ANATOMY AND PHYSIOLOGY

The human body contains an array of interlinked systems that allow it to work autonomously. For the body to be at equilibrium, all these systems must work properly and in harmony.

VITAL SYSTÈMS

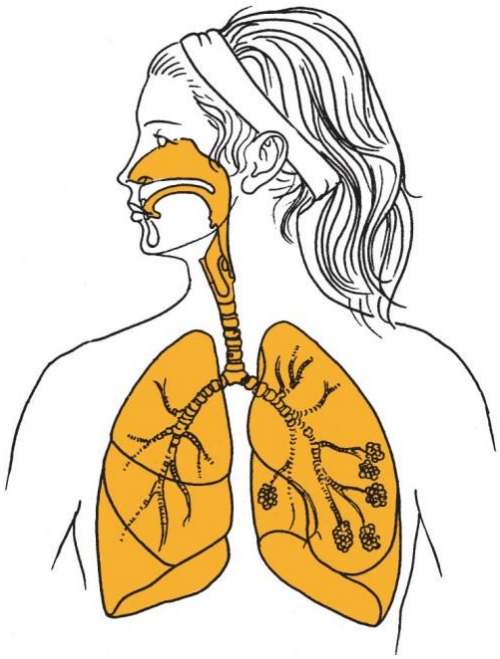
Every cell of the organism requires a constant supply of oxygen (O_2) to accomplish different vital functions, such as the contraction of the cardiac muscle to propel blood, cellular division to allow growth, reparation of the organism, etc. While is it possible to survive for a short while without water or food, it is impossible to deprive oneself of oxygen.

Supplying oxygen is the function of the respiratory system. When a person breathes in, their lungs fill with air and the blood is then oxygenated. The cardiovascular system transports the oxygenated blood from the lungs to all the cells of the organism. It also transports carbon dioxide (CO_2), a waste product of the cells, to the lungs, where it is expelled during the expiration.

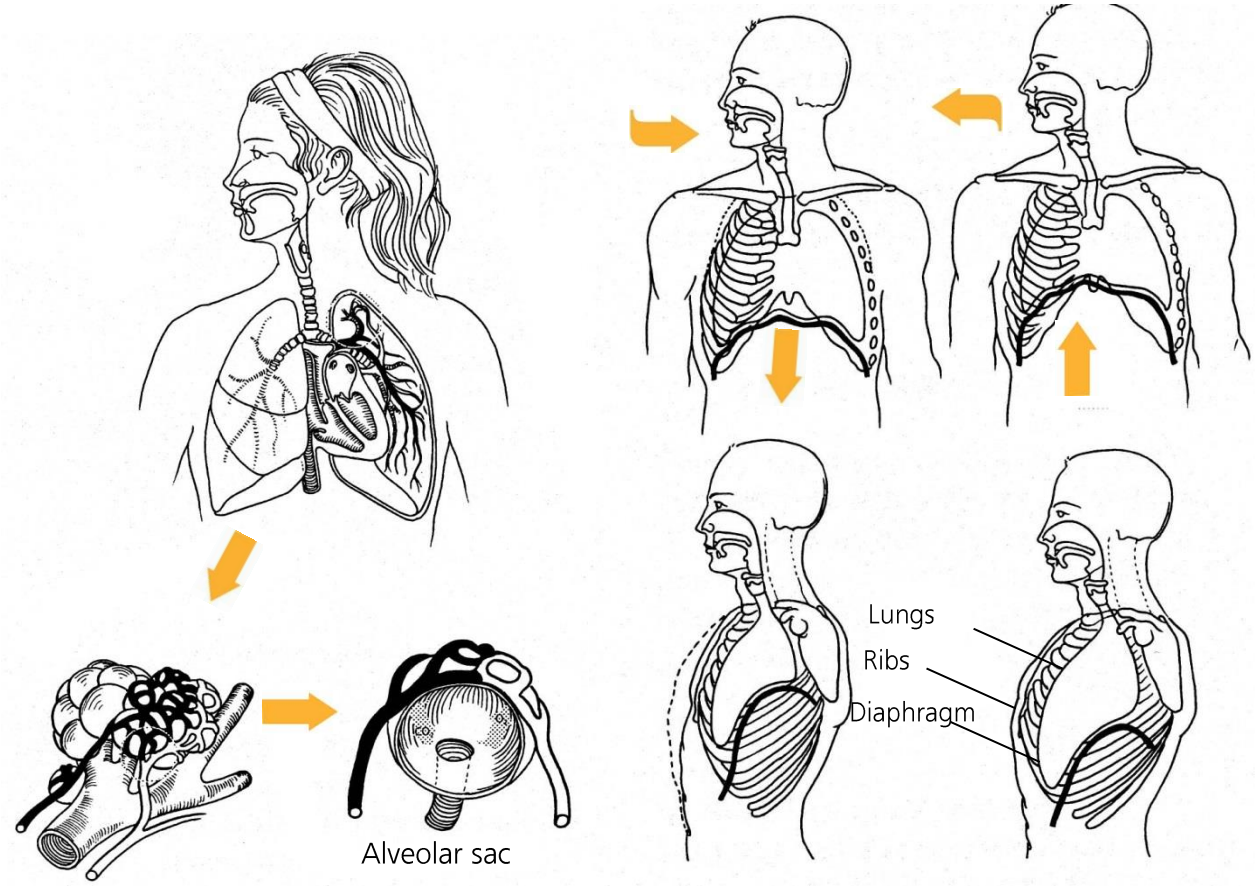
The respiratory system

The nose, the pharynx (the throat), the larynx (the vocal folds), the trachea and the lungs, including the bronchus and the alveoli are the organs of the respiratory system.

The main function of the respiratory system is to allow to constantly supply oxygen to the organism and to eliminate carbon dioxide. The passage by which the air moves in and out of the body is called the airways. During inspiration, air enters by the mouth and the nose. It then moves through the pharynx, the larynx and the trachea, enters the lungs by the bronchi and then the bronchioles (ramifications resembling those of a tree) and, finally, into the alveolus (small pouches of air). The oxygen in the alveolus enters the blood through the capillaries. Carbon dioxide in the blood crosses through the thin linings of the capillaries to enter into the alveolus, to be eliminated during expiration.



Air enters the lungs during inspiration and exits during expiration. When a person inhales, the diaphragm and thoracic muscles contract and air enters the lungs. When the diaphragm contracts, it lowers, and the volume of the thoracic cavity increases, which enables the expansion of the lungs during the inspiration. When a person exhales, the diaphragm and muscles relax, thus enabling expiration. It is because of this contraction that inspiration is called the active phase and expiration the passive phase.



During a normal inspiration, about 500 millilitres (ml) of air enter the airways.

How is breathing controlled?

Breathing is controlled by the autonomic nervous system. Even if it is possible to voluntarily modify one's own breathing, the regulation of this function is still mostly automatic and the amplitude and frequency of inspirations is adjusted as needed.

What triggers inspiration?

Breathing is closely linked to the concentration of carbon dioxide in the blood. When this concentration increases, the organism feels the need to breathe in order to eliminate this excess. This mechanism works thanks to receptors, located mostly in the medulla, which are hypersensitive to carbon dioxide (CO_2). Assembled in clusters, they also control the frequency and amplitude of breathing, via the phrenic nerve.

Every three or four seconds, the neurons of the spinal cord, which pass through the phrenic nerve emerging from the spinal cord at the cervical level, stimulate the contraction of the diaphragm and provoke the inspiration. This nerve is responsible for the frequency of the breaths. In a single minute, an adult can breathe between 12 to 20 times, a child between 12 to 30 times and a toddler between 20 to 30 times. However, this frequency can be modified greatly according to the needs of the organism. The same goes for the amplitude of the respiratory movements.

Did you know?

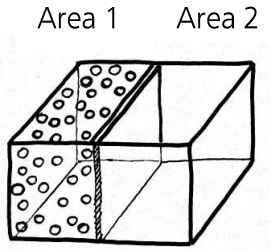
A person can voluntarily reduce or increase their breathing frequency. However, it is impossible to voluntarily modify your own pulse. For example, when a rescuer is recording the breathing frequency of the victim, the latter has a tendency to change their respiratory rhythm.

How does oxygen go from the alveoli to the capillaries, and from the capillaries to the cells?

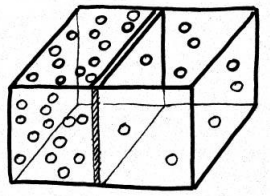
Through **diffusion**, in other words an autonomous movement of particles from one area to another (for example, oxygen passing from the pulmonary alveoli to the pulmonary capillaries). The difference in concentration of molecules between the two areas determine the direction of diffusion (from the most concentrated area to the least concentrated). In the case of the lungs and the capillaries, these two areas are separated by a semi-permeable (or selective) membrane.

To explain this phenomenon, let us take the following example:

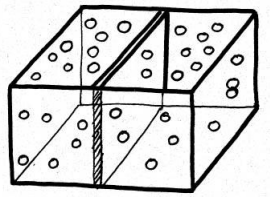
1. Imagine a container separated into two parts by a semi-permeable membrane. The first part is filled with oxygen and the second part is empty (see image).



2. To reach equilibrium, that is to say, for the number of particles to be equal on both sides, certain particles pass through from area 1 to area 2. This is called diffusion (see image).



3. The amount of particles in area 1 will eventually equal the amount of particles in area 2 (see image). At that moment, equilibrium between the two areas is reached.



Did you know?

When muscles are actively working, for example during physical effort, a greater quantity of carbon dioxide ends up in the bloodstream. The medulla detects this surge and provokes an increase in the amplitude and frequency of breathing to eliminate this excess.

All the cells of an organism need a constant supply of oxygen. A lack of oxygen can have severe consequences (for example, the death of heart cells, brain cells, etc.). It is therefore important to be familiar with serious respiratory problems such as obstruction of the airways, asthma or anaphylactic shock in order to be able to quickly dispense first aid.

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The cardiovascular system

The cardiovascular system is comprised of the heart, the blood and the blood vessels. Located between the lungs, the **heart** is the center of the cardiovascular apparatus. About as big as a closed fist, this muscular organ beats over 100,000 times a day!

The heart is an autonomous muscle, which means it can work without being constantly stimulated by the central nervous system. It contains its own nervous system which controls its rhythm (like a natural pacemaker of sorts). This nervous system is comprised of three (3) main parts:

The sinus node

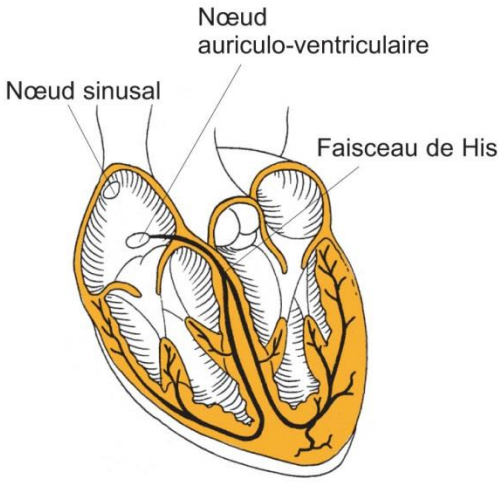
Located in the upper part of the right atrium, this point generates, at a rate of 70 to 80 times per minute, electrical impulses. These impulses are dispatched, via the cardionector cells, through the cardiac muscle towards the other relays of the heart's electrical system

The atrioventricular node

Located between the right atrium and the right ventricle, it transmits the received impulsion or produces its own automatically (60 times per minute) in case of sinus node failure.

The His bundle

Starting from the atrioventricular node, it transmits electric current to the rest of the cardiac muscle, or produces an electrical impulse 30 to 40 times per minute.



Le système de conduction du cœur

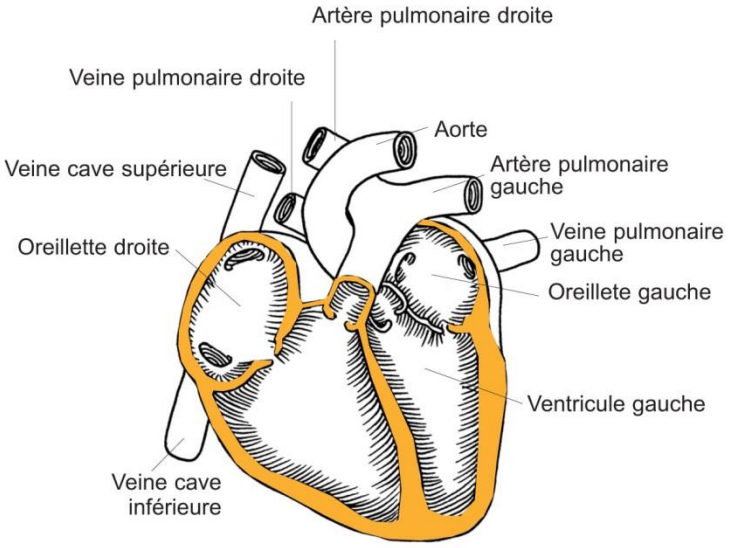
All of these parts of the system ensure the proper functioning of the heart, even if one of its parts is defective. Different nodes are programmed to generate nerve impulses, ensuring a normal cardiac rhythm. It is possible to analyse these impulses using an electrocardiogram (graph representing the heart's electrical activity). Note that the brain can make this rhythm vary depending on the needs of the body (e.g. during physical activity).

Though it is secure, this system can experience difficulties, such as cardiac arrhythmia. Their cases can be varied and are usually associated with a lack of oxygen (such as during an infarction). Arrhythmias can cause an imbalance in the heart's beating, reducing its efficiency. One of the most common arrhythmia is the ventricular fibrillation, which can be treated by defibrillation (for more information, see the AED slideshow).

The main function of the cardiovascular system is to transport blood inside the organism.

The heart is divided into four cavities called cardiac chambers:

- The right atrium;
- The left atrium;
- The right ventricle;
- The left ventricle.



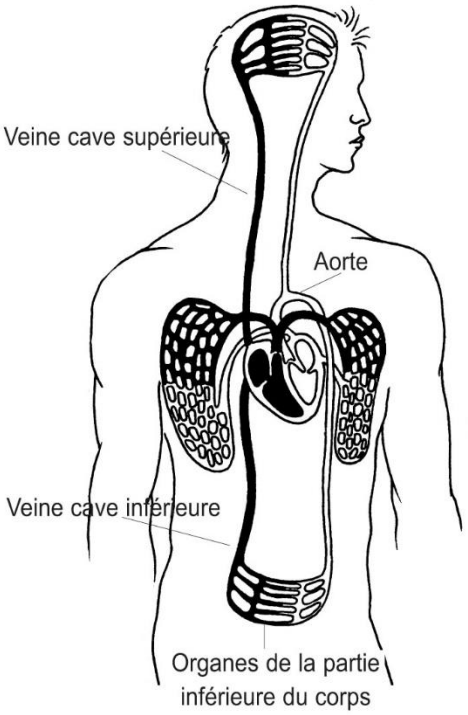
The left and right parts of the heart are isolated from one another. However, the atriums communicates with the ventricles located directly underneath.

The blood vessels create a network of conduits through which the blood can continuously circulate, travelling across the heart, the arteries, the capillaries, the veinlets and the veins. There are two types of vessels: veins and arteries. As a general rule, blood going through arteries is coming out of the heart, and blood going through veins is going into the heart.

Generally speaking, the farther a vessel is from the heart, the smaller it is. This is why there are no large veins or arteries in the toes and fingers. Vessels divide to reach the largest possible amount of cells. As distance from the heart increases, arteries become smaller until they are arterioles, then capillaries. To loop back to the heart, capillaries reunite and become veinlets; these, in turn, become veins that lead to the heart.

The heart is a muscle that has two functions:

- propel the oxygenated blood coming from the lungs into all parts of the body (**greater circulation** or systemic circulation);
- propel deoxygenated, carbon dioxide-rich blood to the lungs, allowing it to trade carbon dioxide for (**lesser circulation** or pulmonary circulation).



The **right side of the** heart is the pump of pulmonary circulation. Blood coming from the superior and inferior venae cavae, deoxygenated and carbon dioxide-rich, enter through the right atrium and flows into the right ventricle. The contraction of the right ventricle pushes the blood in the pulmonary trunk, which divides into two pulmonary arteries, and then into the lungs, or more precisely into the alveoli. There, the blood expels its gaseous waste (for example, carbon dioxide) and becomes oxygenated.

The oxygenated blood comes back through the pulmonary veins, into the **left side of the heart**, which serves as a pump for systemic circulation. It enters through the left atrium and flows into the left ventricle. The contraction of the ventricle propels the blood into the aorta, then into the arterial system all the way into the systemic capillaries.

There, cells catch their fuel (e.g. oxygen) and dump their waste (e.g. carbon dioxide). The deoxygenated and carbon dioxide-rich blood comes back into the right side of the heart through the superior and inferior venae cavae and flows into the right atrium, and the whole process starts anew. Note that the right and left sides work simultaneously, but independently

The heart is responsible for transporting blood and oxygen to cells throughout the entire body, allowing them to resupply. But how does it nourish itself?

Blood flowing continuously through the heart's chambers cannot effectively nourish the cardiac muscle (the myocardium). The latter is too thick for nutriments and oxygen to be able to penetrate its entire thickness. Thankfully, the heart has its own vessels, the coronary arteries, which allow it to stay nourished.

Did you know?

*The **coronary arteries** can be affected by atherosclerosis, an accumulation of fatty deposits caused by various risk factors such as hypertension, diabetes, smoking, etc. This accumulation can compromise the irrigation of a part of the myocardium. This is at the root of the most frequent cardiac problems, such as angina, (partial obstruction) and myocardial infarction (complete obstruction).*

Note
It is important to rapidly identify cardiac problems, because it is the cardiovascular system that ensures blood transportation and thus the organism's supply of oxygen.

How is blood oxygenated?

Before reaching the alveoli, blood contains a little oxygen and a lot of carbon dioxide, whereas the concentration of oxygen in the alveoli is much higher. Consequently, oxygen particles tend to, through diffusion, pass from the lungs (alveoli) to the pulmonary capillaries. Oxygen is thus diffused from the blood to the cells, while carbon dioxide is diffused from the cells to the blood.

While humans breathe around 21% of oxygen, their bodies only require approximatively 5%. Expired air thus contains about 16%. This means that it is possible to supply a person with oxygen and to keep them alive using artificial respiration.

Concentration of most common gasses during inspiration and expiration

Gas	Inspiration	Expiration
Nitrogen (N)	78%	78%
Oxygen (O)	21%	16%
Carbon Dioxide (CO_2)	0%	5%
Rare gasses	1%	1%

How is circulation controlled?

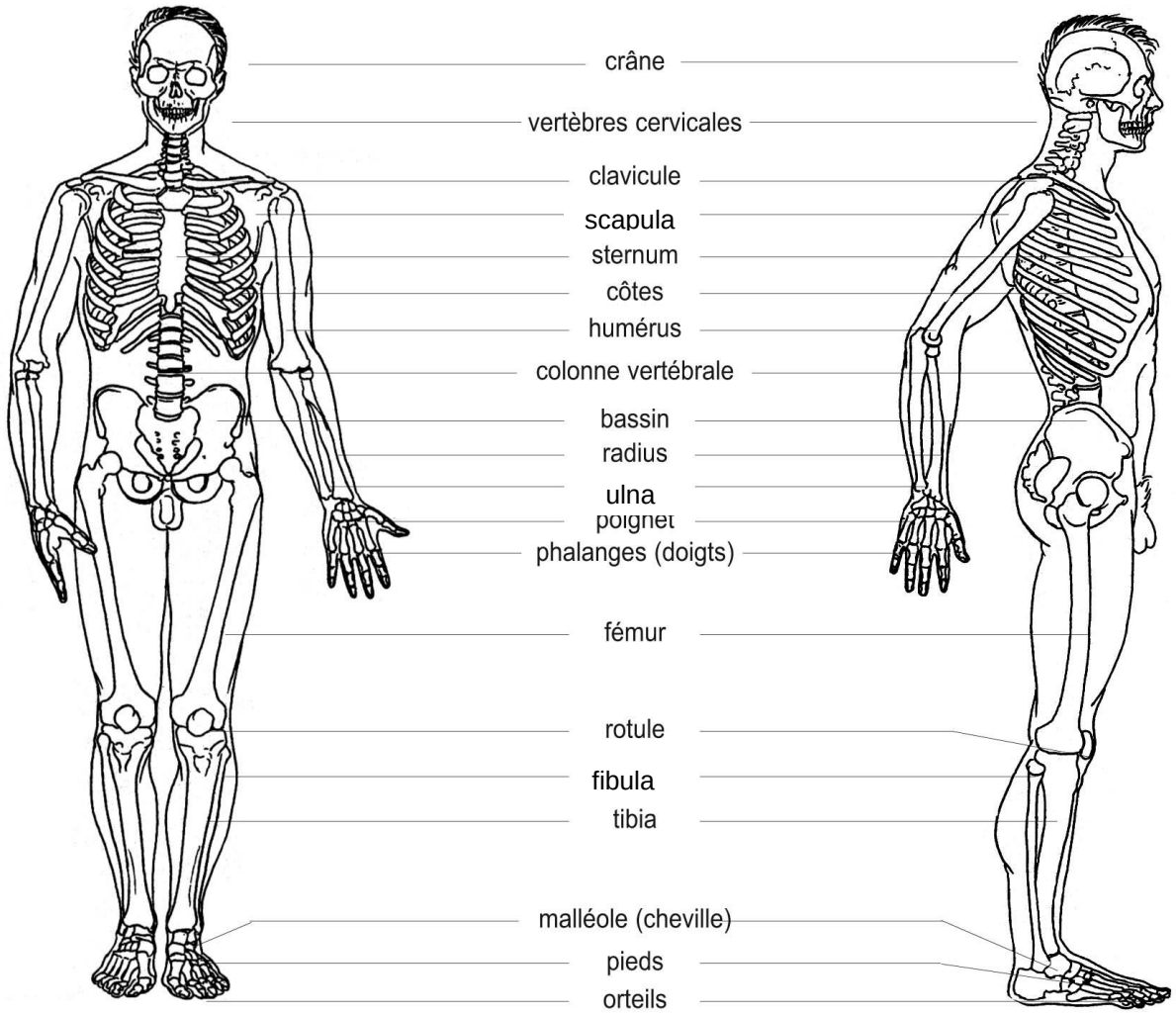
Much like breathing, circulation is controlled automatically by factors such as oxygen and carbon dioxide concentration in the blood, as well as pressure changes.

THE MUSCULOSKELETAL SYSTEM

Movements as simple as throwing a ball or walking require the coordination of the nervous, muscular and skeletal systems.

The skeletal system

The skeletal system is usually comprised of 206 bones. It is the body's framework. All of the body's other systems rest upon it. The skeleton offers support (allowing humans to stand upright), protects the internal organs, and allows for movement. The bones of the skull protect the brain and the vertebrae protect the spine.



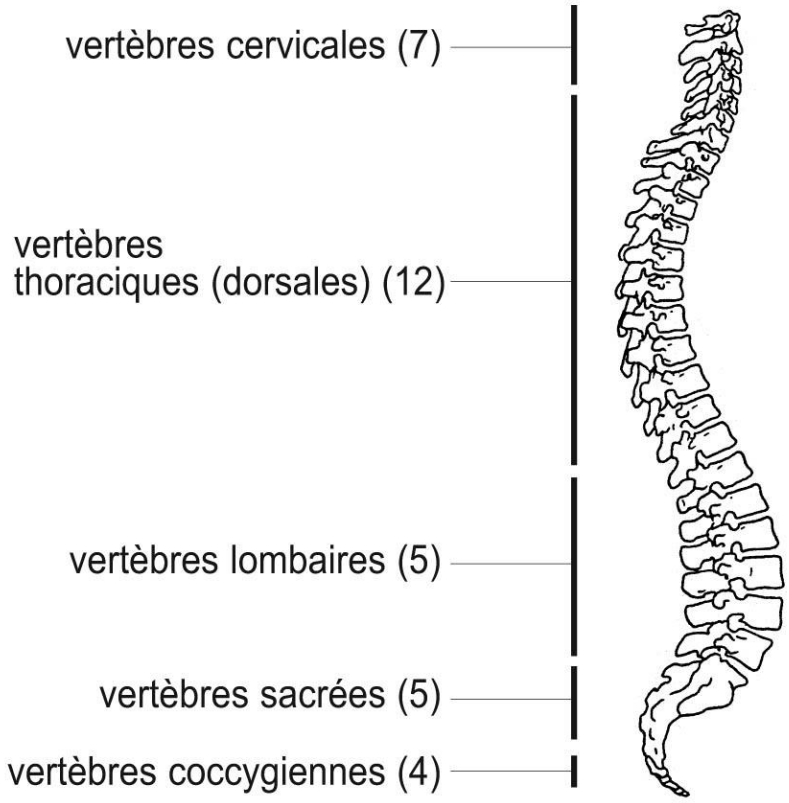
Le squelette

Did you know?

When a bone has a lesion (for example a fracture), everything that is attached to it is disrupted, which can lead to serious problems. For example, a fractured vertebrae in the spine can damage the spinal cord and cause paralysis.

The contact points between two bones, also known as joints, have two basic functions: 1) they link two bones together and 2) they allow for a certain amount of mobility. The bones are attached to each other at the joint by **ligaments**. The illustration on the previous page shows the main bones of the skeletal system.

The **spine** is an important part of the human skeleton: it contains and protects the spinal cord, holds the head and serves as anchor points for the ribs and back muscles. It is composed of 33 vertebrae separated into five sections:



La colonne vertébrale

Each vertebra has a specific shape depending on the section to which it belongs.

The **cervical** vertebrae make up the neck. They are very mobile.

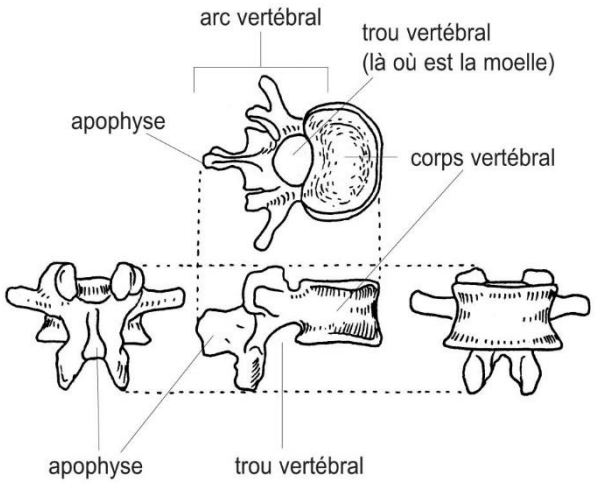
The **thoracic vertebrae** are attached to the ribs. They are part of the thorax and are not very mobile.

The **lumbar** vertebrae are very mobile.

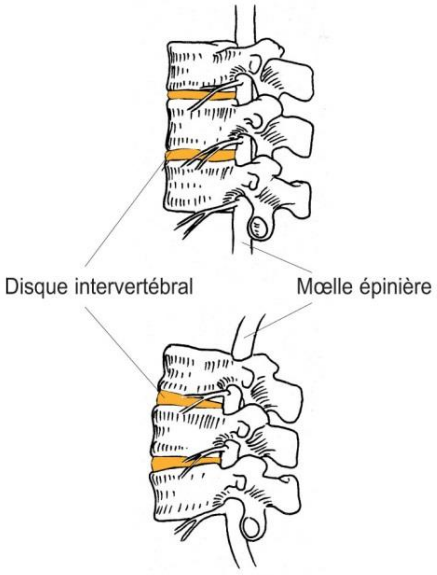
The **sacral and caudal vertebrae** which are welded into their respective group and are linked to the iliac bone.

The **vertebral arch** protects the spinal cord, which is located between the arch and the vertebral body.

The **transverse processes** of a vertebrae are in contact with those of the superior and inferior vertebrae. They can be felt during a palpation. They are the small lumps in the middle of each vertebrae on the spine.



Des coupes longitudinale et transversale d'une vertèbre vue de face et de dos



Les disques intervertébraux

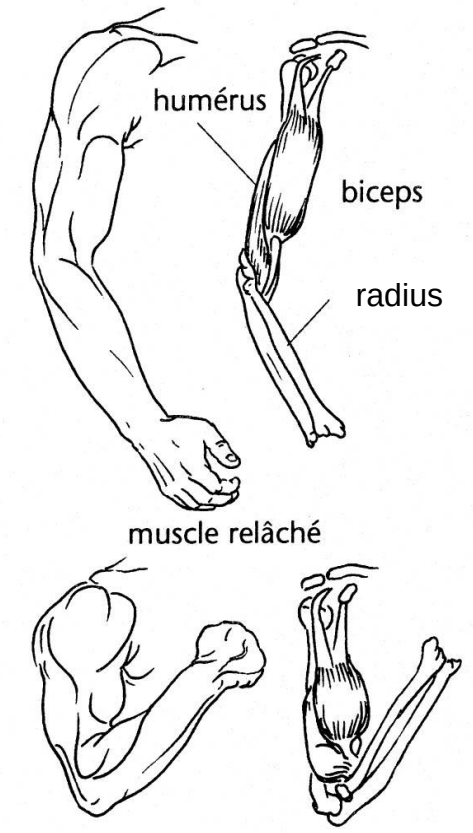
The **intervertebral** disks are shock absorbers. They are made of fibrocartilage and give a certain amount of elasticity to the spine, allowing it to absorb some of the shocks it endures.

The muscular system

The muscular system allows the body to move and, consequently, allows its bones to move. Usually, both ends of a muscle are connected to one or more bones. This means that when the muscle contracts, the least mobile bone pulls the most mobile bone towards it.

Let's take the bicep as an example. This muscle links the humerus to the radius. When the bicep is contracted, the radius is pulled to the humerus.

The **tendons** (part of the muscle) attach the muscles to the bones. The brain controls the muscles by sending messages through the nerves. Muscle movements can be voluntary or



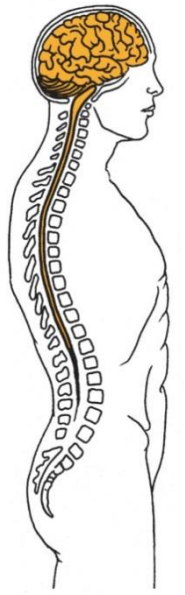
Contracted muscle

involuntary. The brain automatically commands **involuntary muscles**, such as those of the heart, the intestines and the diaphragm. This is why the stomach is contracted independently of our command to ensure mechanical digestion of consumed foods. The **voluntary muscles**, such as those of the arm, are controlled by conscious efforts or a reflex action.

Did you know?

The most common injuries for the musculoskeletal system are fractures, dislocations and sprains. Even if these injuries can seem trivial, they must be treated with great care, since they can damage the nerves, blood vessels or nearby organs, which can lead to serious injuries. Think, for example, of a perforated lung caused by a fractured rib.

The nervous system



The nervous system is comprised of the brain, spine, nerves and neurons. It is the command center for all the bodily functions, including the respiratory and cardiovascular systems.

The central nervous system has three closely linked purposes:

First, it **receives sensory** information (from our senses) through the nerves. This information relates to changes both inside and outside the organism (for example a temperature variation). Then, the brain **processes the sensory** information and determines the action to undertake. Finally, it **transmits a command** through the nerves (for example a motor response).

The **spinal cord** is a bundle of nervous fibers that starts at the brain and runs down the center of the spine. The **nerves** coming from the spinal cord spread into every part of the body.

Did you know?

The brain and spinal cord cannot regenerate their cells. An injury afflicting a certain part of the brain can destroy its functions. For example, if the part controlling the right arm's motor control, the arm can stop working for good

THE INTEGUMENTARY SYSTEM

The integumentary system is comprised of the **skin**, the **mucosa** and the **nails**. The skin has many essential functions. If the human body was not protected by the skin, it would quickly fall victim to bacteria, water loss and heat

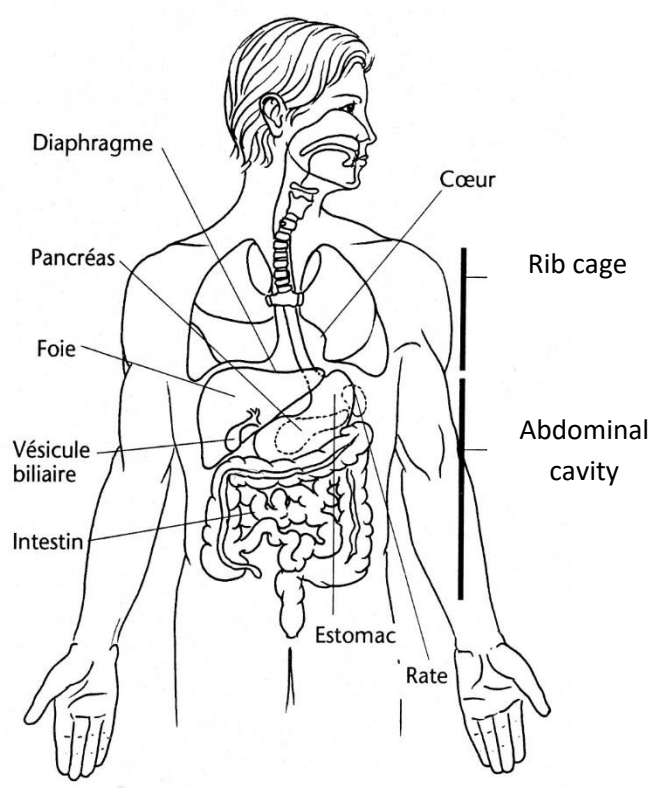
Did you know?

The skin can suffer injuries, such as tearing (abrasion or lacerations), perforations, burning, chilblain, etc. Some of these injuries can lead to serious infections or bleeding and be accompanied by a considerable loss of body fluids. Adequate treatment is necessary at once.

THE ABDOMINAL CAVITY AND THE RIB CAGE

The respiratory and cardiovascular systems together form the cardiorespiratory system. This system is located mainly in the **rib cage**, which is comprised of the spine, the ribs, the sternum and the diaphragm (the breathing muscle). The heart is located between the left and right lungs and rests on the diaphragm, spilling over slightly to the left.

The rib cage is separated from the abdominal cavity by the diaphragm. The **abdominal cavity** contains many organs: the stomach, intestines and the liver, whose function is to digest and absorb nutriments; the pancreas, which produces insulin and contributes to the regulation of the sugar levels in the blood; the spleen, which carries the primary cells which will later become the white blood cells used for the organism's defense; and finally the kidneys, which regulate the composition and volume of blood and eliminate its waste through the urine.



Did you know?

Abdominal trauma can cause very serious internal bleeding, for example a spleen injury.