastrointestinal wall.

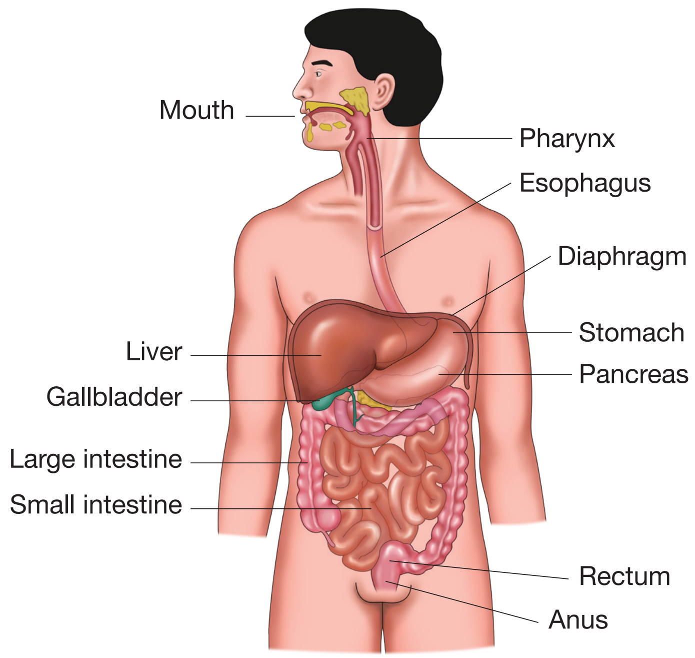

Figure 2.9 Digestive organs

6) Urinary system

As you live, many waste products, excess salts, and non-volatile acids are produced in your bodies as a result of metabolism. The **urinary system** functions to produce urine in the kidneys so as to efficiently remove these substances from the blood and excrete them from the body through the urine. By adjusting the amount and concentration of urine produced, it maintains the amount of circulating blood and its chemical composition.

The urinary system is comprised of the **kidneys** and **urinary tracts** (**ureters**, **bladder**, **urethra**) (Figure 2.10). The kidneys filter and concentrate blood to make urine. The kidneys are located on the left and right sides of the spinal column. Each is about 10 cm in length, 6 cm in width, and 3 cm in thickness. They are slightly larger than the fist, protrudes like a bow on the outside and indents on inside, giving them their bean-shape. By regulating urine production, the kidneys keep fluid volume, osmotic pressure, and pH (acid-base balance) constant, excrete unnecessary metabolites and drugs, and maintain the homeostasis of the fluid environment. The kidneys also have the endocrine function of secreting renin, which is involved in blood pressure regulation, and erythropoietin, which has a hematopoietic effect, as well as activating vitamin D for calcium metabolism.

The bladder is a stretchable sac-like organ that temporarily collects urine. The amount of urine produced per day is about 1.5 L, but the capacity of an adult bladder is 250– 600 mL. You feel a light urinary urge when about 150 mL is collected and a strong one with about 250 mL.

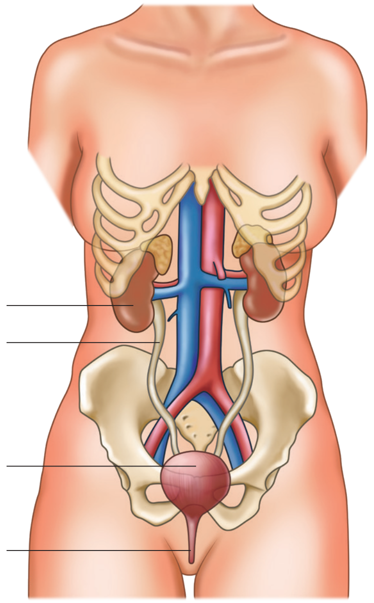

Figure 2.10 Urinary organs

7) Endocrine system

The **endocrine system** consists of **endocrine glands** that are found widely throughout the body (Figure 2.11). It produces chemical substances (transmitters) according to purpose. These substances are collectively called **hormones**. The endocrine system regulates various functions of the body by secreting (releasing) hormones directly into the blood. Hormones work as messengers responding to instructions from the brain, and act on specific organs (**target organs**) in cooperation with the nervous system to control the activities of each part of the body such as metabolism, growth/development, and reproduction. Excessive secretion or deficiency of hormones leads to serious health consequences, with excessive secretion possibly causing hyperfunction, and reduced secretion causing hypofunction.

Major endocrine glands include the **pituitary gland, thyroid gland, pancreas, adrenal glands, and gonads**. For example, **growth hormone**, one of the representative hormones from the pituitary gland, mainly affects the growth of bones and skeletal muscles, determining the size and height of the body. Growth hormone is secreted during exercise and sleep, that's why they say "children who sleep (and exercise) adequately grow well." Reduced secretion from the pituitary gland during childhood causes short stature. The pancreas secretes **insulin** and **glucagon** into the blood, hormones involved in the regulation of blood sugar levels (glucose levels in the blood). Insulin is the only hormone produced in the body that can lower blood sugar levels. When insulin does not function properly, blood sugar levels spike, leading to the possible onset of diabetes.

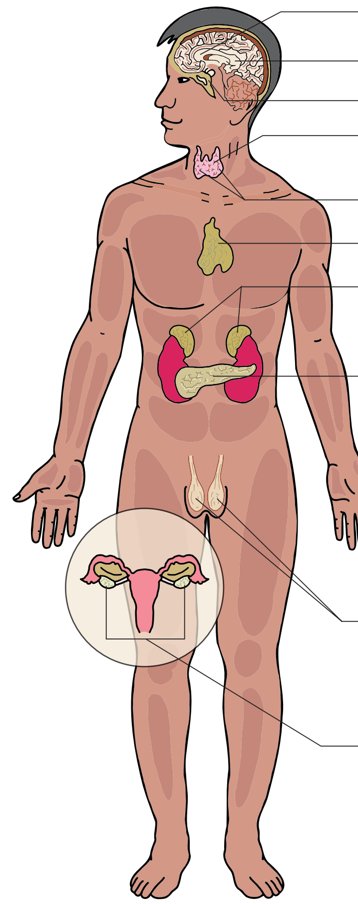

Figure 2.11 Endocrine organs

8) Sensory system[4]

Sensation is awareness and consciousness of sensory information input from the outside or inside of the body. For example, when you say "Ouch!" it means that you have become aware of pain stimulus. For humans to carry out actions and follow their will, they need to carry out a series of actions by swiftly grasping various information from the outside, making judgments based on the information, and working on the surroundings. The sensory system detects internal and external information and conveys that information to the central nervous system.

Receptors are parts of the body that are sensitive to physical and chemical stimuli such as light, sound, body posture and movement direction, temperature, taste, and smell of things. On the other hand, **sensory organs** have a series of structures that transmit these stimuli to the **afferent nerves** (Figure 2.12).

There are **general senses and special senses**. Receptors for the general sense, also called **somatic sense**, can be found all over the body, specifically in the skin, muscles, joints, and internal organs. The general senses include the senses of pain, touch, pressure, temperature, and proprioception (sensory function to feel the relative positional relationship of each part of the body, which forms the body-image). Special senses include vision, hearing, taste, smell, and parallelism. Receptors for these senses are located in specific organs such as eyes, ears and semicircular canals, tongue, nose, and skin.

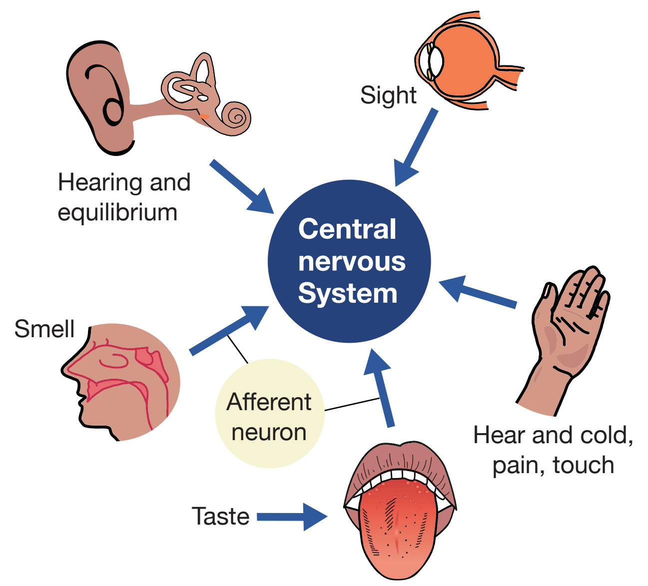

Figure 2.12 Sensory organ system (exchange of signal information)

Column: Why can we see in the dark? (Mechanism allowing to see in the dark)[2]

In "vision," which is the mechanism by which you can see things, sensitivity to light constantly changes according to the intensity (brightness) of light so that you can obtain appropriate light and color information. When you suddenly go to a bright place after being in a dark place for some time, you feel it is very bright, but that glare disappears in a relatively short time (**light adaptation**). This is because photoreceptor cells rapidly reduce their photosensitivity, and miosis occurs due to the contraction of the iris sphincter muscle (pupillary light reflex), which also reduces the inflow of light.

On the other hand, if you move from a bright place to a dark place suddenly, at first you will not be able to see anything, after which you will gradually be able to see things (**dark adaptation**). In dark adaptation, mydriasis is caused by the dilator muscle of the pupil. Vitamin A deficiency causes failure to adapt to darkness and this is called "night blindness." Vision is discussed in detail in Chapter 8.

9) Reproductive system

Reproduction is the act or process by which male and female germ cells, namely **eggs** and **sperms** are fertilized, to create new beings with the genetic information of each cell. The reproductive system has two functions. The first is production, development, and transport of eggs and sperms, and the second is the secretion of hormones. There are two types of reproductive organs, **primary reproductive organs** and **secondary reproductive organs**. The primary reproductive organ, which is the gonad (**ovary** in females and **testes** in males), has two functions: secretion of hormones and production of egg and sperm. During growth, the functions of the reproduction system change significantly, the details of which are discussed in Chapter 11.

(1) Male reproductive system (structure and functions)

The male reproductive organs consist of (1) testes; (2) epididymises, sperm ducts, and ejaculatory ducts (for maturation of sperms, transport path, and ejection); (3) seminal vesicles and prostate (attached gland); and (4) penis and scrotum (extrinsic region) (**Figure 2.13**). Reproductive functions include (1) sperm formation in the testes, (2) sexual response (various physical and mental changes that occur when sexually stimulated), and (3) regulation of reproductive functions by hormones.

(2) Female reproductive system (structure and functions)

The female reproductive organs consist of (1) ovaries; (2) fallopian tubes, uterus, and vagina (for transportation route); and (3) mons pubis, clitoris, labia majora, labia minora (**Figure 2.13**). Reproductive functions are (1) conception and preparation for pregnancy, (2) pregnancy, and, similar to male, (3) sexual response, and (4) regulation of reproductive functions by hormones.

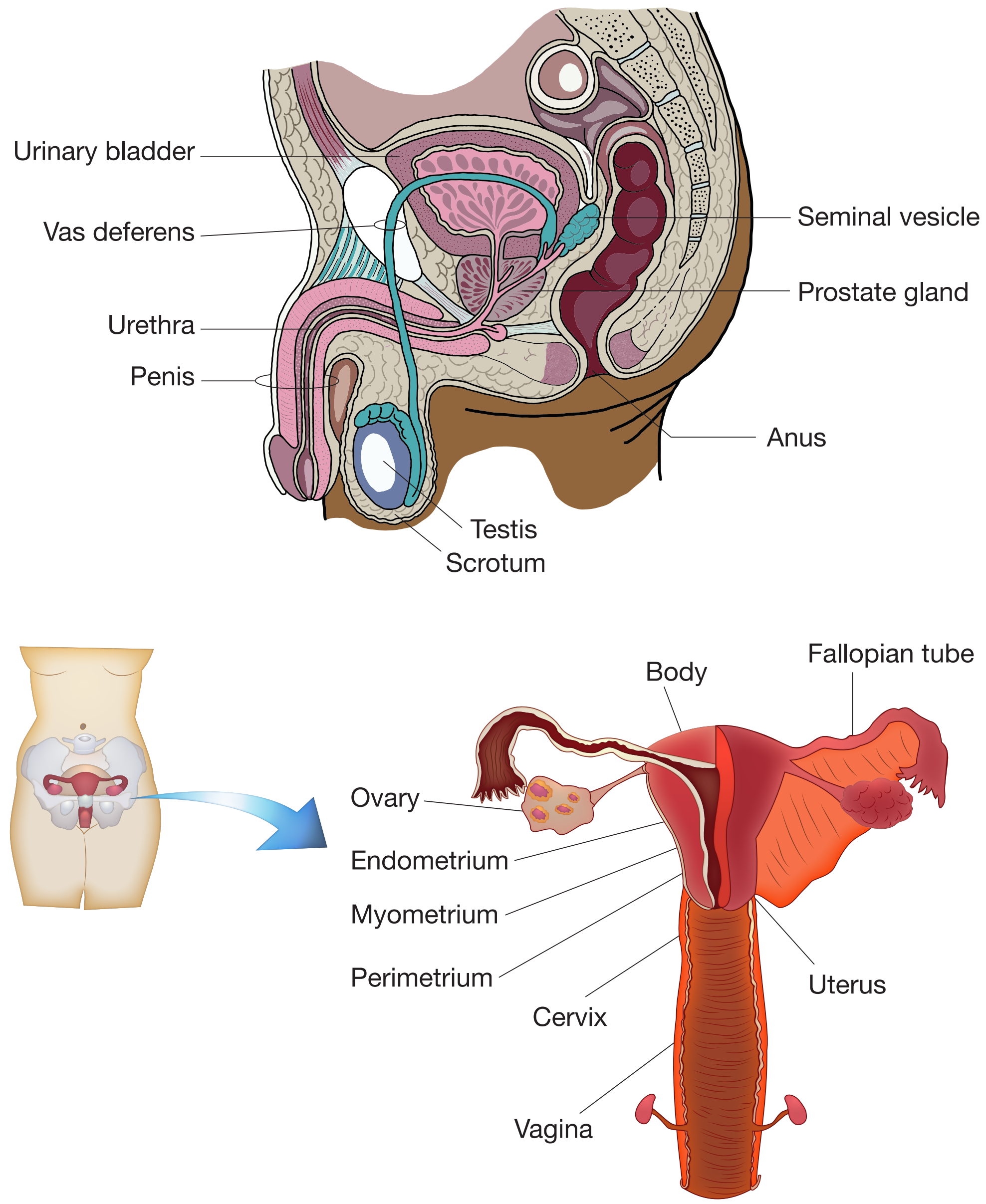

Figure 2.13 Reproductive system (top: male reproductive organs, bottom: female)

10) Immune system[5]

Immunity is a self-defense mechanism in which immune cells in the body prevent the entry of foreign invaders or pathogens, such as bacteria and viruses, and eliminate harmful substances produced in the body. Many types of **immune cells** work together to play the roles of discovering, transmitting information about, and attacking foreign invaders. There are two main types of immune functions that eliminate foreign substances entering the body: **innate (natural) immunity** and **adaptive (acquired) immunity**.

Innate immunity is a mechanism that identifies a wide range of characteristics common to pathogens and acts swiftly. It includes **phagocytosis** (action of taking foreign substances into cells and digesting them) by neutrophils, monocytes, dendritic cells, and macrophages to eliminate foreign substances, inflammatory reactions, and attack by natural killer (NK) cells. On the other hand, adaptive (acquired) immunity works against foreign substances that cannot be eliminated by innate immunity. In this case, lymphocytes act specifically on foreign substances. It can be divided into **humoral immunity**, in which B cells **produce antibodies** from the actions of lymphocytes, and **cellular immunity**, in which killer T cells **directly attack** cancer cells and infected cells (Table 2.2).

The immune system works to identify what is in the body as its "self" or "nonself," and to eliminate the latter. To do this, the immune system coordinates innate immunity and adaptive (acquired) immunity to deal with disease-causing microorganisms (pathogens). On the other hand, because the immune system may overreact to your "self" and cause diseases (**autoimmune diseases**), there is a system that adjusts the immune system to maintain the immune homeostasis of the living body in a balanced way.

There are many types of organs that contribute to immune cells and immunity (Figure 2.14). For example, almost all immune cells are produced in the bone marrow. Immature T cells produced in the bone marrow gather and mature in the thymus. The thymus, consisting of left and right parts, is located in such a way that it covers the heart. During puberty, the thymus reaches a maximum weight of 30–40 g. After puberty, the thymus begins to atrophy. The details of immunity are discussed in Chapter 7.

Table 2.2 Types and functions of human immunity and defense

Type		Main functions	Target
(1) Physical/chemical defense		Skin, mucous membranes, saliva, sweat, tears, runny nose, gastric acid	Various foreign substances (Nonspecific)
(2) Innate immunity		Phagocytotic elimination, inflammatory reactions, NK cell attack	
(3) Adaptive immunity (Acquired immunity)	Humoral Immunity	Antibodies produced by B cells react specifically with the antigens to eliminate them	Specific foreign matter (Specific)
	Cellular Immunity	Killer T cells and B cells eliminate cancer and infected cells	

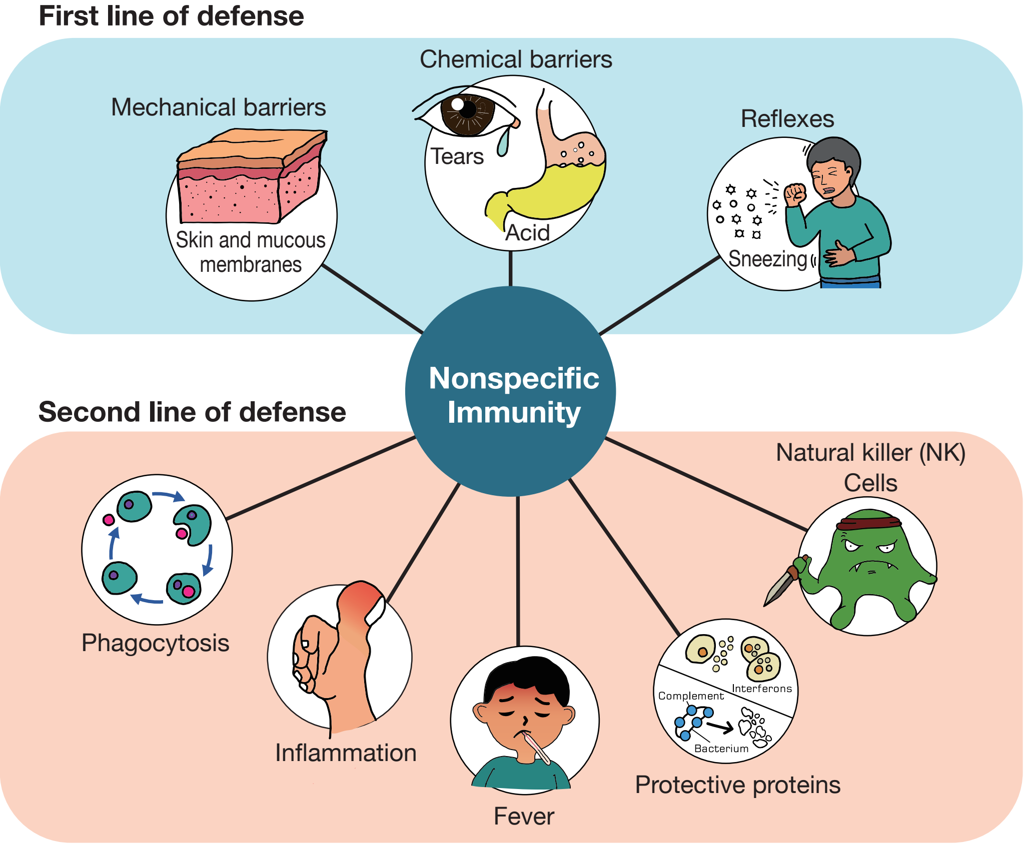

Figure 2.14 Immunity functions (innate immunity)[4]

3. Mechanisms that support human activities in daily life

Mechanisms maintaining defense functions and regulatory mechanisms for sustaining life and the homeostasis of the human body

1) Homeostasis of internal environment and its regulatory mechanism

What happens to your bodies in your daily lives? Living things have functions that help them stay balanced and maintain a similar state with their surrounding environment. This is called **homeostasis** (see also Chapter 6). To maintain homeostasis, the mechanism of information transmission in the living body is crucial, and two systems serve this purpose: the **nervous system that transmits information by electrical signals** and the **endocrine system that transmits information via chemical substances.**

2) Thermoregulation

The system that keeps the body temperature constant is very important for the brain and for sustaining life. For example, hyperthermia such as **heat stroke** causes brain dysfunction, and can be life-threatening.

(1) Body heat production and dissipation

Your body temperature differs by location. The temperature at the core of the body is called **core temperature** and cannot be measured directly. For this reason, rectal temperature, oral temperature, and axillary temperature are used. The rectal temperature is the closest to the core temperature. Even if the environmental temperature fluctuates, it remains more or less constant at about 37°C, which is 0.4–0.7°C higher than axillary temperature. The temperature of the skin and muscles is called **outer shell temperature**, and it differs according to the body part and outside temperature.

(2) Thermoregulation mechanism

The **temperature regulatory center** in the hypothalamus (diencephalon) works on cutaneous blood vessels, sweat glands, and arrector pili muscle to regulate temperature. Thermoregulation in humans is controlled by the sensitivity of skin temperature receptors and temperature receptors in the hypothalamus. (**Figure 2.15**).

When the body temperature rises, the sympathetic nerves work less, the blood vessels passively dilate, and sweating dissipates heat from the skin to regulate the body temperature within the normal range. Meanwhile, when the body temperature decreases, the sympathetic nerves constrict blood vessels.

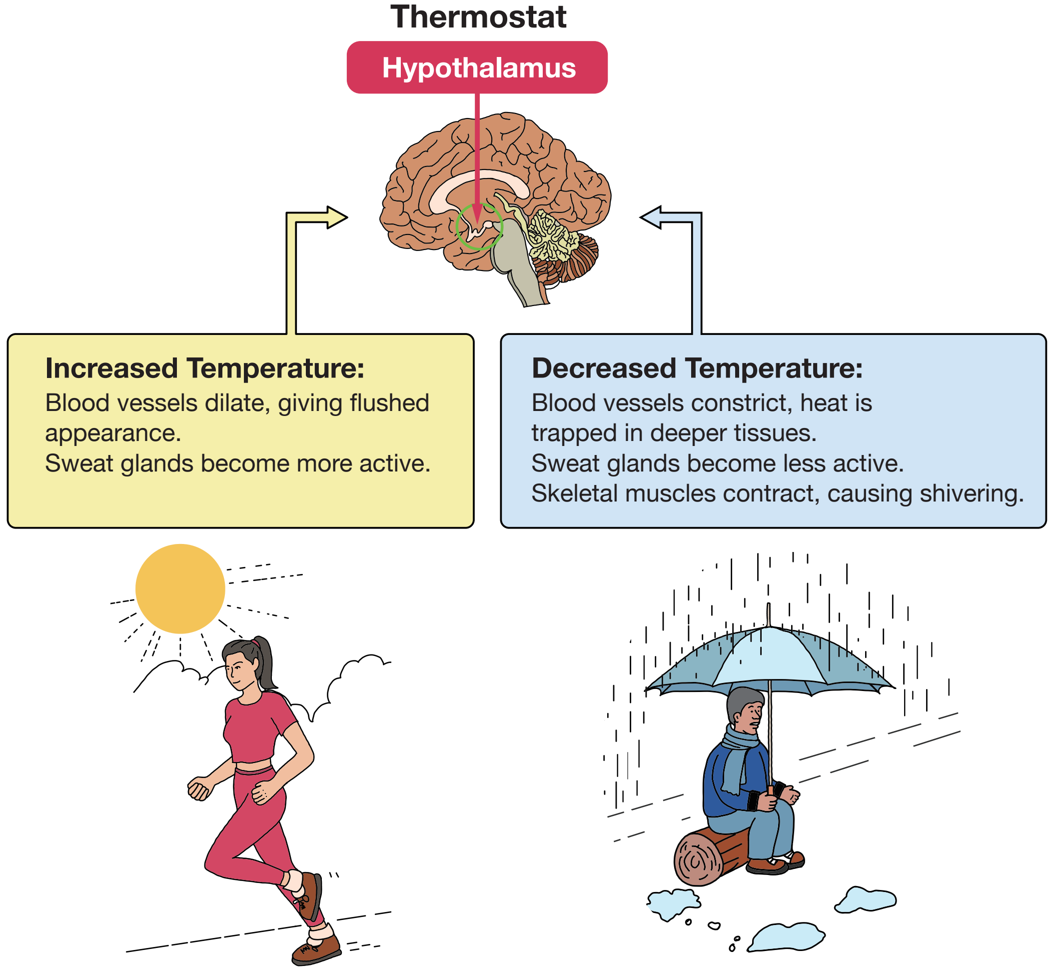

Figure 2.15 Mechanism of body temperature regulation [4]

This reduces the amount of blood flowing to prevent heat dissipation, and inadvertent muscle contraction causes heat production. Exceeding the limit of the thermoregulation range may lead to consciousness disturbance or death.

(3) Diurnal fluctuation (see also Chapter 6)

Body temperature drops to the lowest level during sleep in the early morning, starts rising as you wake up, and sharply rises after breakfast. After that, it continues to rise gradually and peaks in the evening, after which it starts dropping. This change in body temperature in the cycle of one day is called **diurnal fluctuation (circadian rhythm).** Circadian rhythm is present in many vital activities such as body temperature and blood pressure and affects sleep and dietary patterns. If disturbed, sleep rhythm will be disrupted, for example, resulting in sleep disorders. It is said that a good way to regulate this rhythm normally is to receive sunlight in the morning.

Column: Body temperature rhythm of women during and after puberty [6]

In women during and after puberty, the body temperature fluctuates due to the effects of hormone secretion according to the menstrual cycle. From menstruation to preovulation, body temperature is low (normal body temperature). After ovulation, the body temperature rises. The difference between the low and high temperature periods is about 0.5°C. This fluctuation is due to the progesterone (secreted from the corpus luteum formed in the ovaries during the secretory period) acting on the hypothalamus in the temperature regulatory center.

Exercises for further thought and research

[2-1] Use information about the body: Challenge the quiz!

(1) Does the number of times you blink change when using a smartphone?

(i) Increases (ii) Same (iii) Decreases

(2) How much do you breathe in one day? (In terms of 500 mL plastic bottles)

(3) How much blood is sent from the heart to the entire body in one minute? Measure your pulse for one minute and make a prediction based on it (see Chapter 15 for how to measure your pulse).

References

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3 Anatomical Physiology: Structure and functions of the human body (1). Igaku-Shoin, Tokyo. 2018.
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Answers

[2-1] Use information about the body: Challenge the quiz!

(1) Does the number of times you blink change when using a smartphone?

A. **(iii)**. You blink less when concentrating on something such as when looking at the screen of your smartphone. When you blink less, tears do not spread on the surface of the eyes, causing the eyes to dry. It can also cause "dry eye which leads to subjective symptoms such as dryness and uncomfortable sensation and damage (scratches) on the surface of the eyes.

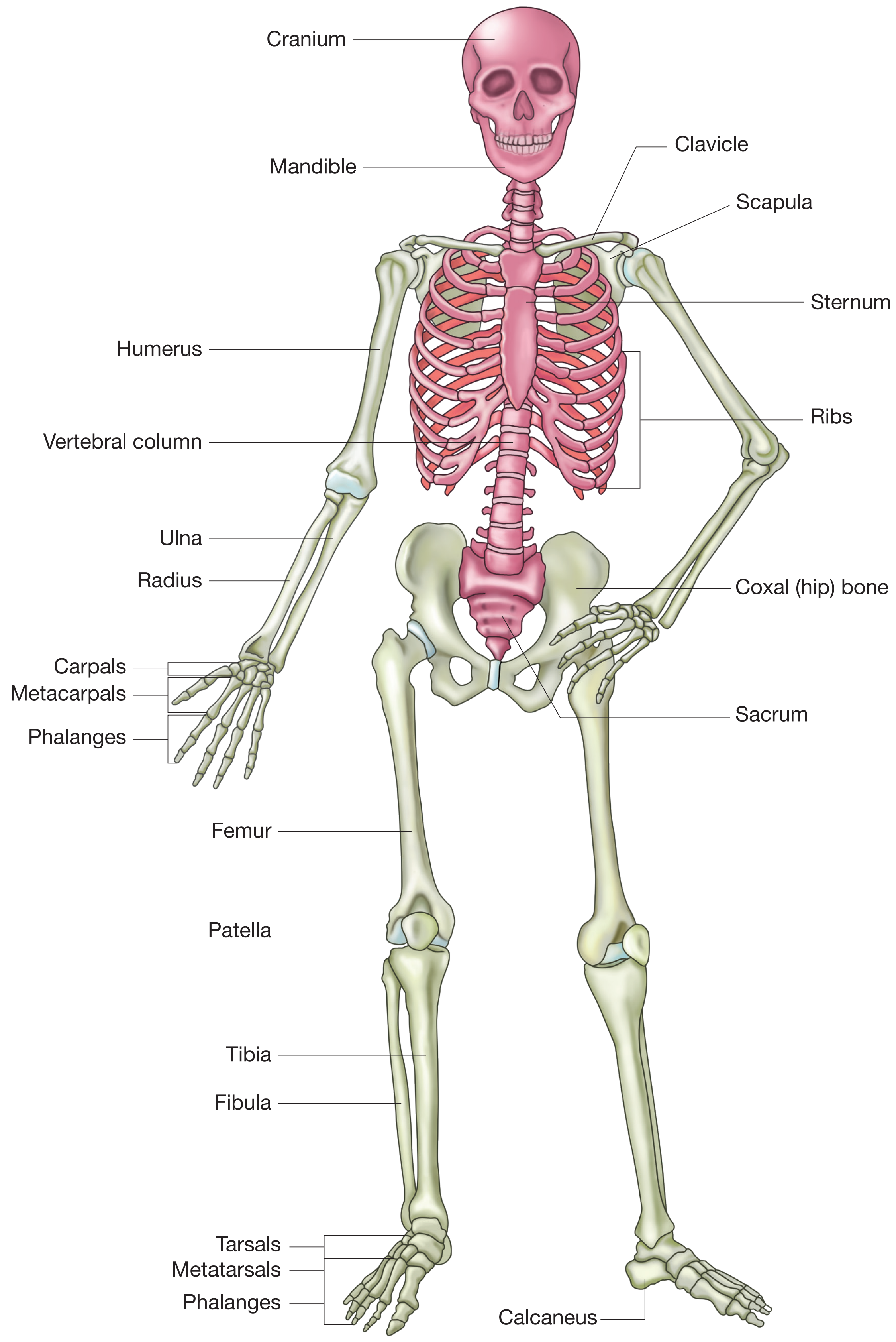
(2) How much do you breathe in one day? (In terms of 500 mL plastic bottles)

A. **About 11,520 L** (taking the amount you breathe each time to be about 0.5 L)

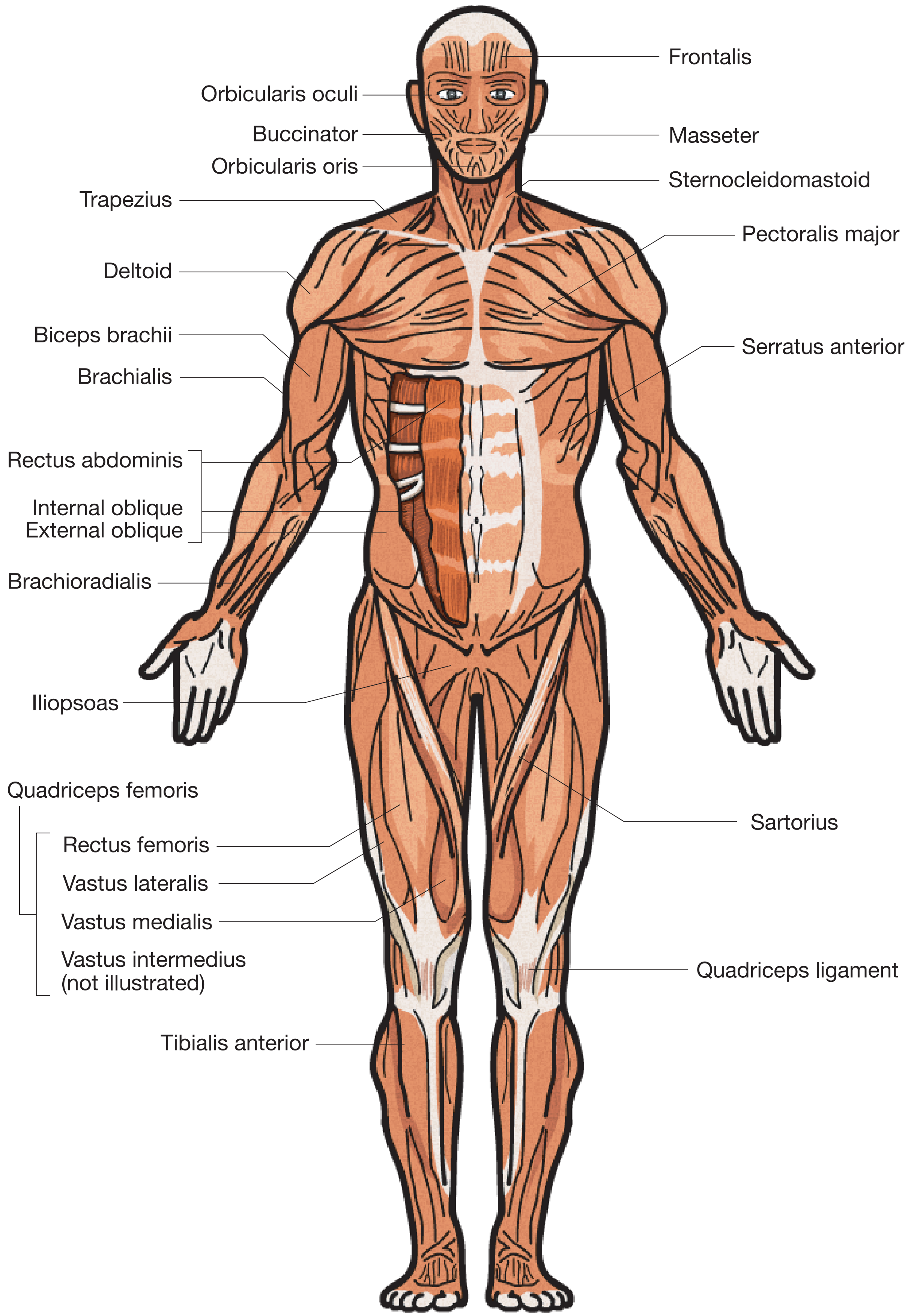
(3) How much blood is sent from the heart to the entire body in one minute?

A. **Approximately 5 L.** For adult, approximately 60–70 mL of blood is pumped out by one contraction of the heart. The heart beats 60–80 times per min. Normally, your heart rate is equal to your pulse rate. For example, 60 mL × 80 times = approx. 5 L volume of blood is sent to the entire body in 1 min. The volume of blood pumped out per minute varies depending on the individual's age, body size, gender, health condition, and exercise experience.

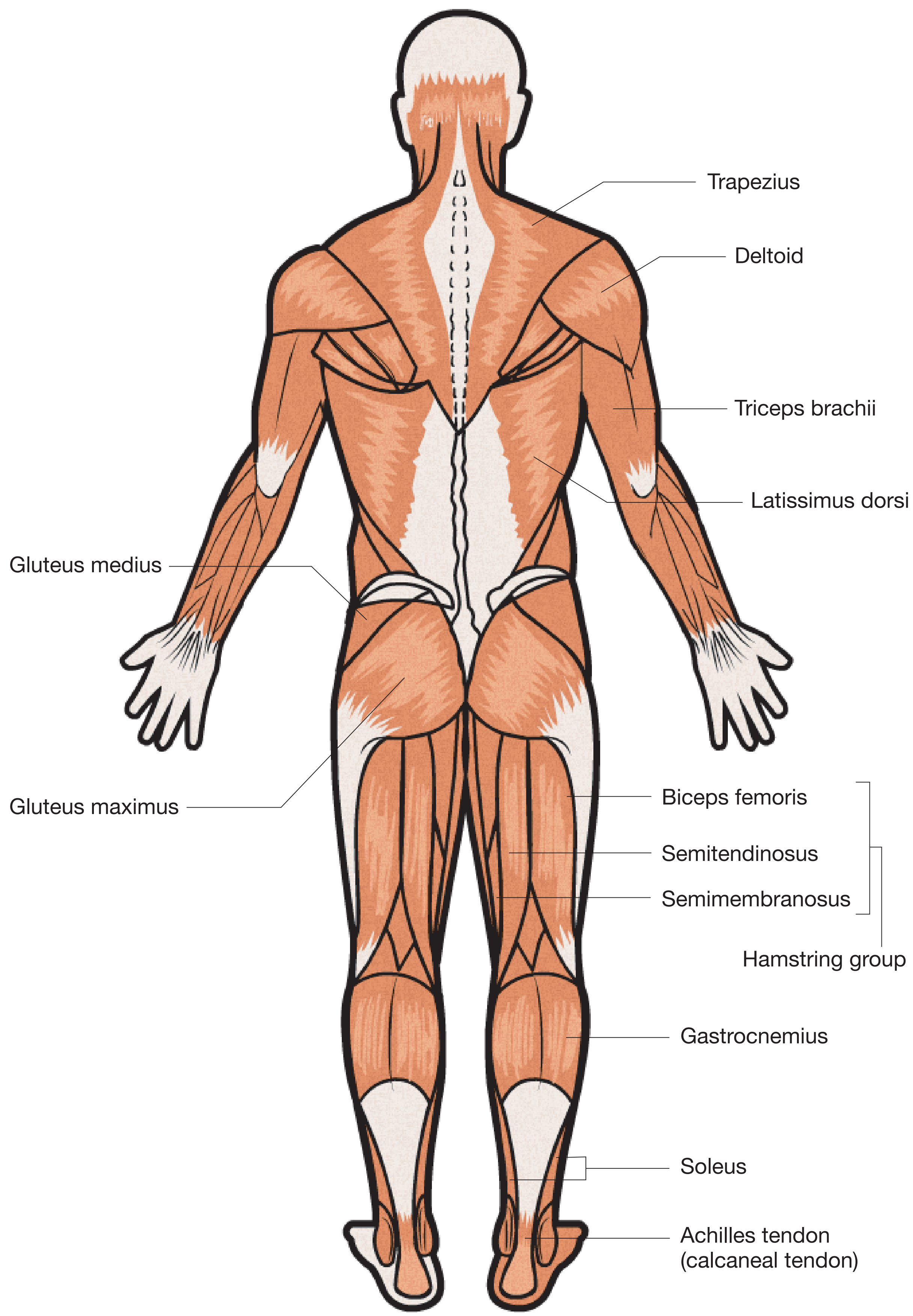
Supplemental materials (Suppl.)



Suppl 2.1 Skelton. Axial skeleton (pink) and appendicular skeleton (tan).



Suppl 2.2 Major muscles of the body. Anterior view.



Suppl 2.3 Major muscles of the body. Posterior view.