Ministry of Higher Education and Scientific Research
Abdelhamid Ibn Badis University Mostaganem
Faculty of Natural Sciences and Life
Department of Food Sciences

Teaching support

Physiology of Major Functions

Course:

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Specialisation: Food Sciences

Level: Bachelor's degree in food sciences/3rd year ,Food, Nutrition and Pathology (ANP)

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Course Plan

I- Blood

1- Liquid compartment and role of formed elements.

2- Primary and secondary hemostasis.

II- Nervous system

1- Structure.

2- Organization.

3- General functions.

III- Cardiovascular system

1- Homeostasis at rest and during exercise.

IV- Respiratory system

1- Functional anatomy. 2-Mechanisms.

2- Homeostasis.

V- Urinary system

1- Anatomophysiology

2- Hydromineral homeostasis

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Chapter I:

The Blood

I.1. Composition of blood

Blood is composed of blood cells suspended in plasma. The whole is contained in blood vessels. The total volume of blood in an adult human is 5 litres.

I.1.1. Liquid part - Plasma

Plasma is the liquid component of blood in which the formed elements are suspended. It consists of 90% water, 10% ions and various molecules that are transported throughout the body. It accounts for 55% of blood.

It must be distinguished from blood serum, a liquid produced from a retracted blood clot, whose composition is slightly different from that of blood plasma, as it lacks fibrinogen in particular.

I.1.1.1. The main molecules in plasma solute

(the solvent being water, which is the main component of blood) are: -Glucose.

-Lipids.

-Proteins (which can be separated by electrophoresis into several peaks, albumin, α1, α2, β, γ), the main ones being:

Albumin, which plays a role in oncotic pressure and as a transporter (of bilirubin, hormones, drugs, ions, etc.).

Immunoglobulins of the immune system.

Complement proteins, which play a major role in initiating the immune response and inflammation. Blood coagulation proteins (coagulation factors).

Some of these elements are hormones, which may be proteins, modified amino acids, steroids, or modified lipids (including prostaglandins and thromboxanes).

I.1.2. Solid fraction - Formed elements

These include red blood cells, white blood cells, and blood platelets. They account for 45% of blood. Suspended Cells Account for 45% of the Total Volume, Which Corresponds to the

Hematocrit. Their morphology can be studied on a smear stained with May Grünwald Giemsa (MGG).

There are several cell types:

-Red blood cells or erythrocytes

Women: 4 to 5 million red blood cells in 1mm3 of blood. Men: 5 to 6 million red blood cells in 1mm3 of blood.

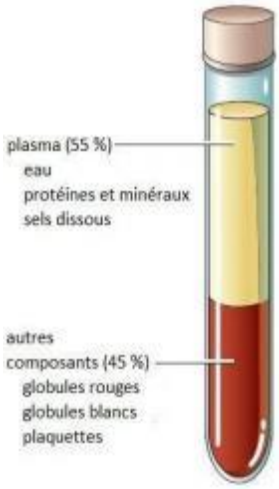
-White blood cells or leukocytes

There are approximately 5,000 to 11,000 white blood cells in 1mm3 of healthy blood, divided into:

-Polymorphonuclear or Granulocytes: 40 to 80% of Leukocytes. -Monocytes: 2 to 10% of leukocytes.

-Lymphocytes: 20 to 40% of leukocytes.

-Platelets: 200 to 400,000/mm³ .



The formed elements of blood have a limited lifespan; there is a dynamic balance between their

production (haematopoiesis and lymphopoiesis) and their destruction. Haematopoiesis is the production of blood precursors (proliferation, differentiation and maturation) and takes place in the haematopoietic organs (bone marrow in adults, liver and spleen in embryos). Lymphopoiesis involves the production of lymphoid precursors, which occurs in the bone marrow. It ends with the maturation of lymphocytes in the thymus for T lymphocytes and the proliferation of cells in the secondary lymphoid organs.

In a normal adult, only mature cells pass into the peripheral blood.

I.1.2.1. Red blood cells

Red blood cells are anucleated cells whose essential component is an oxygen-binding haemoprotein:

haemoglobin (approximately 14.5 g/100 ml). The main role of these cells is to transport oxygen and carbon dioxide between the pulmonary alveoli and the tissues.

I.1.2.1.1.Appearance under an optical microscope

These cells are 5 to 7 µ in diameter, homogeneous in appearance, and orange-coloured when stained with May Grünwald Giemsa. They are 1.8 µm thick (Figure 1).

I.1.2.1.2.Appearance under scanning electron microscopy

These Are Biconcave Cells, Flattened in the Center and Disc-Shaped. They Have No Mitochondria,

ribosomes or REG. The plasma membrane of red blood cells is the site of antigens that determine blood groups (ABO system, Rhesus system and other erythrocyte systems), which are receptors carried by glycophorin molecules. These cells have a lifespan of 120 days. Their production is 200x109 new cells per day (Figure 2).

I.1.2.1.3. Function of red blood cells

Oxygen and Carbon Dioxide Are Transported by Hemoglobin. Hemoglobin Is Made up of Globin, A

protein associated with four heme groups. Each heme group combines a porphyrin ring with a ferrous iron atom.

Reticulocytes, young red blood cells containing a few mitochondria and ribosomes, are also found in circulating blood (less than 1% of red blood cells).

I.1.2.2. White blood cells

These Cells Participate in the Body's Specific Defenses.

I.1.2.2.1. Monocytes

These cells have a very short lifespan in the bloodstream (approximately 24 hours). They then pass into the tissues where they differentiate into macrophages. They belong to the mononuclear phagocytic system. Under an optical microscope, they appear rounded, with a diameter of 15 to 20 µm. The cytoplasm is bluish-grey (stormy sky) in MGG stain and has a slightly granular appearance. There are

cytoplasmic veils at the periphery, visible under an optical microscope. The nucleus is central, horseshoe-shaped or E-shaped (Figure 3).

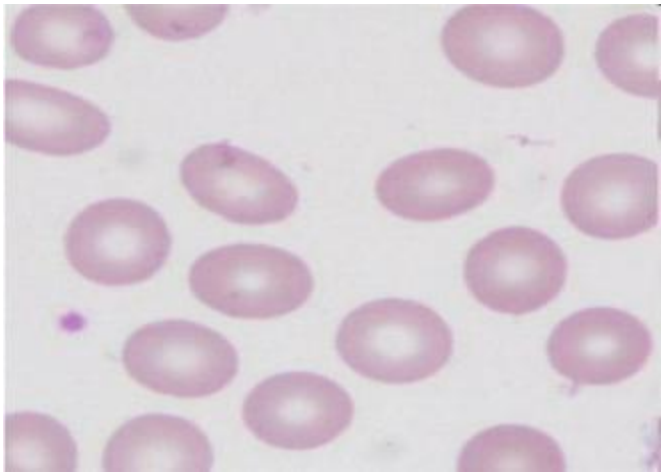


Figure 1: Appearance in Optical Microscopy of Red Blood Cells

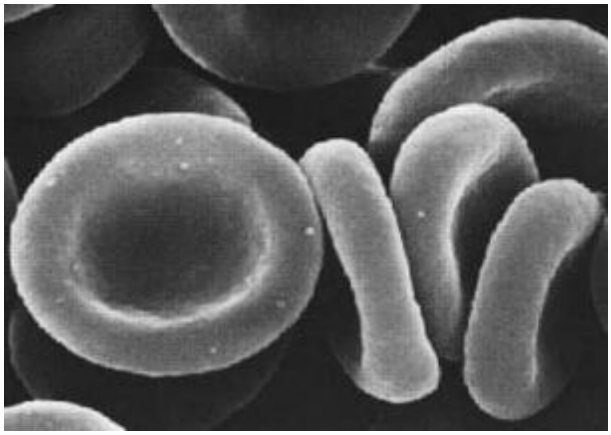


Figure 2: Appearance in Scanning Electron Microscopy of Red Blood Cells

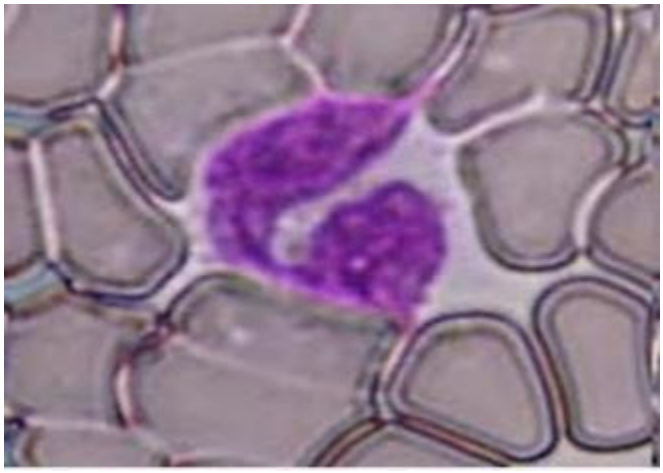


Figure 3: Appearance in Optical Microscopy of Monocytes

In electron microscopy, chromatin is fine, organelles are well developed and located in the notch of the nucleus. There are many small azure granulations corresponding to lysosomes. The plasma membrane is irregular with numerous expansions and microvilli. Monocytes represent 2 to 10% of all white blood cells (figure 4).

I.1.2.2.1. Lymphocytes

These are mononuclear cells, with a high nuclear/cytoplasmic ratio. Their lifespan is variable; some memory lymphocytes can have a very long lifespan. In optical microscopy, they are small cells, about 7 µm in diameter, with a nucleus occupying almost the entire cell. Their shape is regular and rounded. There is a small peripheral cytoplasmic fringe with a mauve appearance in MGG. The nucleus is spherical, dense (figure 5).

In transmission electron microscopy, chromatin is dense, there is no nucleolus. The cytoplasm is poor in organelles (a few ribosomes and a reduced ergoplasm), (figure 6). All lymphocytes are morphologically similar but there are several groups of lymphocytes highlighted by membrane antigenic markers: B lymphocytes and T lymphocytes, whose maturation occurs in the thymus. A third group related to T lymphocytes is also described: NK cells or Natural Killer

cells. The blood lymphocyte population comprises 8 to 12% B lymphocytes, 70 to 80% T lymphocytes, and 5 to 15% NK cells.

I.1.2.2.1.1. Function of Lymphocytes

These cells are responsible for specific immune responses. B lymphocytes undergo differentiation in the bone marrow (primary lymphoid organ). They are responsible for humoral immunity and can produce antibodies or immunoglobulins after antigen presentation by an antigen-presenting cell (macrophages, follicular cells, dendritic cells). B lymphocytes possess membrane immunoglobulins that constitute the phenotypic marker of these cells.

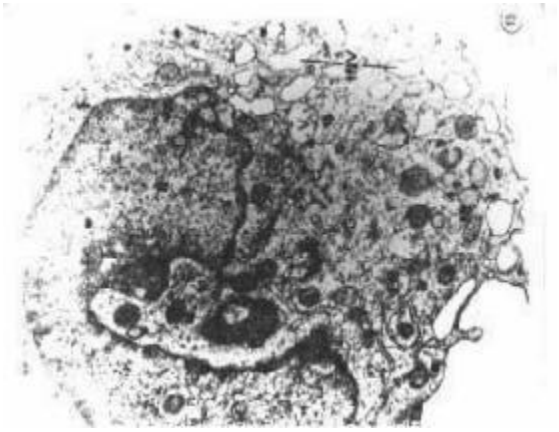


Figure 4 Scanning Electron Microscopy Appearance of Monocytes

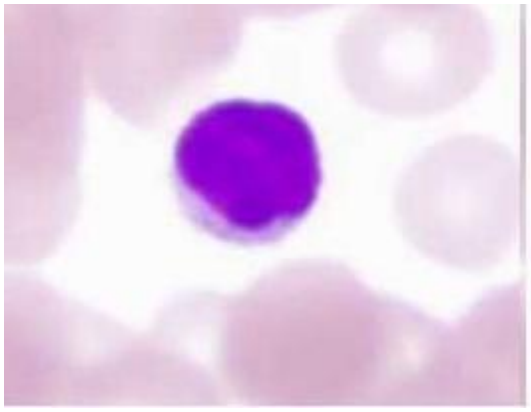


Figure 5: Optical Microscopy Appearance of Lymphocytes

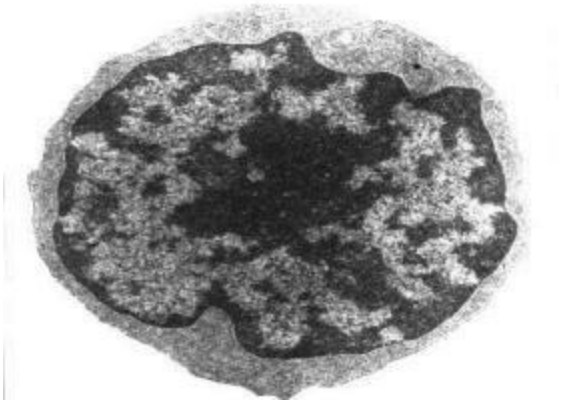


Figure 6: Scanning Electron Microscopy Appearance of Lymphocytes

The production of antibodies occurs in the secondary lymphoid organs where lymphocytes

transform into plasma cells. T lymphocytes acquire their differentiation in the thymus (primary lymphoid organ).

Mature T lymphocytes express the CD3 membrane receptor. Among these mature lymphocytes, several groups are distinguished by the presence of other membrane receptors:

CD4 or T helpers who recognize the antigen in association with class II HLA molecules (represent about half of T cells).

CD8 or T suppressors or cytotoxic T cells who recognize the antigen in association with class I HLA molecules (20 to 30% of T cells).

T lymphocytes participate in the humoral immune response by stimulating or inhibiting the production of antibodies by B lymphocytes but are also involved in cellular immunity and secrete cytokines or lymphokines.

I.1.2.2.3. The Polymorphonuclear Cells

This group of cells has common characteristics. They contain a multilobed nucleus (figure 7). The lobes are connected to each other by fine chromatin bridges. In the cytoplasm, there

are two types of granulations: primary nonspecific granulations, rich in hydrolases and peroxidases, common to all polymorphonuclear cells, and secondary granulations specific to each group with different staining properties. In the mature cell, nonspecific granulations decrease.

I.1.2.2.4. Neutrophils

These are the most numerous polymorphonuclear cells - 40 to 75% of all white blood cells. Their lifespan is about 24 hours. Their specific granulations are neutrophilic.

In optical microscopy, these are cells about 12 µm in diameter, the nucleus is generally trilobed but the number of lobes varies from 2 to 5 lobes and is an indicator of cell maturation (figure 8). The Arneth formula is the distribution of neutrophilic polymorphonuclear cells based on the number of lobes. The cytoplasm appears clear, non-stainable with MGG. Indeed, the Azurophilic granules can only be stained by specific detection of myeloperoxidase.

In electron microscopy, the nucleus has dense chromatin, the cytoplasm contains two types of granules: non-specific or primary azurophilic granules that contain myeloperoxidase, acid hydrolases, and lysozyme, and specific secondary granules, neutrophilic, small in size (0.3 to 0.8 µm) scattered in the cytoplasm. These granules lack lysosomal enzymes and peroxidases but contain lysozyme and collagenase. There is a band rich in actin filaments at the periphery of the cell (figure 9).

The function of these neutrophils is the non-specific defense of the organism, particularly the anti-bacterial fight. This function is enabled by the properties of neutrophils:

The phenomena of diapedesis allow them to leave the blood environment by passing between endothelial cells. These phenomena are ensured by cytokines secreted at the site of infection, notably interleukin 8 (IL-8), which activates neutrophils, and by adhesion molecules that appear on the surface of the neutrophil and bind to their specific ligand located on the endothelial cells.

Chemotaxis attracts them to the sites of inflammation: IL-8 secreted by monocytes as well as certain fractions of complement participate in this chemotaxis, notably by causing a reorientation of the cytoskeleton and organelles within the cell. The properties of phagocytosis allow it to destroy foreign agents, particularly bacteria. Phagocytosis can be facilitated by a phenomenon of opsonization characterized by a specific binding of lipopolysaccharides from certain bacterial walls or with immunoglobulins that bind to their receptor located on the

membrane of the neutrophil.The action of myeloperoxidase from azurophilic granules gives it a bactericidal activity, allowing it to destroy phagocytosed bacteria.

I.1.2.2.5. Eosinophils

These cells represent 1 to 3% of white blood cells. They have a half-life in circulating blood of 4 to 5 hours and then move into tissues (skin, lung, digestive tract) where they remain for 8 to 10 days. The proportion of eosinophils in the tissues is 100 times greater than that in the blood.

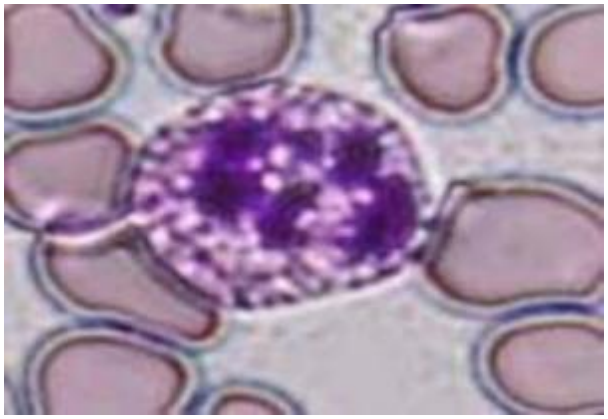


Figure 7: Optical Microscopy Appearance of Polymorphonuclear Cells

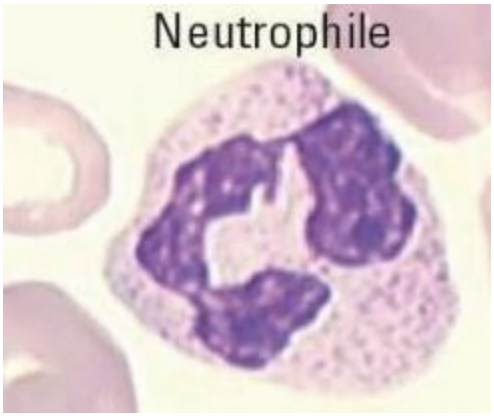


Figure 8: Optical Microscopy Appearance of Neutrophils

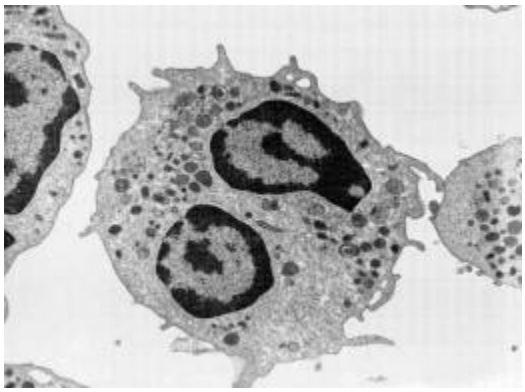


Figure 9: Electron Microscopy Appearance of Neutrophils

In optical microscopy, their diameter is 10 to 14 µm, the nucleus is generally bi-lobed, the cytoplasm appears orange in MGG, granular in appearance due to the presence of specific granulations (figure 10).

These granulations are large and acidophilic. In electron microscopy, the specific granulations, eosinophilic, are large, ranging from 0.5 to 1.5 µm in diameter and contain a granular matrix within which there is an elongated crystalline formation (figure 11).

These granulations contain a peroxidase (different from the myeloperoxidase of neutrophils) and acid hydrolases.

I.1.2.2.5.1. Function of Eosinophils

These cells participate synergistically with other cells in immediate and delayed hypersensitivity reactions. They have, to a lesser extent than neutrophils, bactericidal and phagocytic properties. They primarily act in the destruction of parasites through high molecular weight proteins (Eosinophil Cationic Protein - ECP and Major Basic Protein - MBP) contained in the crystalloid of the granulations. The plasma membrane has a receptor for immunoglobulins of type IgE and for histamine.

I.1.2.2.6. Basophils

These cells are the least numerous of the polymorphonuclear cells, (0 to 1% of the total white blood cells). The lifespan of these cells is 3 to 4 days.

In optical microscopy, these cells have a diameter of 10 to 14 µm (figure 12). Their nucleus is irregular. It can take on a clover-like appearance, which is generally masked by the numerous metachromatic granulations (which take on a red coloration with acidic dyes such as toluidine blue or alcian blue) that appear purple in MGG.

In electron microscopy, the granulations appear homogeneous, formed of small dense grains surrounded by a membrane (figure 13). These basophilic granulations contain histamine and heparin (sulfated glycosaminoglycans).

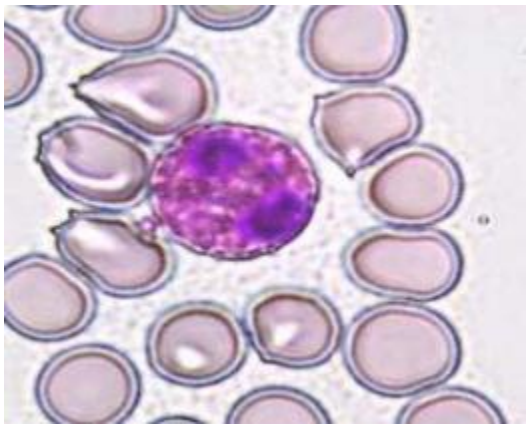


Figure 10: Appearance in Optical Microscopy of Eosinophils

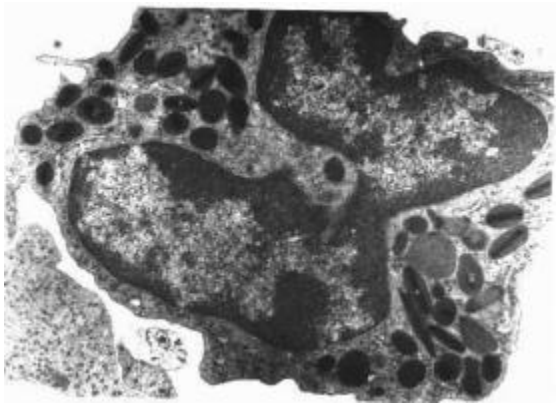


Figure 11: Appearance in Electron Microscopy of Eosinophils

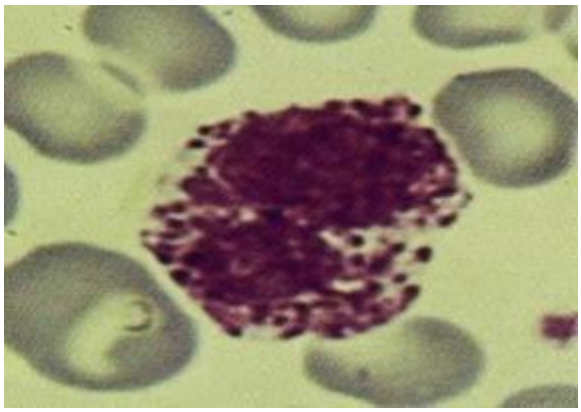


Figure 12: Appearance in Optical Microscopy of Basophils

I.1.2.2.6.1. Role of Basophils

It is the cell responsible for immediate-type allergic reactions. The plasma membrane of

basophils has receptors for the Fc fragment of immunoglobulins of type IgE. As a result, the IgE specifically produced against an allergen is fixed to the membrane of basophils. When there is renewed contact with the allergen, the bridging of IgE by the allergen causes the degranulation of basophils, which is responsible for allergic manifestations.

I.1.2.3. Platelets

Their lifespan is 8 to 12 days. In optical microscopy, blood platelets or thrombocytes are anucleated cellular fragments 2 to 5 µm in diameter. Two zones are distinguished: the center of the cell (chronomere) containing granules and the more homogeneous periphery (hyalomere) (figure 14).

In electron microscopy, they appear rich in dense azurophilic granules containing ADP and glycogen. Their cytoskeleton is highly developed, notably with a marginal bundle of circular microtubules and actin microfilaments (thrombas thenine). There is also a canalicular network formed by invagination of the plasma membrane, thus increasing the surface area of the membrane.

I .1.2.3.1. Function of Platelets

They play a fundamental role in the initial phenomena of coagulation. The outer leaflet of the plasma membrane contains a thick glycocalyx rich in adhesion molecules that are expressed when the platelet is activated. They thus adhere to collagen when there is a breach of the endothelium. Actin and the microtubule system cause adhesion of platelets to each other. The bundle of microtubules, by depolymerizing into filaments, participates in the aggregation of platelets. The peripheral actin crown also allows, by contracting, the extrusion of the contents of the granules through the canalicular network, and causes the synthesis of thromboxane from arachidonic acid contained in the phospholipids of the plasma membrane. The released thromboxane has a vasoconstrictive action. The substances secreted cause the adhesion of other platelets.

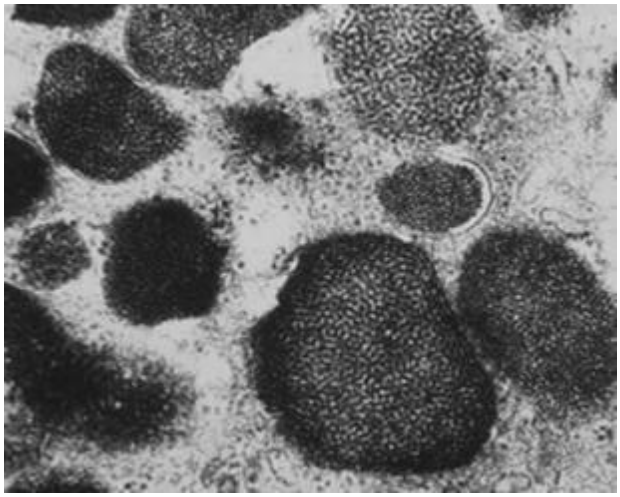


Figure 13: Appearance in Electron Microscopy of Basophils

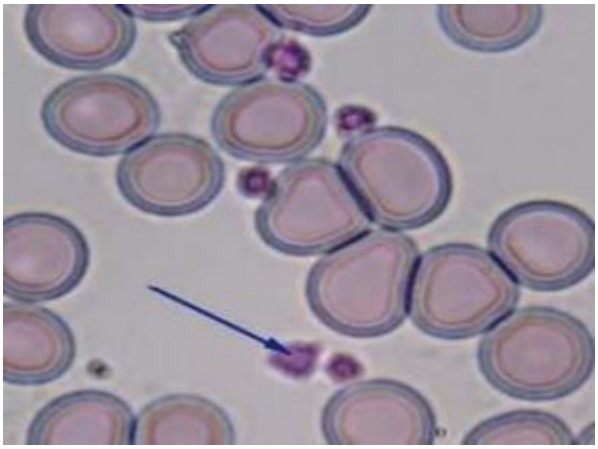


Figure 14: Appearance in Optical Microscopy of Platelets

I.2. Hemostasis

Blood is composed of a liquid = plasma and formed elements of blood = red blood cells, white blood cells, platelets. It is at the level of the plasma (coagulation factor) and platelets that the mechanisms capable of transforming a liquid mass (blood) into a solid mass are found: this phenomenon is called coagulation. It will be associated with vascular modifications. The whole is referred to as hemostasis = cessation of hemorrhage.

I.2.1. Definition of Hemostasis

It is the set of phenomena that lead to the cessation of hemorrhage in the event of vascular lesions.

I.2.2. Mechanism of Hemostasis

Hemostasis occurs in several stages that interlock with each other. The body's reaction differs depending on the lesion:

• Capillary vessels → rapid (primary phase).

• Large caliber vessels → primary and secondary phases, even tertiary. Formation of a clot by defense mechanisms.

I.2.2.1. Primary Hemostasis

It corresponds to the set of mechanisms that will lead to the formation of the platelet plug.

I.2.2.1.1. Vascular Time =Wall Time.

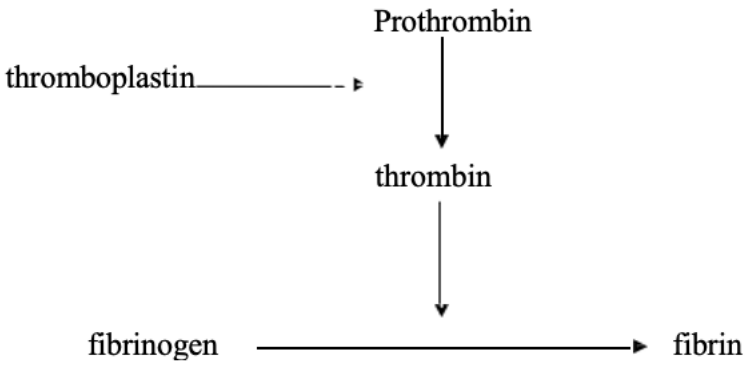
There is a vessel injury → mechanisms. The wall of the vessel and the platelets will change. The lesion is located at the level of the capillaries or venules = retraction or arteries = vasoconstriction of the vessels (tightening) → blood flow decreases = it slows down circulation.

I.2.2.1.2. Platelet Time

The vessels are targeted = injuries: the platelets adhere to the collagen of the connective tissue of this vessel = platelet adhesion. They aggregate with each other to form a mass that will obstruct this breach = platelet plug = white thrombus: platelet aggregation at the level of connective tissue (figure 15). This aggregation is due to the release of ADP (Adenosine DiPhosphate) from the damaged cells. The platelet mass releases serotonin and has a role in vasoconstriction. This is the step before coagulation.

I.2.2.2. Secondary Hemostasis

The plasma time = coagulation time constitutes the actual coagulation and involves many coagulation factors ranging from 1 to 12. These factors are proteins. This coagulation leads to the formation of a red thrombus = fibrin clots enclosing red blood cells = erythrocytes = red blood cells that come to reinforce the platelet plug. Coagulation is due to the transformation of fibrin (protein) which has been transformed by fibrinogen which itself has been transformed by a superior element = thrombin (enzyme) activated by prothrombin (liver) activated by thrombopl-astin (in the liver): it is a chain reaction. This is the coagulation cascade (figure 16).



- This phenomenon is related to 3 closely linked processes

I.2.2.2.1. Thromboplastin Formation

The transformation of prothrombin into thrombin involves a complex set activators.

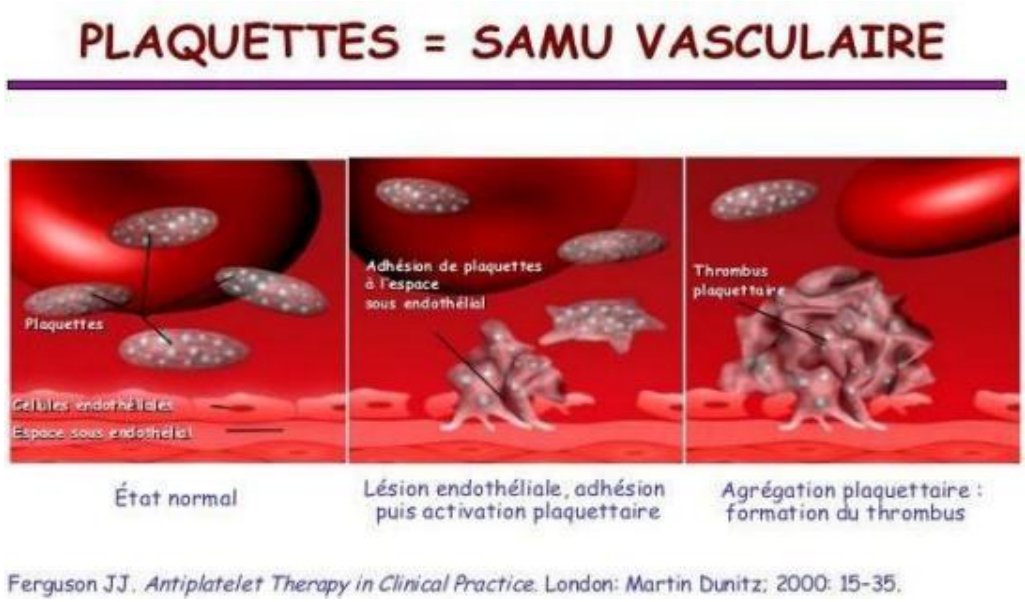


Figure 15: Thrombus Formation Ferguson, (2000)

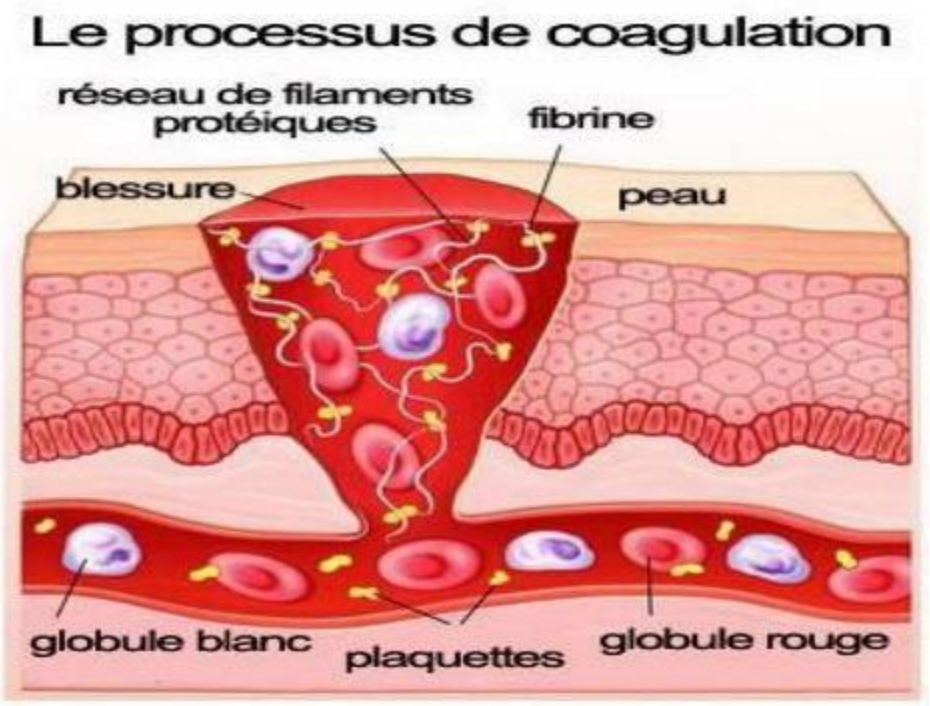


Figure 16: Formation of the Hemostatic Plug Ferguson, (2000)

I.2.2.2.2. Thrombin Formation

Coagulation factors are combined and activated + calcium (figure 17). They will activate prothrombinase (protein) which transforms into prothrombin which in turn transforms into thrombin.

- Coagulation Factors

Coagulation factors, as their name indicates, are molecules involved in blood coagulation. Most of these factors are soluble molecules in the blood, with the exception of tissue factor (factor III) which will be released when there is damage to the blood vessel. You will also note that most of these factors are produced in the liver, and that the production of some is dependent on vitamin K. Consequently, liver problems or vitamin K deficiencies can influence blood coagulation.

I.2.2.2.3. Fibrin Formation

Unstable fibrin becomes stable through factor VII and transforms into fibrinase and then into fibrinogen (factor I) by thrombin.

I.2.2.3. Fibrinolysis= dissolution = healing in progress

Retracting the clot. This is the dissolution of the clot after 72 hours: it is due to the enzymatic action of plasma, plasmin = fibrinolysin.

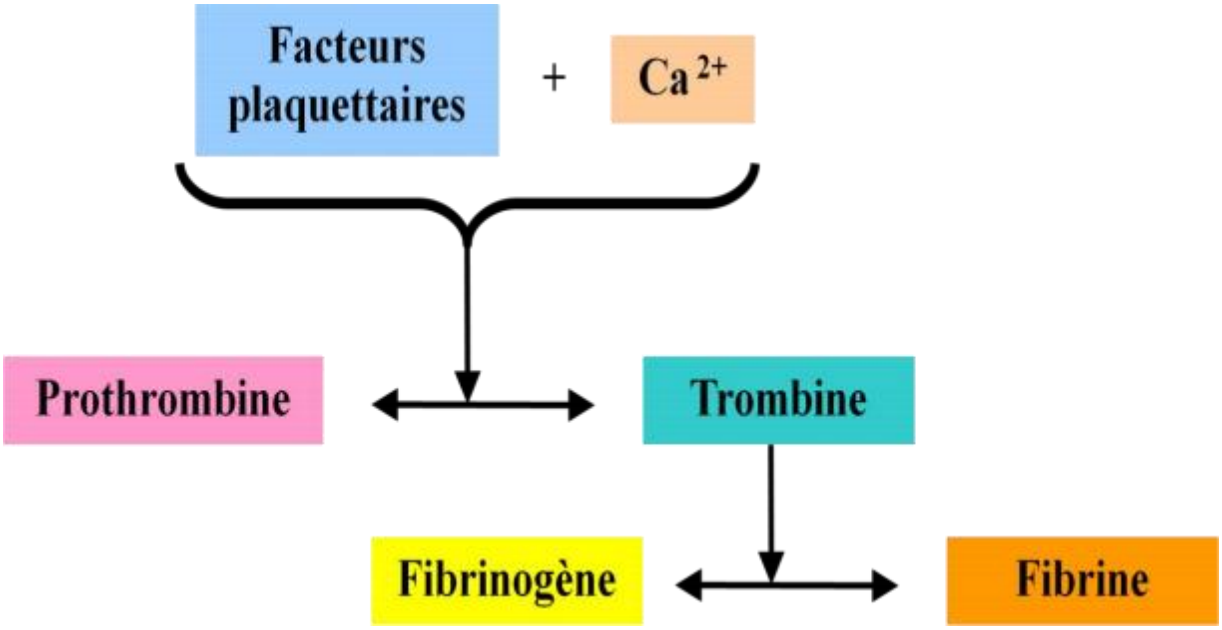


Figure 17: Secondary Hemostasis

Chapter II: Nervous System

II.1. Structure of the Nervous System

The nervous system is a biological system animal responsible for coordinating actions with the' external environment and for rapid communication between the different parts of the body. In all vertebrates, we distinguish the central nervous system(brain and spinal cord), from the peripheral nervous system(nerves and nerve ganglia). At the cellular level, the nervous system is defined by the presence of highly specialized cells called neurons, which have the very particular ability to carry an electrochemical signal. Furthermore, the nervous system contains support cells called glial cells, which provide structural and functional support to neurons.

The nervous system can fail under many conditions:genetic anomalies,physical trauma, poisoning,infections or simply due to the effect of aging. A disturbance of the nervous system most often causes severe symptoms due to the importance of this system in the functioning of the body.Neurology and psychiatry are the branches of medicine that seek to treat the pathologies of the nervous system.Neurosciences refer to the scientific study of the nervous system, both in terms of its structure and its function, from the molecular scale to the level of organs.

II.2. Microscopic Organization

The nervous system is composed of two types of cells:neurons and glial cells. Neurons constitute the active part of the nervous system (transmission and processing of signals) while glial cells provide a support function (protection, metabolism, recycling). Apart from microglia, these cells are generated from a common progenitor, the neural stem cell.

II.2.1. Neuron

The neuron is the main cell functioning in the nervous system. This excitable cell is capable of transmitting a signal of an electrochemical nature from one point to another in the organism. This signal consists of the propagation of depolarizations of the plasma membrane coupled with the release of chemical molecules at the connection points with other cells.

This mechanism of neurotransmission is common to all neurons, but the information conveyed by this signal depends on the neuron (figure 18). Thus, the neurons of the optic nerve convey information related to vision while those destined for the skin convey information about touch. An important function of neurons is to process these different forms of information within

several networks to enable the performance of tasks as complex and varied as memorization, motor skills, or the body's homeostasis. The great diversity of neurons present in the nervous system reflects the diversity of tasks performed by these cells.

The neuron comes into contact with the cells of the innervated organs or with other neurons thanks to the presence of two types of extensions:the dendrites and the axon.

II.2.2. Dendrite

The dendrite is an extension implanted on the cell body. There are often several for the same neuron, which appear in the form of fine and short branches, ending in numerous ramifications. The number and shape of dendrites vary according to the type of neurons and partially allow for the identification of the latter.

Dendrites conduct nerve impulses, but they can essentially conduct this impulse only in one direction, from the end of the dendritic branches to the cell body (a direction called "cellulipetal "). The direction of conduction of the impulse differentiates dendrites from the axon.

For the processing of the signal transmitted by the neuron, dendrites constitute the input(input of information) of the neuron, while the axon is the output (output of information).

II.2.3. Axon

The axon is presented in the form of an elongated stem, with a smooth surface, of invariable caliber. There is only one axon per nerve cell, whereas there can be several dendrites. The axon is sometimes very short, but its length can sometimes be considerable:

For peripheral nerves, for example, the motor neuron is located at the level of the spinal cord and the termination of the axon is at the level of the motor plate of the muscle it innervates, which represents a distance sometimes of several decimeters. The axon ends like the dendrites with highly branched arborizations that can contact several cells at once.

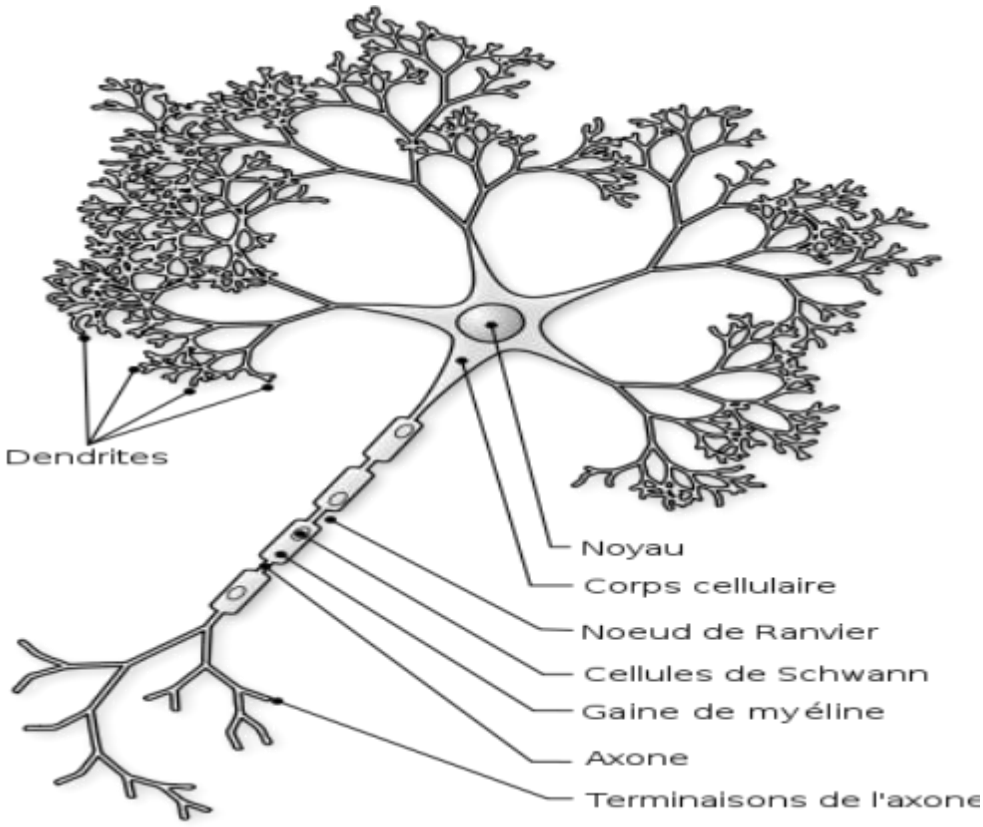


Figure 18: Main Cell of the Functioning of the Nervous System

The axon only conducts nerve impulses in one direction, generally from the body of the nerve cell to the terminal branches of the axon (the so-called "centrifugal" direction), but it can potentially conduct them in both directions. This is what happens with the sensory neurons of the skin, which do not have dendrites but an axon with two branches: one heading towards the periphery and the sensory receptors and one towards the central nervous system.

The action potential therefore propagates from the receptors along the first branch of the axon in the centripetal direction and then passes into the second branch, this time in the centrifugal direction towards the central nervous system. In this case, the neuron does not have an axon and a dendrite, but a branched axon with two branches. The terminal part of this axon can release neurotransmitters into so-called synapses to perform very rapid actions following sensory stimulation without waiting for a response from the central nervous system, which is significantly slower to react. It is this presence of synapses that allows this extension to be identified as an axon rather than a dendrite.

II.2.4. Synapse

The synapse is the place where the neuron transmits a signal to another cell by releasing:

□ □ From an electrical signal, this mode of transmission is mainly observable in invertebrates and lower vertebrates.

□ □ From a neurotransmitter chemical. This chemical signal delivered by the neuron can be excitatory (example: acetylcholine), inhibitory (example: GABA), or more subtly modulate the activity of the receiving cell.

II.2.5. Glial Cell

The nervous system is equipped with supporting cells, called glial cells. These cells were once considered maintenance cells, but recent discoveries in neuroscience show that they perform a variety of functions necessary for the proper functioning of the nervous system.

The best-studied function is the formation of the myelin sheath around axons. This insulating sheath allows for much faster and more efficient conduction of the electrical signal than on an unmyelinated axon. Two types of cells fulfill this function: the oligodendrocytes and the Schwann cells.

The astrocytes are cells that ensure homeostasis and protection of the neurons' environment. They participate notably in the blood-brain barrier which isolates the brain from the rest of the organism in vertebrates. They can also participate in the formation and functioning of synapses between neurons.

The microglia are the immune cells of the nervous system. The nervous system is divided into two distinct parts:

- The central nervous system.
- The peripheral nervous system.

II.3. Central Nervous System (CNS)

The central nervous system or neuraxis is the portion of the nervous system consisting of part of the brain, grouping the cerebrum, the brainstem and the cerebellum; on the other hand, part

of the spinal cord. It has a role in receiving, processing, integrating, and emitting nerve messages. It is therefore composed of:

II.3.1. Brain

It is the main structure of the brain. It resembles a pinkish gray mass and is about twice the size of your fist. Its consistency, however, is rather soft, and it is the center of voluntary motor control. The brain is also the center of conscious sensitivity. It is the gray matter of the brain that receives all sensations coming from the sensory organs; although it is the eye that captures an image, it is the brain that sees and interprets the image. Similarly, the nose captures a burnt smell, but it is the brain that interprets this smell. It is the center of our intelligence, our memory, our thoughts, our will, etc.

II.3.1.1. Composition of the Brain

The brain can be divided into two parts:

II.3.1.1.1. The White Matter

The white matter is made up of myelinated axons and glial cells.

In fact, it is the myelin on the axon that gives the white matter its white appearance.

II.3.1.1.2. Gray Matter

It is the gray and brown part that mainly contains cell bodies, dendrites, and short unmyelinated axons. Thus, gray matter forms the cerebral cortex, which is a thin covering that covers each hemisphere (figure 19).

The cerebral cortex is responsible for language, memory, personality, conscious thought, etc.

II.3.1.2. Subdivisions of the Cerebral Cortex (The Lobes)

II.3.1.2.1. Occipital Lobe

Main function: receives and analyzes visual information. If the occipital lobe is damaged, the person may see objects without being able to recognize them.

II.3.1.2.2. Temporal Lobe

Main function: receives and interprets hearing (understanding speech, recalling visual and verbal memories)

II.3.1.2.3. Parietal Lobe

Main function: receives and interprets sensory information coming from the skin.

II.3.1.2.4. Frontal Lobe

Responsible for reasoning, critical thinking, memory, personality, and the use of language. Contains the motor areas for voluntary actions (figure 20).

II.3.2. Brainstem

At the junction between the brain, cerebellum, and spinal cord, consisting from top to bottom of the midbrain, the pons(or pons Varolii), and the medulla oblongata(or elongated medulla).

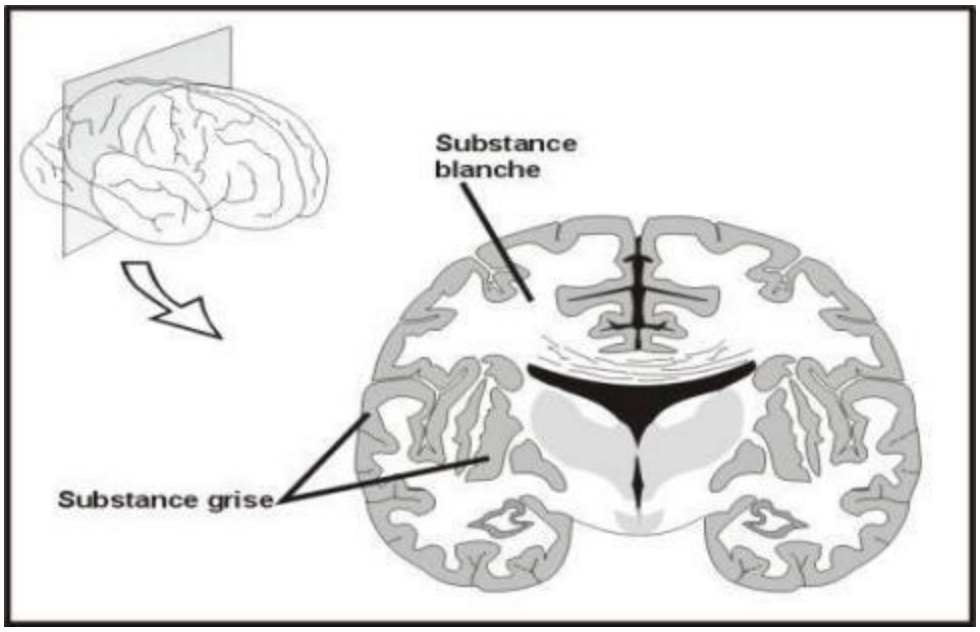


Figure 19: Composition of the Brain

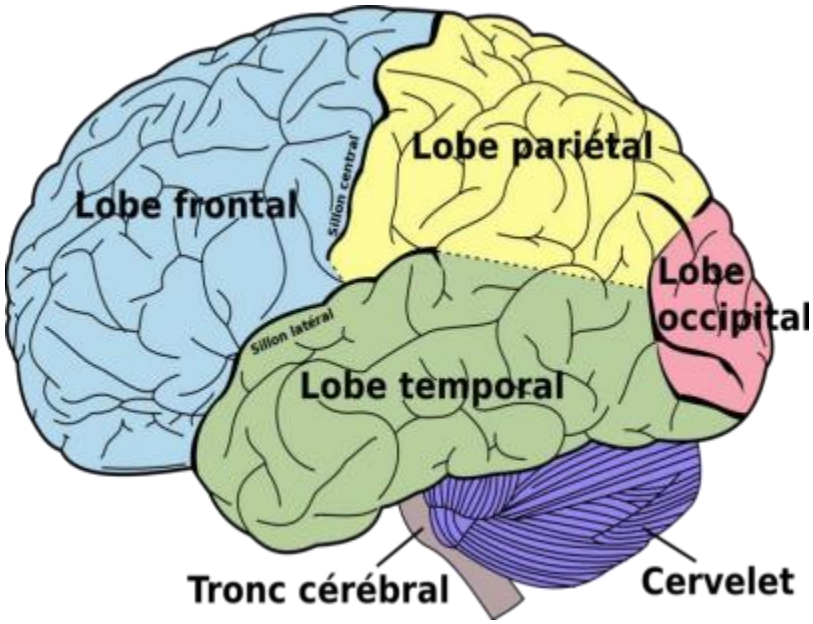


Figure 20: Subdivisions of the Cerebral Cortex (The Lobes)

II.3.3. The Spinal Cord

Appears as a cord about 50 cm long and 1 cm in diameter. Located inside the vertebral column. Contains gray matter at the center that is responsible for reflex actions and sensory information. The gray matter is surrounded by white matter that conducts orders from the brain to the limbs and conducts sensations from the limbs to the brain (figure 21). The entire central nervous system is protected by a bony envelope, consisting of the cranial box for the brain and the vertebral column for the spinal cord. Other protective tissue envelopes are located between the bone and the neuroaxis, these are the Meninges (figure 22).

II.3.3.1. The Cerebrospinal Fluid

The spinal cord and the brain are surrounded by a fluid called cerebrospinal fluid.

This fluid is similar to plasma and primarily serves to protect the very fragile nerve tissues. This fluid continuously circulates inside the brain. A small part also circulates around the spinal cord.

It renews quickly and has functions of mechanical protection, anti-infectious, and nutritional. A test called a lumbar puncture is used to detect any abnormalities in this fluid such as the presence of blood, bacteria, etc.

II.3.4. Cerebellum

Resembles a bit like a cauliflower. An archaic portion of the brain, connected in parallel to the dorsal side of the brainstem, is the nerve center of balance and coordinates automatic movements such as walking. It also serves to give precision to automatic movements.

Is the "autopilot" of the human body, exercising functions of maintaining posture, balance, coordination between movements, and motor memory.

II.3.4.1. Cerebellar Disorders

A person severely affected loses all sense of balance and their movements become uncoordinated.

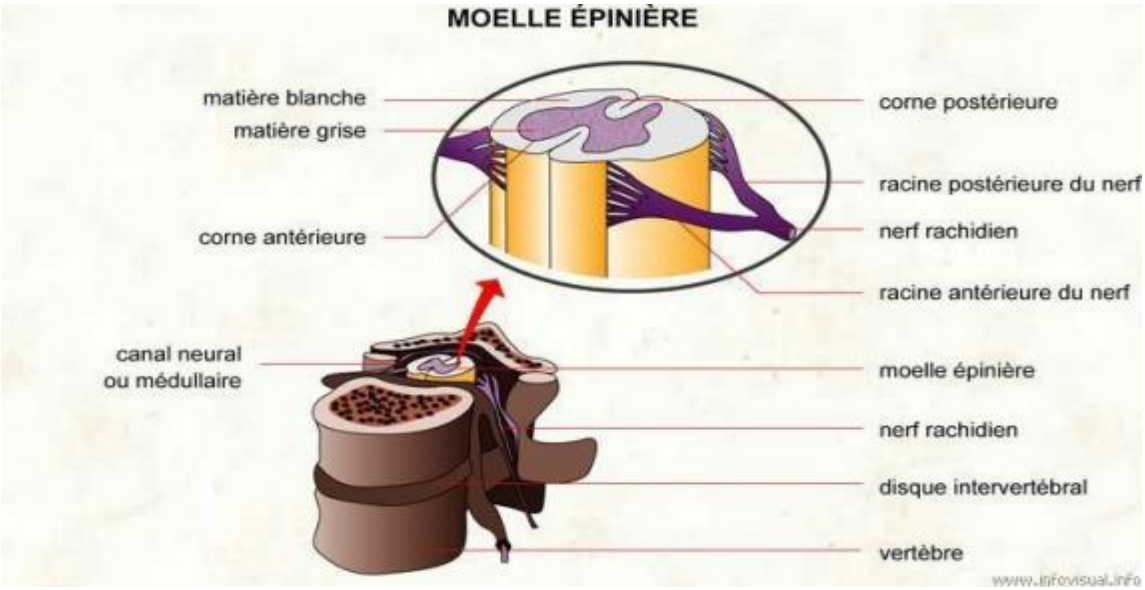


Figure 21: The Spinal Cord

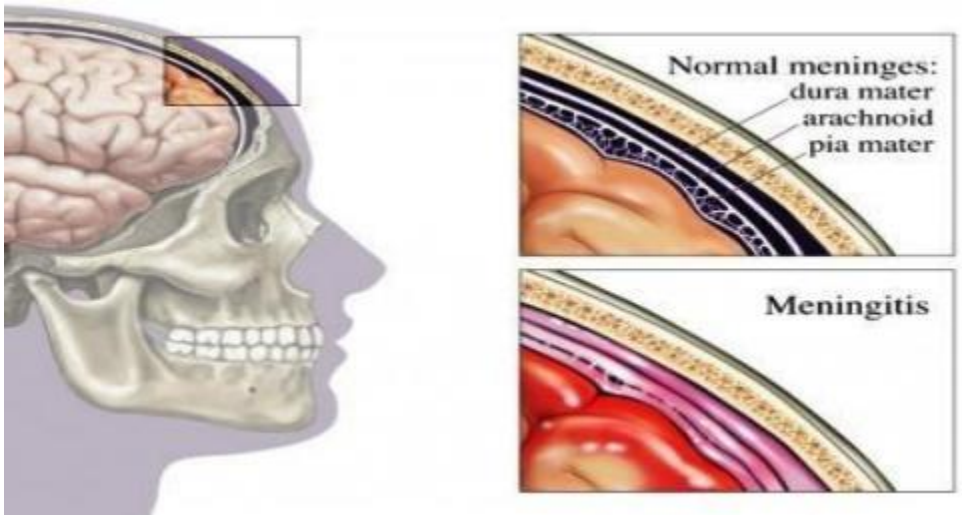


Figure 22: The Meninges

In this case, even if the brain gives the command to touch his nose with his index finger, the individual will be unable to coordinate his movements enough to accomplish this seemingly simple task. Disorders can be caused by aging or a tumor.

II.3.5. Medulla Oblongata

Controls the functioning of internal organs, vital functions such as heartbeats and breathing,

blood pressure, etc.

Part of the spinal cord (figure 23). Therefore, if there is a rupture of the spinal cord at the level of the medulla oblongata, the individual dies since vital functions such as heartbeats and breathing will no longer be ensured.

II.3.6. Pons

Serves as a relay center between the neurons of the right and left hemispheres of the brain, the cerebellum, and the rest of the brain.

Composed of nerve fibers (axons), it is the largest mass of white matter in the brain (figure 24).

II.3.7. Hypothalamus

Helps regulate the internal environment of the organism and certain aspects of behavior (figure 25). Contains neurons that govern:

- Blood pressure
- Heart rate
- Body temperature
- Thirst and hunger
- Emotions

II.3.8. Thalamus

Made up of neurons that connect different parts of the brain to each other. Known as the " bedroom," it regulates consciousness, alertness (related to various senses), and sleep.

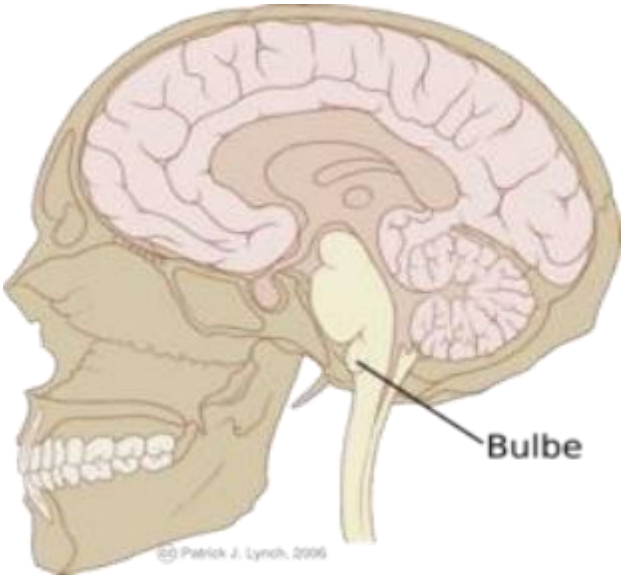


Figure 23: Spinal Bulb

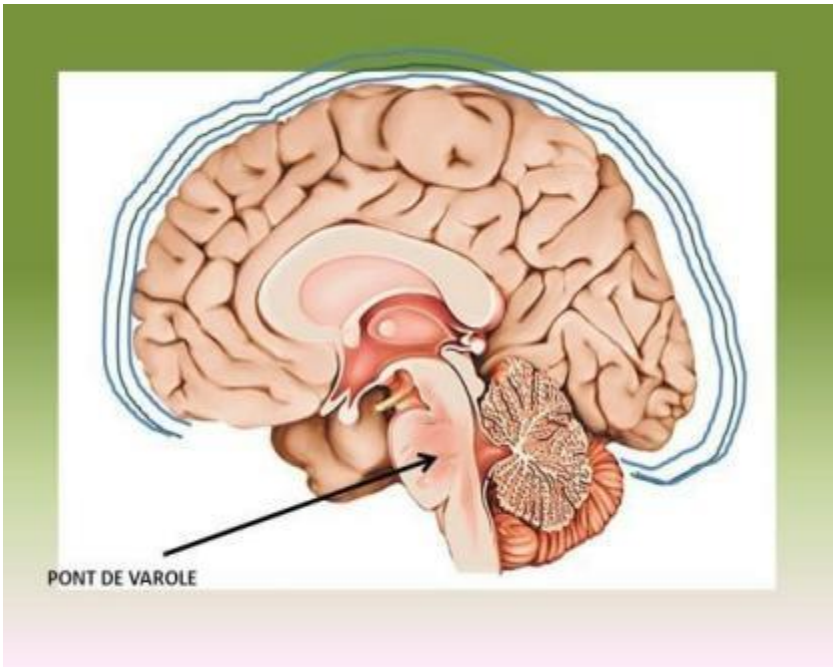


Figure 24: Pons Varolii

II.3.9. Corpus Callosum

It is a set of nerve fibers that connect the left and right hemispheres of the brain.

II.4. The Peripheral Nervous System (PNS)

The peripheral nervous system consists of sensory and motor nerves, which originate mainly from the spinal cord and the brainstem, and which terminate at one or more organs (skin, muscle, viscera, ...) (figure 26).

Located outside the CNS, it is formed of nerves (which are bundles of axons) coming from the brain and spinal cord.

These nerves are communication lines that connect all parts of the body by transmitting impulses.

There are three types of nerves:

- Motor nerves: originate from the brain and transmit orders to different parts of the body.
- Sensory nerves: come from sensory organs. They bring to our brain the visual, auditory, olfactory, gustatory, and tactile sensations.
- Mixed nerves: are both sensory and motor.

II.4.1. Functional Organization

II.4.1.1. Somatic System

Responsible for voluntary actions, its sensory neurons transmit the information received by the receptors to the inside. Its motor neurons transmit information to the skeletal muscles.

II.4.1.2. Autonomic System

The autonomic system maintains homeostasis by adapting the body to variations in external and internal environments, with the help of the hypothalamus and the medulla oblongata. It does this by controlling involuntary actions, primarily manipulating smooth muscles (including the myocardium) and glands.

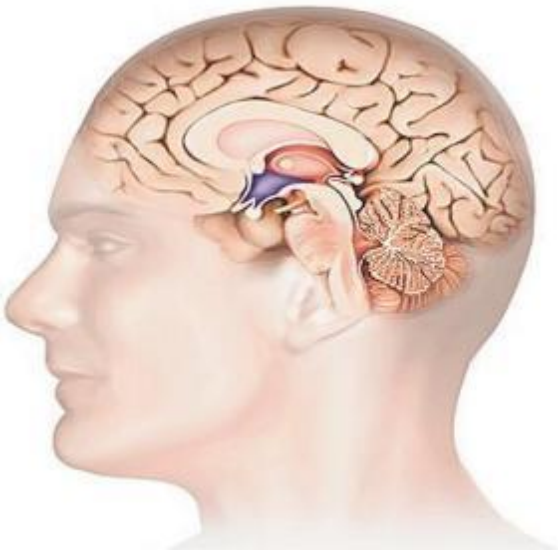


Figure 25: Hypothalamus

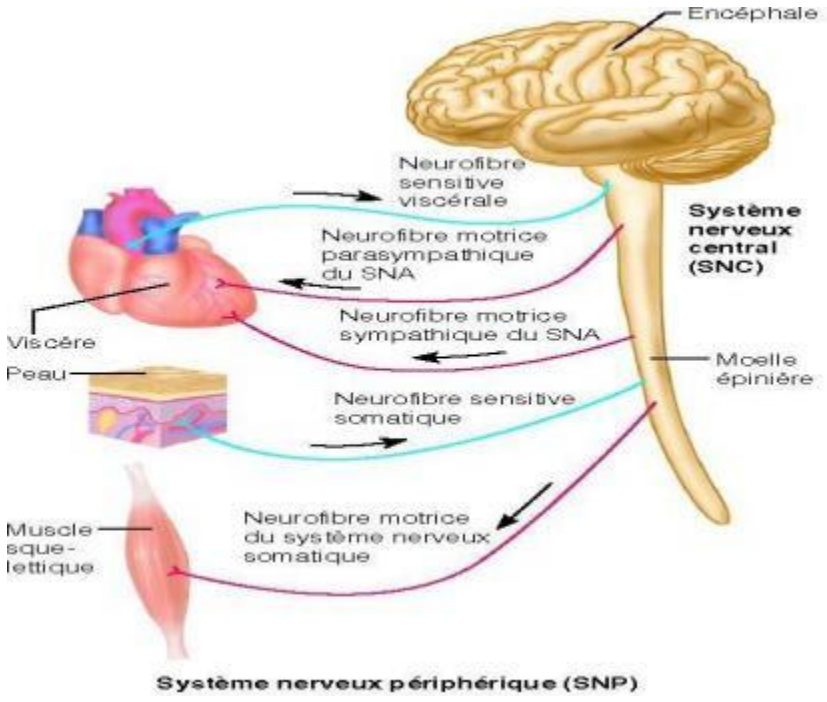


Figure 26: Peripheral Nervous System, Central Nervous System

The autonomous system is divided as follows:

II.4.1.2.1. The Sympathetic Nervous System

- The sympathetic nervous system functions to react to emergency situations (fight or flight response).
- Whether of emotional nature or physical stress, nerve impulses increase to combat danger, and release norepinephrine which excites target muscles (figure 27).

II.4.1.2.2. Parasympathetic Nervous System

It generally does the opposite of the sympathetic nervous system. Acting as a regulator, it calms us. In calm situations, it dominates the sympathetic nervous system. It acts to restore and conserve energy. It can, for example, decrease heart rate. (rest and digestion response).

II.5. The Functions of the Nervous System

Three primary functions:

- Receive sensory information: It receives information about internal and external changes.

These changes are called stimuli. They are received through sensory receptors.

- Integration: It interprets the received information and decides on the action to take.
- The motor response: The response that was taken during the integration phase is transmitted to the muscles and glands.

II.6. Responsibilities of the Nervous System

The nervous system is responsible for:

- The development of our intellectual faculties.
- The mechanisms of voluntary motor control.
- The sensations that connect us with the outside world, namely thinking, acting, feeling, hearing, seeing.
- The functioning of the glands, of our organs.
- The functioning of nutrition and the growth of the cell.

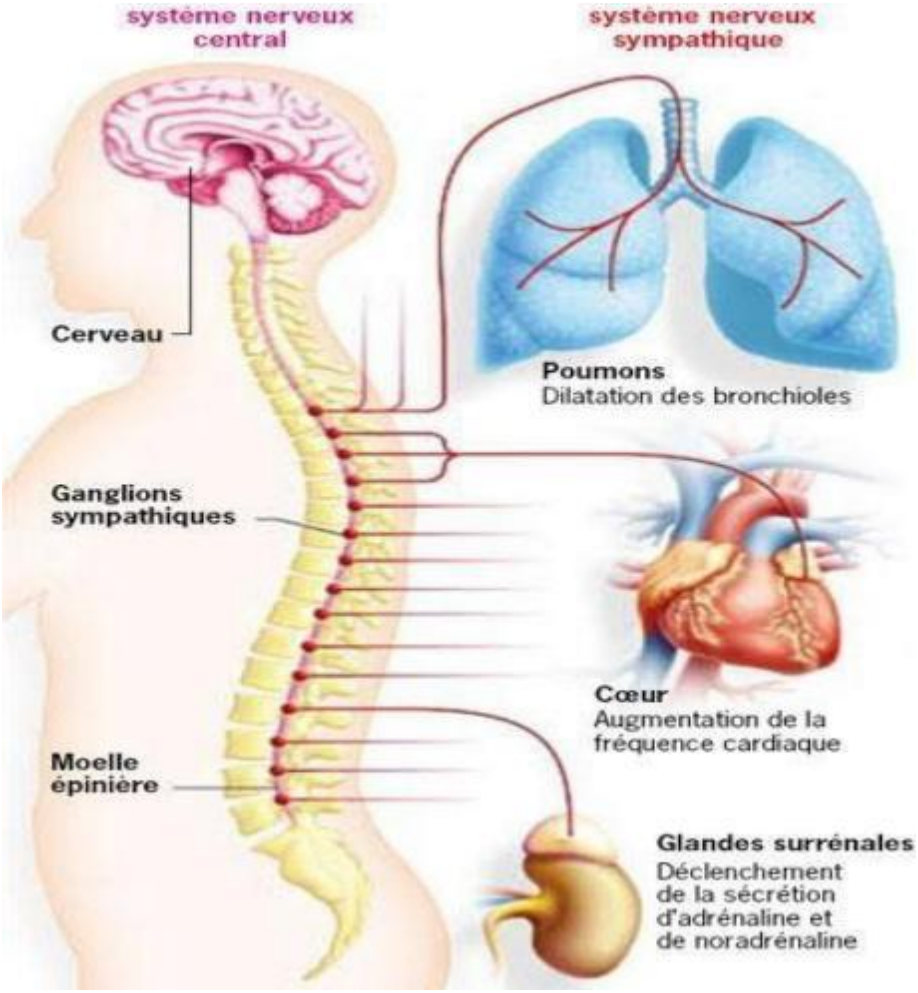


Figure 27: The Sympathetic Nervous System

Chapter III: Cardio-vascular System

III.1. Cardiac Physiology

The cardiovascular system consists of:

- A pump (the heart).
- A set of pipes (the arteries, veins, and capillaries).

III.1.1. The Heart

Is no bigger than your closed fist. It is anterior to the spine and posterior to the sternum (figure 28). It is partially covered by the lungs and placed obliquely in the thorax, with its apex (tip) oriented towards the left hip and resting on the diaphragm. The heart is very resilient, can function for many years, and usually works without being noticed.

In people who regularly engage in intense exercise, the heart gradually adapts to this effort. It thus gains in power and efficiency. On the other hand, vigorous and occasional exercise can cause a myocardial infarction (heart attack).

The cardiovascular system participates in homeostasis: maintaining certain physiological values at a constant level.

The cardiovascular system has a role in:

- Distribution to cells: nutrients, amino acids, fatty acids, vitamins, and oxygen.
- Elimination: waste produced by cells (CO2, lactate).
- Transport:O2, CO2, and hormones.
- Regulation: body temperature, blood pH, water volume, mineral salts.

III.1.1.1. The Anatomy of the Heart

Consists of three layers of tissue (figure 29):

– The pericardium: outer covering of the heart.
– The myocardium: the muscular tissue of the heart.
– The endocardium: inner lining that coats the chambers of the heart.

The heart is divided into two distinct parts (which do not communicate with each other): the right heart and the left heart (figure 30). Each part includes an atrium and a ventricle. The right

atrium communicates with the right ventricle through a valve called the right atrioventricular valve. The same applies to the left atrioventricular valve.

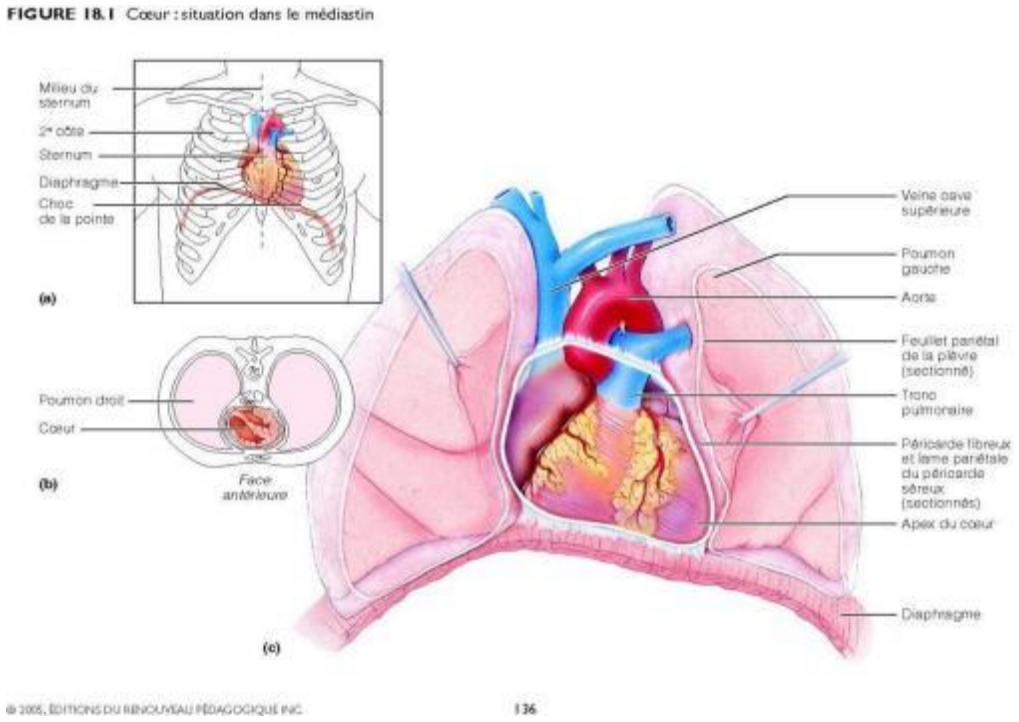


Figure 28: Localization of the Heart

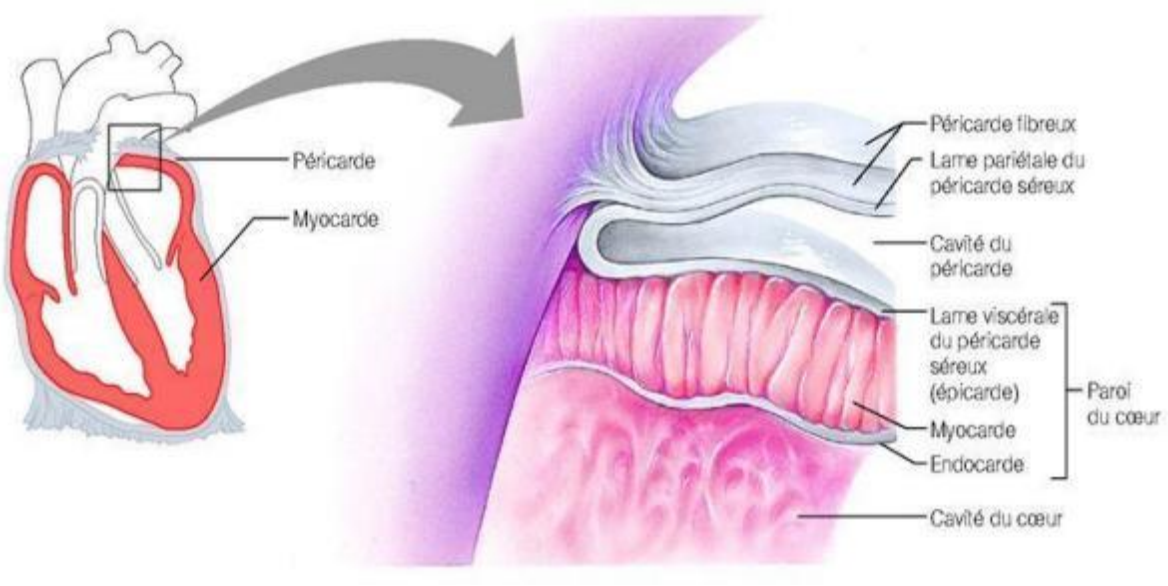


Figure 29: The Anatomy of the Heart

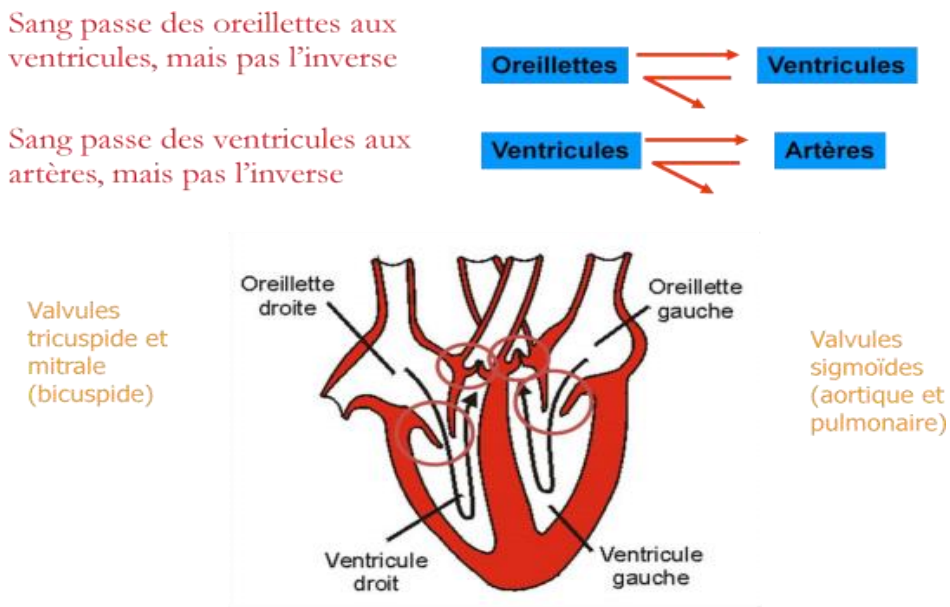


Figure 30: The Right Heart and the Left Heart

III.1.1.1.1. The Anatomy of the Heart: the Atria

Blood arrives at the atria through the veins and leaves the ventricles through the arteries.

The atrioventricular valves prevent blood from flowing backward and re-entering the atria once it has entered the ventricles. The atria are the cavities located at the upper part of the heart and are considered entry chambers.

The walls of the atria are thin and contribute very little to the heart's pumping activity.

III.1.1.1.2. The Anatomy of the Heart: the Ventricles

The ventricles are the cavities located at the lower part of the heart and are considered exit chambers. Their walls are much thicker as they are made up of a larger amount of muscle tissue whose main action is to contract in order to propel blood into circulation.

III.1.1.1.3. The Anatomy of the Heart: the Valves

In addition to the left and right atrioventricular valves, there are two other valves:

– The aortic valve.
– The pulmonary trunk valve.

The four valves of the heart allow blood to flow in one direction from one chamber to another. They therefore prevent blood from flowing back into the atria when the ventricles contract.

III.1.1.2. The Physiology of the Heart

The blood enters the heart and then exits into the entire body. It returns and makes another round in the heart to exit again. This process repeats for all heartbeats.

The heart beats by itself without needing to receive nerve impulses. It contracts on its own and spontaneously.

III.1.2. The Blood Vessels

Blood circulates in the body thanks to the blood vessels. There are various types of blood

vessels that are classified according to the type of blood they carry, their location, and their functions:

– The arteries.

– The veins.
– The capillaries.

III.1.2.1. The Arteries

They carry oxygenated blood from the heart to the organs, are located deep within the body. Their wall is thick and elastic, can expand to allow blood to pass during each contraction of the myocardium. Blood therefore circulates there until its smallest branches, which are called arterioles.

III.1.2.1.1. The Main Arteries of the Body: The Aorta

Is about the size of your thumb, is the largest in the human body. It exits directly from the left ventricle and then divides into several smaller arteries, branching into several (main) branches:

– The carotid artery
– The brachial artery
– The abdominal aorta
– The femoral artery - The radial artery

III.1.2.2. The Veins

Upon leaving the capillaries, the blood that then contains the waste from the cell takes the path of the venules, which are very small branches of the veins. The blood subsequently reaches the veins, which transport it to the heart.

The veins are located much closer to the surface of the body than the arteries, the blood flows through them more slowly than in the arteries and in a continuous manner. The wall of the veins is much thinner than that of the arteries and is formed in such a way as to prevent the blood from flowing backward (valves).

III.1.2.2.1. The Main Veins of the Body

Just as most arteries are branches from the aorta, veins are branches that connect to the two venae cavae that empty into the right atrium of the heart.

– The superior vena cava.
– The inferior vena cava (figure 31).

III.1.2.3. The Capillaries

They are tiny blood vessels, 50 times smaller than a hair, that connect arteries and veins together. Blood flows through them very slowly, allowing exchanges between blood and cells. Oxygen and nutrients are delivered to the cell while the cell's waste is collected by the blood.

III.2. The Circulation

The heart is actually a double pump: one pump, the right heart. The other, the left heart. Each of the pumps has specific functions:

– The right heart: is the pump that handles the pulmonary circulation to send blood (deoxygenated) to the lungs.
– The left heart: is the pump that handles the systemic circulation, which is responsible for distributing blood (oxygenated) to the entire body (figure 32).

III.3. Properties of the Myocardium

III.3.1. Nodal Tissue and Cardiac Automatism

The heart has a mechanical activity that is electrically controlled.

Cardiac autorhythmicity: existence of myocardial cells that spontaneously produce an electrical signal that stimulates neighboring cells. This group of cells constitutes the nodal tissue.

Two cellular clusters:

- Sinoatrial node or Keith and Flack.
- Atrioventricular node or Aschoff-Tawara node.

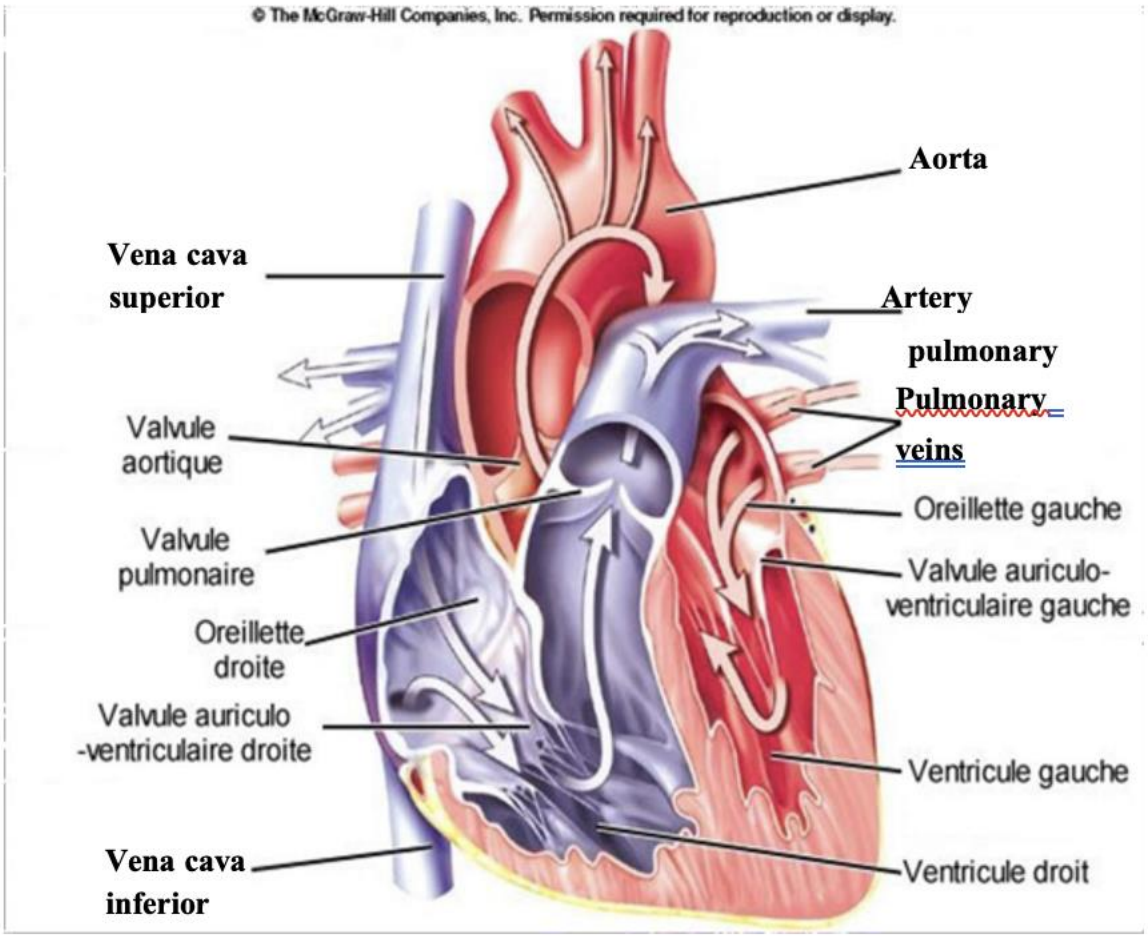


Figure 31: The Main Veins, Arteries, Valves of the Heart

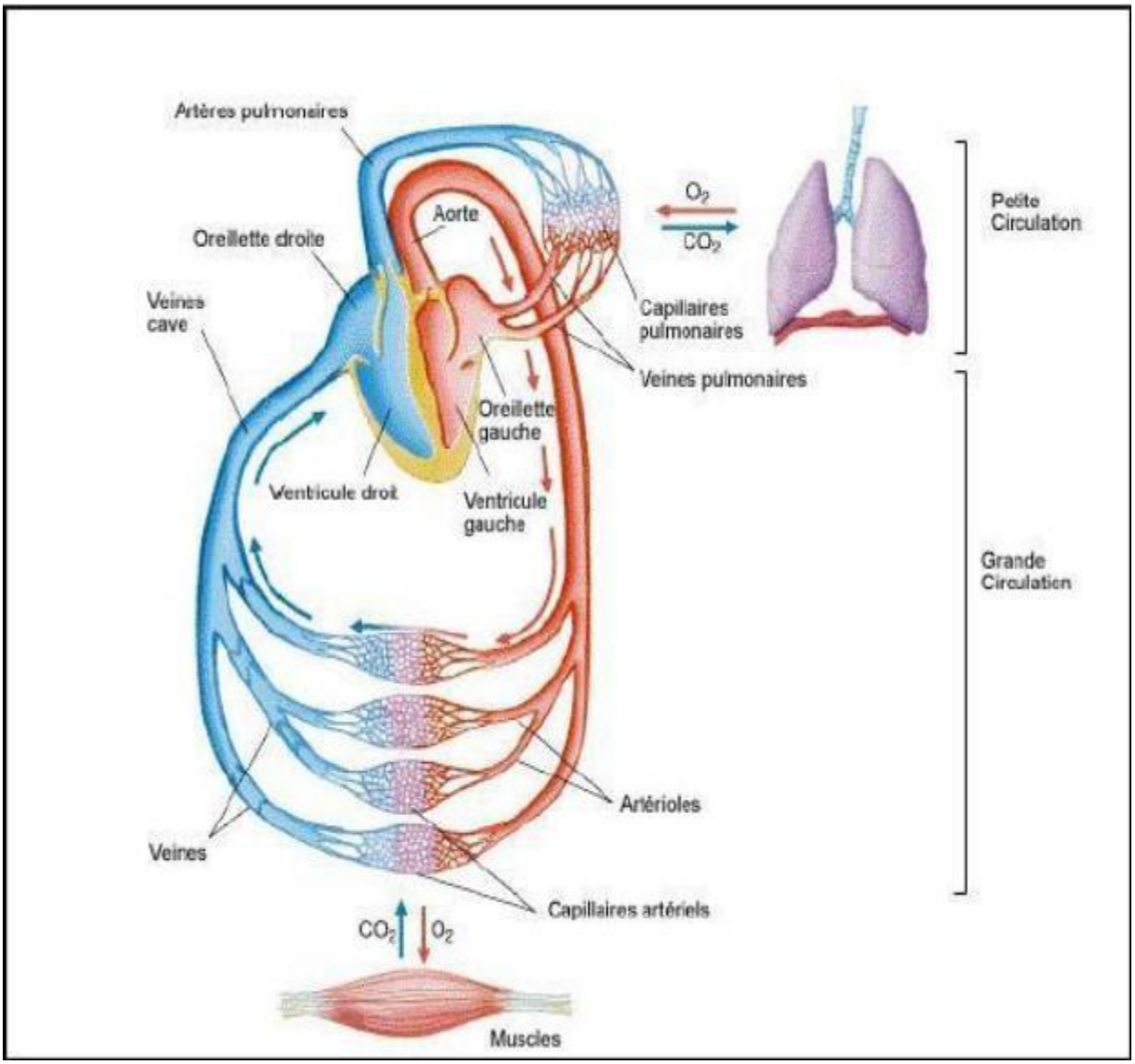


Figure 32: The Pulmonary Circulation and the Systemic Circulation

Extension by the His bundle, divided into 2 branches: Purkinje fiber network.

Birth of the heart stimulation process in the sinus node.

Sinus node = pace-maker imposes its rhythm on the entire heart = sinus rhythm.

Propagation to the atria which contract as a block. Relayed by the atrioventricular node, reaches both ventricles through the His bundle and the Purkinje network (figure 33).

III.3.2. The Cardiac Action Potential

III.3.2.1. The Electrocardiogram

Any working muscle is the seat of a depolarization wave, that is to say, a current that can be recorded by two electrodes placed judiciously (figure 34).

The heart, like any muscle, produces a current. Due to its crucial role in the body and the complexity of its functioning, the electrical study of the heart, or electrocardiography, has taken on great importance in cardiac physiology and pathology. The electrocardiogram is the result of recording the electrical activity of the heart, studied from different <<angles>>.

The more these different study points, called leads (points where electrodes are placed), are numerous and overlap, the more accurate the <<portrait>> of cardiac activity obtained will be.

Electrocardiogram (ECG): recording of the electrical activity of the heart.

The electrical activity of the heart can be monitored from the skin (Marey, Waller 1880). Each phase of the heartbeat has a specific electrical trace.

III.3.2.2. The Cardiac Cycle

Alternation of contractions and relaxations: a pump propelling blood. The cardiac cycle is the pattern of repetitions of contractions and relaxations (figure 35).

Two main phases: diastole and systole. Blood flows from a high-pressure system to a low-pressure system.

Phase 1: General Diastole – Passive flow of blood from the atria to the ventricles.

Phase 2: Atrial Systole – Contraction of the atria and active filling of the ventricles.

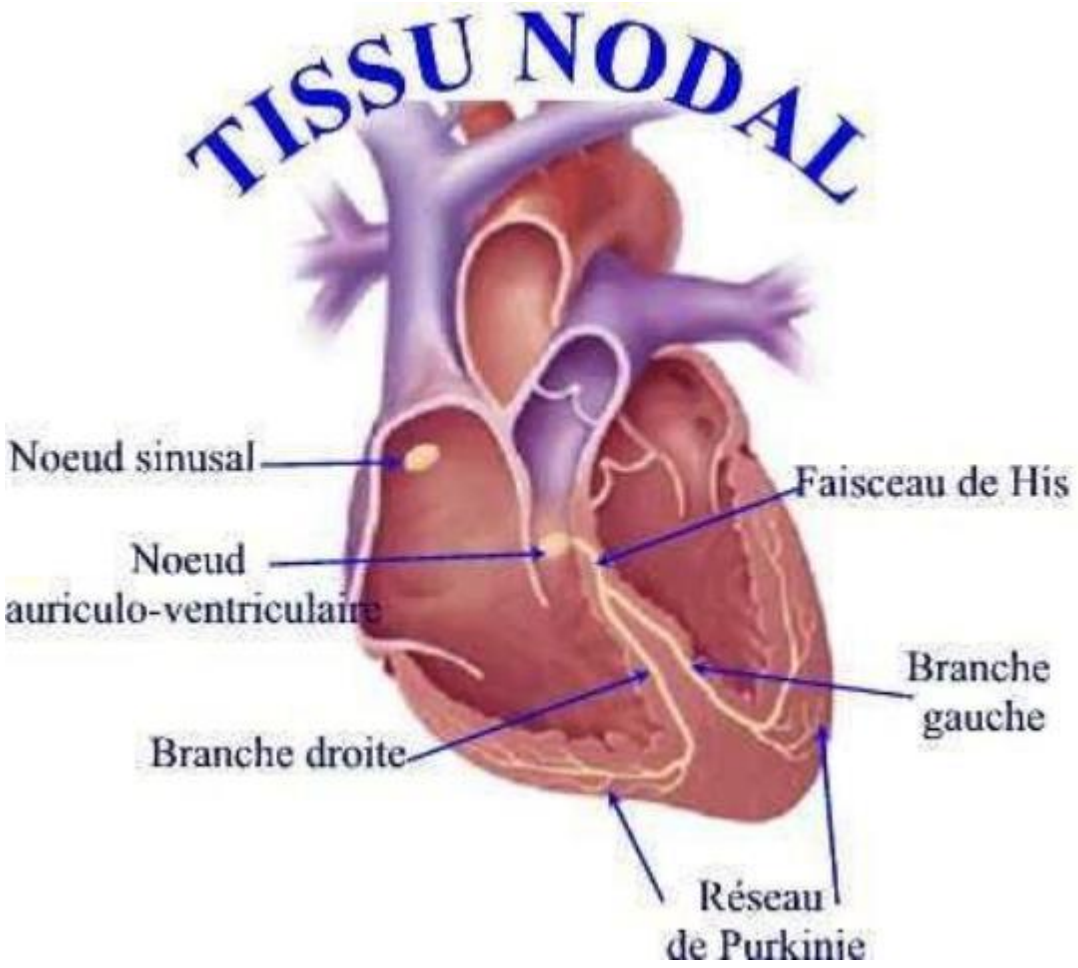


Figure 33: Nodal Tissue

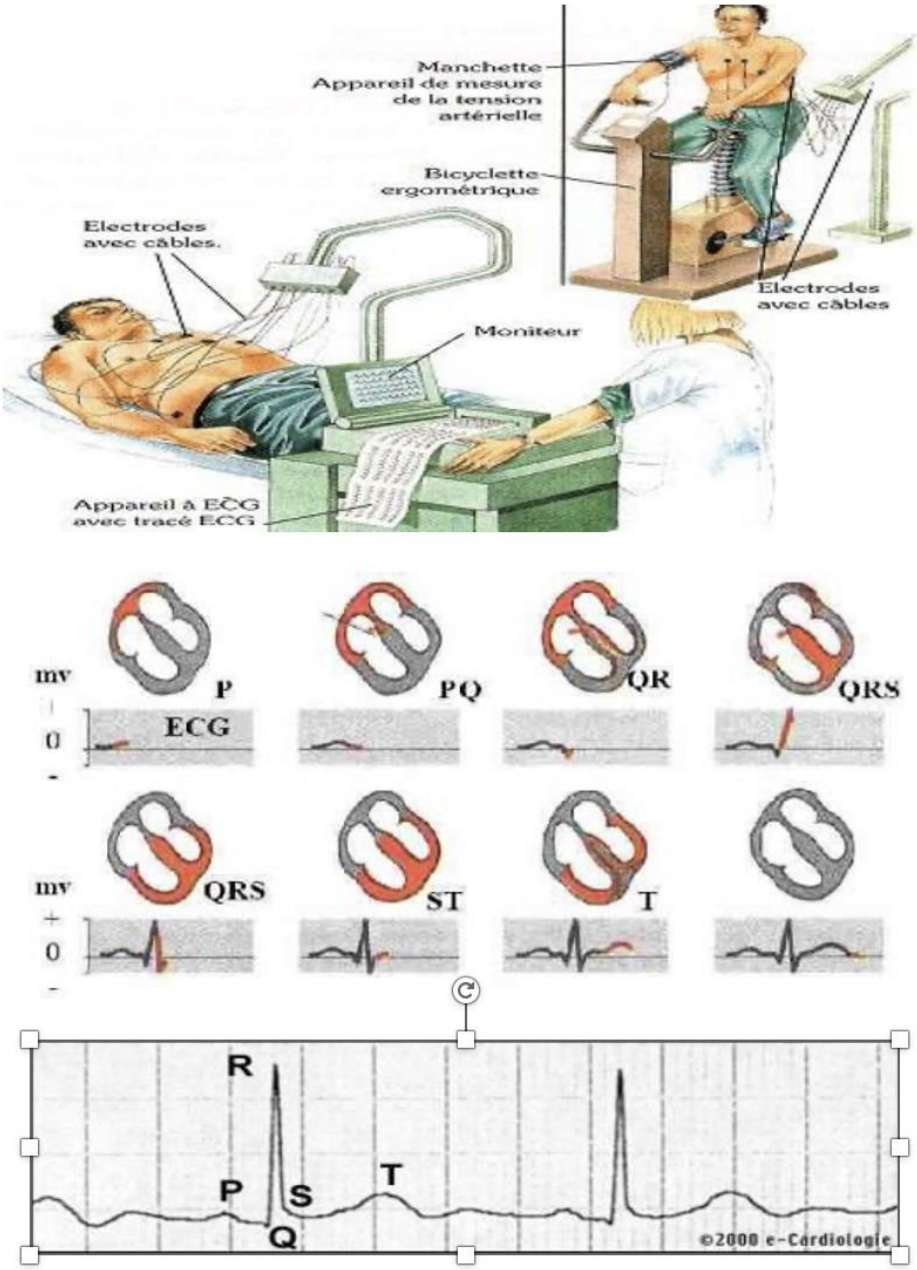
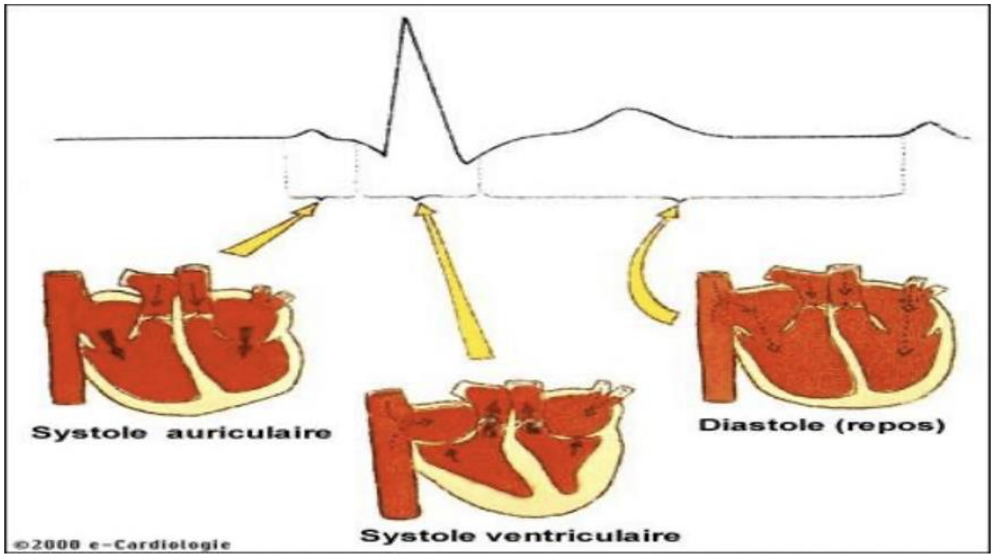


Figure 34: The Electrocardiogram (ECG)



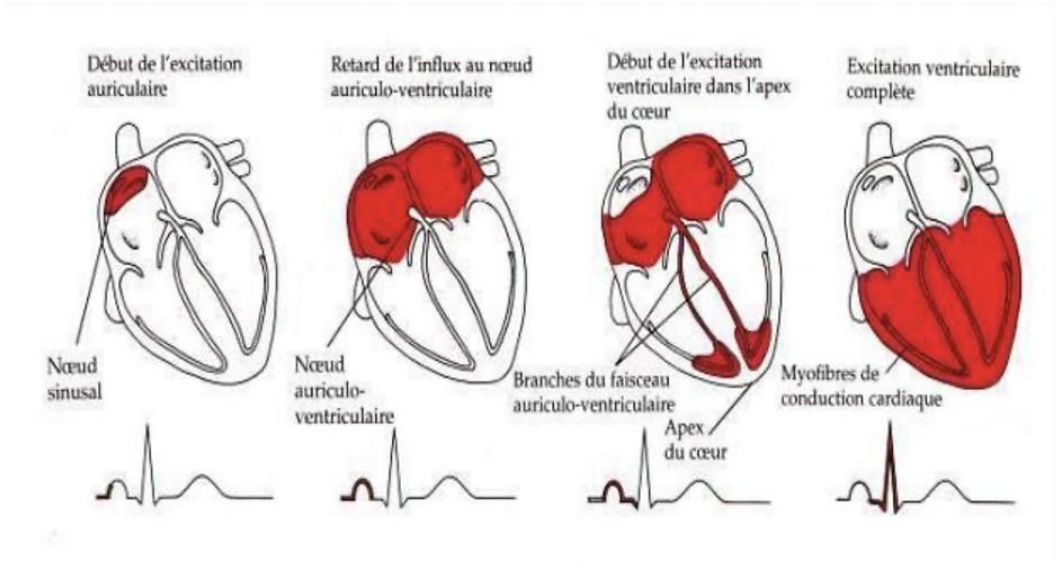


Figure 35: The Cardiac Cycle

Phase 3: Atrial diastole – relaxation of the atria.

Phase 4: Ventricular systole – Contraction of the ventricles and passive flow of blood into the atria. Ejection of blood into the aorta.

Phase 5: Ventricular diastole: relaxation of the ventricles.

To function as a pump, the heart successively repeats two phases:

Depolarization of the cells that causes systole: contraction phase.

Repolarization of the cells that causes diastole: relaxation phase that allows the filling of the atria and ventricles.

A cardiac cycle thus includes an alternation of electrical and mechanical phenomena.

III.3.3. Regulatory Phenomena

The cardiac muscle has an automatic functioning, but not completely autonomous. The heart must indeed adapt to the needs of the organism (muscle work) or undergo certain repercussions (tachycardia from fear or emotion).

III.3.3.1. Intrinsic Regulation

Cardiac fibers have an adaptation capacity that allows for an increase in the contraction power of a muscle. During work, dilation allows its fibers to lengthen.

III.3.3.2. Extrinsic Regulation

In a healthy person, adaptation to the needs of the organism is ensured by the autonomic nervous system, which can act on the acceleration of heart rate, the instantaneous adaptation of the respiratory rhythm ...

The nervous system that controls the heart is the autonomic nervous system, sympathetic and parasympathetic, which includes:

- Higher centers, cardio-regulators.
- Motor nerves, accelerators, and moderators, which directly transmit the orders from the centers to the cardiac pump.

III.3.3.2.1. Heart Rate and Parasympathetic System

The parasympathetic system, whose mediator is acetylcholine, is cardiomodulatory.

- Slows the heart by lengthening diastole.
- Reduces the strength of atrial systole.
- Lengthens the atrioventricular conduction time.
- Weakens the tone of the myocardium.

The parasympathetic cardio-regulatory centers are located in the medulla. Their motor nerve is the vagus nerve, also called the pneumogastric nerve, the tenth pair of cranial nerves. This nerve, among its multiple functions, has a contingent of fibers destined for the heart. The fibers branch out to almost all cardiac tissues.

The pneumogastric or vagus nerve continuously imposes a certain slowing of the spontaneous heart rate, which is called the moderating vagal tone. This vagal tone slows the sinus heart rate to 70-80, which is 120-130/min spontaneously.

III. 3.3.2.2. Heart Rate and Sympathetic System

The sympathetic system, whose chemical mediator is norepinephrine, is cardioacceleratory.

- Accelerates the heart by shortening its diastole.
- Increases the power of the atrial systole.
- Shortens the time of atrioventricular conduction.
- Strengthens the tone of the myocardium.

The sympathetic cardio-accelerator centers are located in the anterior horn of the spinal cord.

The sympathetic nerves constantly impose a certain acceleration on the spontaneous heart rate. However, this accelerator tone is normally masked by the more powerful vagal slowing tone.

III.4. Blood Pressure and Cardiac System

There is a close hydraulic relationship between cardiac output, thus heart rate, and blood pressure. The cardio-regulatory centers are directly connected to blood pressure indicators or baroreceptors located on one hand at the level of the aortic arch, and on the other hand at the level of the carotid bifurcation.

A decrease in blood pressure detected by the baroreceptors of these detectors immediately leads to an acceleration of heart rate by suppression of the slowing vagal tone. Conversely, an increase in blood pressure leads to a slowing of the heart rate.

Stroke volume (SV): Volume of blood ejected from the heart by the ventricles with each contraction (100 ml).

End-diastolic volume (EDV): Volume of blood contained in the ventricles just before ventricular systole (160 ml) = preload volume.

End-systolic volume (ESV): Volume of blood contained in the ventricles at the end of each systole (60 ml) = afterload volume.

$$SV = EDV – ESV$$

Heart rate (HR): number of ventricular contractions per second, expressed in beats per minute bpm (average = 60 - 70 bpm).

Max HR = variable depending on individuals, it gradually decreases with age and with training.

Cardiac output (CO) = volume of blood expelled by each ventricle per unit of time. Expressed in liters per minute.

$$Qc = VES \times Fc$$

Average Qc = 5 l/min. Varies according to the needs of the organism.

Chapter IV: Respiratory System

IV.1. Respiratory System

The respiratory system is the system(set of organs), which allows breathing, that is to say the gas exchanges between the organism and the environment.

In animals, breathing refers to both the mechanisms that allow the transfer of gases between the organism and the environment (absorption of oxygen O2 and release of carbon dioxide CO2).

IV.1.1. Respiratory Pathways

IV1.1.1. Nasal Cavities

The nasal cavities or nasal fossae are two spaces separated by a partition: the nasal septum. Irregular cavities, lined with a highly vascularized mucosa. Surface area of air/mucosa contact multiplied (turbinates).

They are located:

- Above the oral cavity.
- Below the cranial cavity.
- Inside the orbital cavities and the maxillary sinuses.
- In front of the nasopharynx.

The nasal cavities are the upper part of the respiratory system. In addition, they contain the organs involved in'olfaction.

IV.1.1.1.1. Roles of the Nasal Cavities

- Warming.
- Humidification.
- And filtration of the inspired air.

IV.1.1.2. Pharynx

It is located between the nose and the trachea. It is an aerodigestive crossroads between the airways (from the nasal cavity to the larynx) and the digestive tract (from the oral cavity or mouth to the esophagus). It works closely with the larynx to control the opening and closing of the respiratory tube (trachea) and the digestive tube (esophagus). A common area for the airways and

to the digestive tract. Implantation of the tonsils and adenoids and implantation of a mucosal fold that closes off the trachea during swallowing: the epiglottis (figure 36).

IV.1.1.2.1. Roles of the Pharynx

- Swallowing: separation of air / solids and liquids (epiglottis), aerodigestive crossroads.
- Defense against infection (tonsils and adenoids).
- The respiration.
- The hearing.

IV.1.1.3. Larynx

The larynx is a cartilaginous organ of the respiratory system located at the level of the throat.It is located anteriorly to the aerodigestive crossroads formed by the pharynx.It is thus the intermediary between the pharynx and the trachea and houses the vocal cords. It is part of the airways. It closes access to the airways while food is sent into the digestive tract. Corresponds to the "Adam's apple," forms the upper opening of the trachea: the glottis (figure 37).

IV.1.1.3.1. Role of the Larynx

The larynx has three functions:

- Organ of phonation, organ of sound production: its role phonatory is very important, although not vital.
- A respiratory function, an integral part of the respiratory tract.
- A role in swallowing: its closure protects the lower airways.

IV.1.1.4. Trachea

The trachea is a conduit made of fibrous and cartilaginous tissue connecting the larynx above to the left and right main bronchi below. Belonging to the'respiratory system', it allows the'air'to flow between these structures. The trachea is the elastic fibrocartilaginous conduit connecting the larynx to the bronchi. It allows, during breathing, the air to flow from the larynx to the bronchi during inhalation, and vice versa during exhalation.

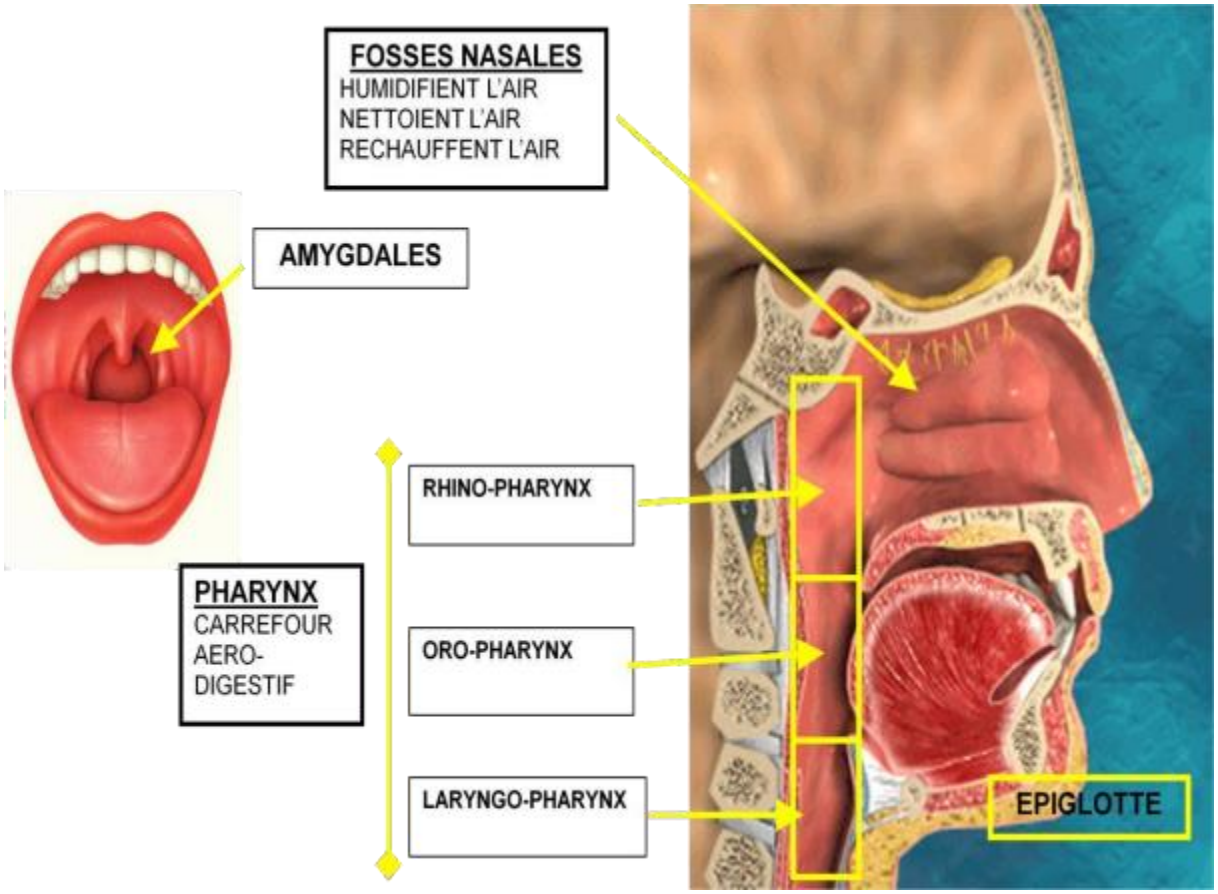


Figure 36: The Respiratory Pathways

The trachea begins in the neck at the level of the sixth cervical vertebra and follows the larynx.It then plunges into the thorax where it travels through the mediastinum(behind the sternum and between the lungs) before dividing into the right and left main bronchi. The tracheal bifurcation is called the "tracheal carina". It runs in front of the esophagus, with which it shares its microvascularization.

The trachea measures between 120 and 150 mm in length and 14 to 15 mm in diameter. It consists of 16 to 20 cartilage elements shaped like a horseshoe, placed horizontally and with the open part facing backward. These elements are stacked and separated by fibrous tissue. They form the anterior and lateral walls of the trachea. The posterior wall is a thin smooth muscle membrane (figure 38).

IV.1.1.4.1. Roles of the Trachea

- Conduction of air.
- Humidification and purification of inspired air.

IV.1.2. Bronchi and Bronchioles

The bronchi are two tubes about 12 mm in diameter that lead to the left and right and conduct air to the bronchioles in each lung.

Each main bronchus (right and left) divides into increasingly finer branches. The entire air circuit is lined with a mucous membrane rich in ciliated cells and mucus-producing cells. The terminal bronchioles end the airways in glove-like fingers at the level of the pulmonary lobules.

IV.1.3. The Exchange Zone

IV.1.3.1. Lungs

The lung is an invaginated organ that allows the exchange of vital gases, notably oxygen and carbon dioxide. Oxygen is necessary for the metabolism of the organism, and carbon dioxide must be expelled.

The human has two lungs, left and right, two thoracic organs, separated from each other in the center by the mediastinum. They rest on the diaphragm and are protected by the rib cage.

Thoracic in front, outside, and behind, except at their apex, as they protrude.

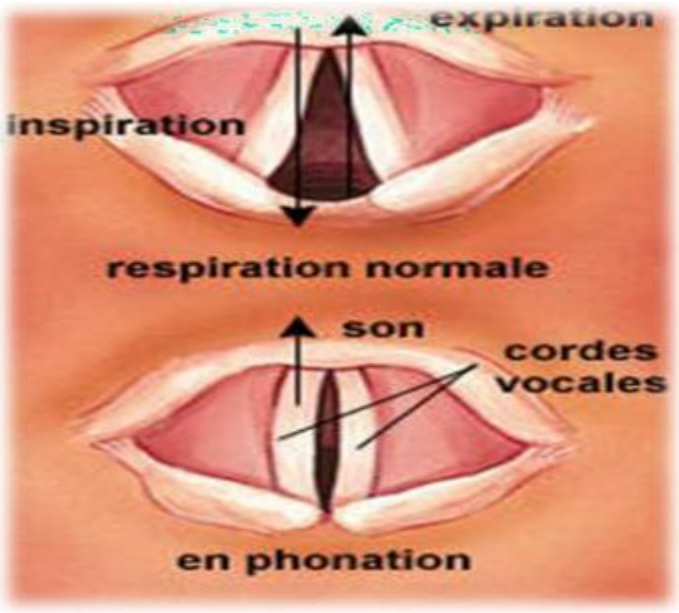


Figure 37: Organ of Phonation (Larynx)

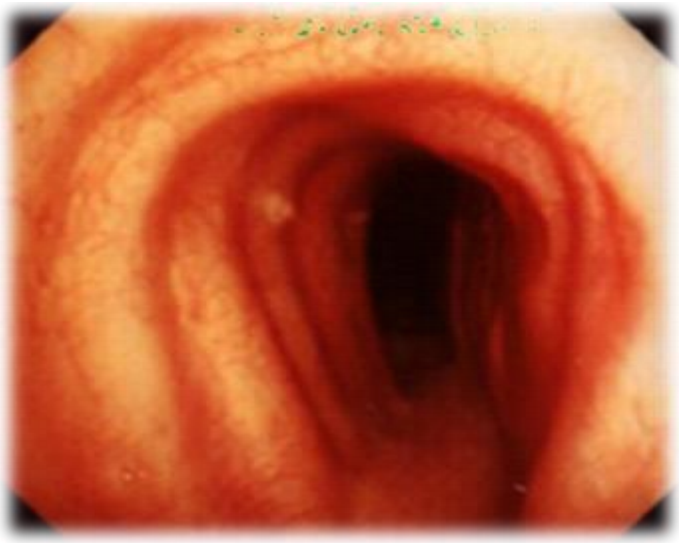


Figure 38: The Trachea

Ventrally the upper border of the first rib, and even rises above the clavicle, at the base of the neck, in the supraclavicular hollow.

The right lung is divided into three lobes (upper, middle, and lower), the left divided into two (upper and lower). On the left, the lingular part of the upper lobe corresponds to the right middle lobe, while the culminal part (culmen) corresponds to the right upper lobe. The

lobes are separated by fissures, two on the right (the large or "oblique," and the small or "horizontal") and one on the left (the oblique), (figure 39).

IV.1.3.2. Pulmonary Alveolus

Minute air sacs about 0.2 mm in diameter. The lungs of a human being contain about 300 million alveoli.

The alveolus is the functional unit of the respiratory system. Microscopic sac and the site of gas exchange. Several hundred million per lung, 200 m 2 of total surface area, 70 m 2 of air/blood contact.

Lined with a surfactant liquid that keeps the alveolus open: the surfactant. Alveolo- capillary unit.

- Intimate contact between a pulmonary alveolus and a pulmonary capillary.
- Formation of a single entity between the two walls: the alveolo-capillary membrane.
- Allowing gas exchange air/blood.

IV.1.4. The Rib Cage

IV.1.4.1. Costal Grill

Twelfth pairs of ribs (right and left), articulated with the sternum in front and articulated with the dorsal vertebrae in the back (figure 40).

IV.1.4.2. Diaphragm

The diaphragm is an organ made of muscular tissue. When it contracts, it causes air to be inhaled into the respiratory system. When it relaxes, air is exhaled.

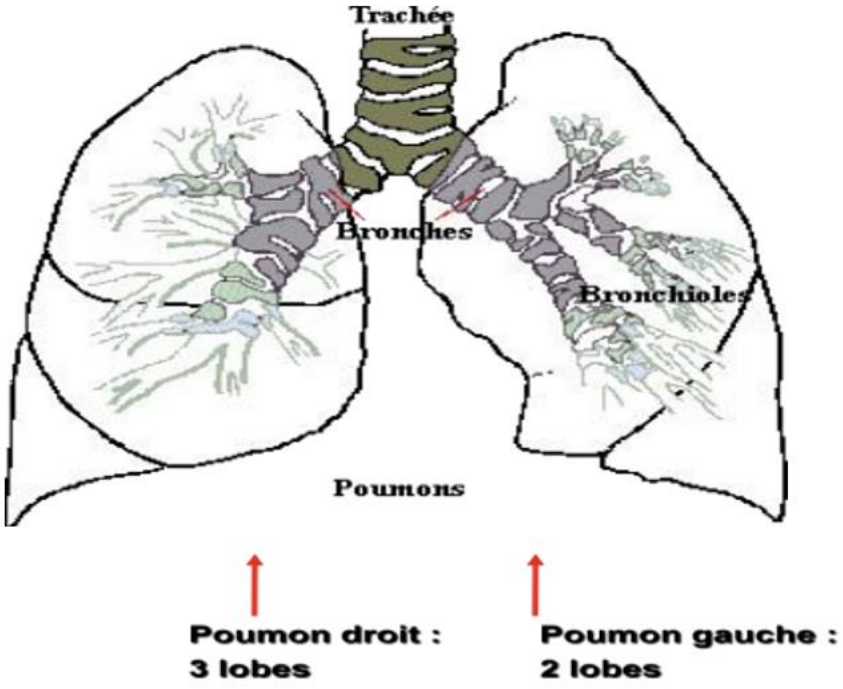


Figure 39: The Lungs

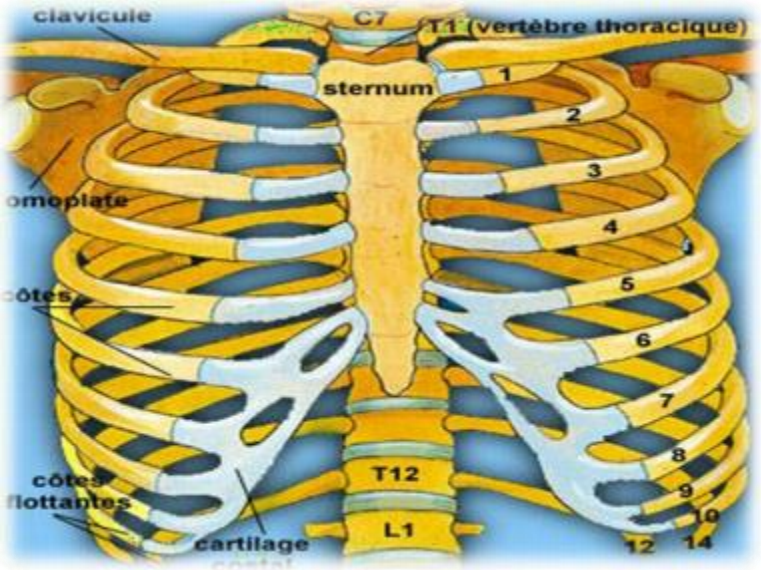


Figure 40: The Rib Cage

IV.1.4.3. Pleura

The parietal pleura, located against the thoracic wall, of the visceral pleura, attached to

the lungs (figure 41). The two pleural cavities (right and left) are not connected to each other. The layers of the two pleurae meet at different pleural sinuses.

Like all serous membranes, they have a role in reducing friction caused by movements (respiratory in this case). They are lined by an epithelium secreting a small amount of lubricating fluid.

IV.2. The Neurological Centers

IV.2.1. Spinal Bulb

Located at the level of the first cervical vertebrae, it is the site of automatic respiratory control centers (figure 42). It allows for continuous analysis of blood carbon dioxide levels (sensors).

IV.2.2. Nerve Pathways

Allowing the exchange of information between the brain and the respiratory centers and between the respiratory centers and the pulmonary system.

IV.3. Safety Reflexes

IV.3.1. Swallowing

Swallowing is the action of swallowing. The term refers both to the action of swallowing one's saliva after the occlusion of the dental arches and the movement of the food chewed to the stomach. It is part of mastication, which includes all the syllabic and technical operations (prehension,mastication,insalivation, swallowing) that occur before digestion in the digestive tract. Swallowing is the primary protection of the tracheobronchial tree. Closure of the glottis (larynx) by the epiglottis, elevation and backward push of the base of the tongue, elevation of the soft palate (figure 43).

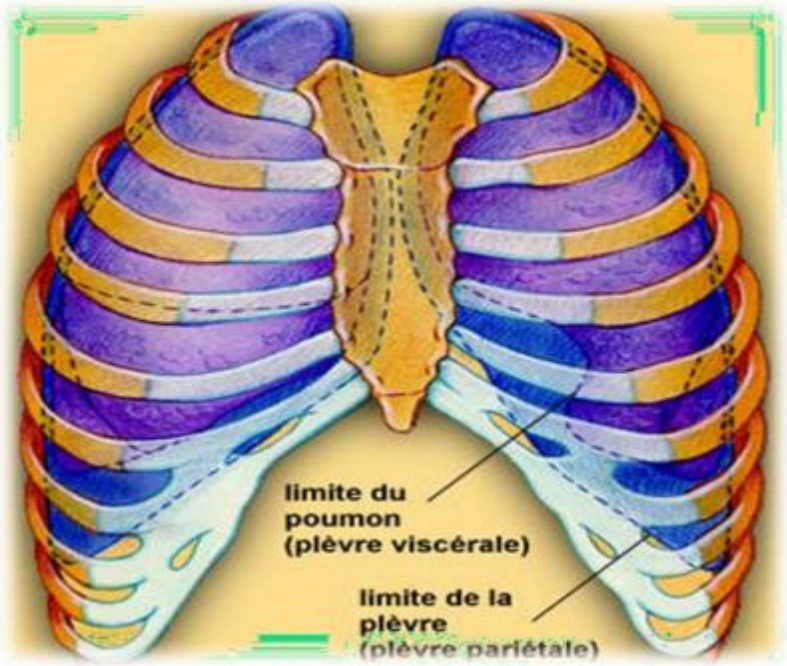


Figure 41: The Sheets of the Two Plethoras

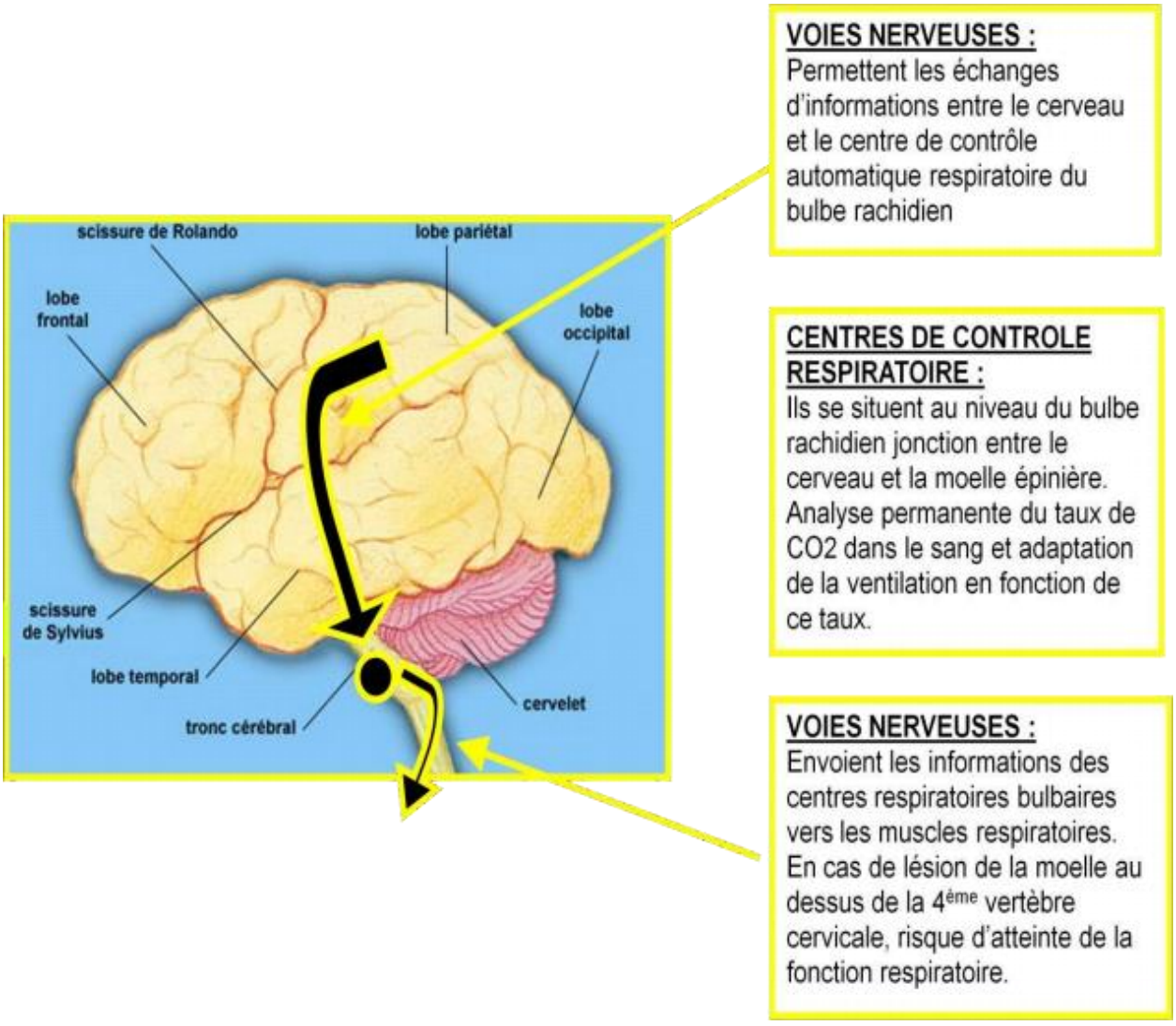


Figure 42: The Neurological Centers

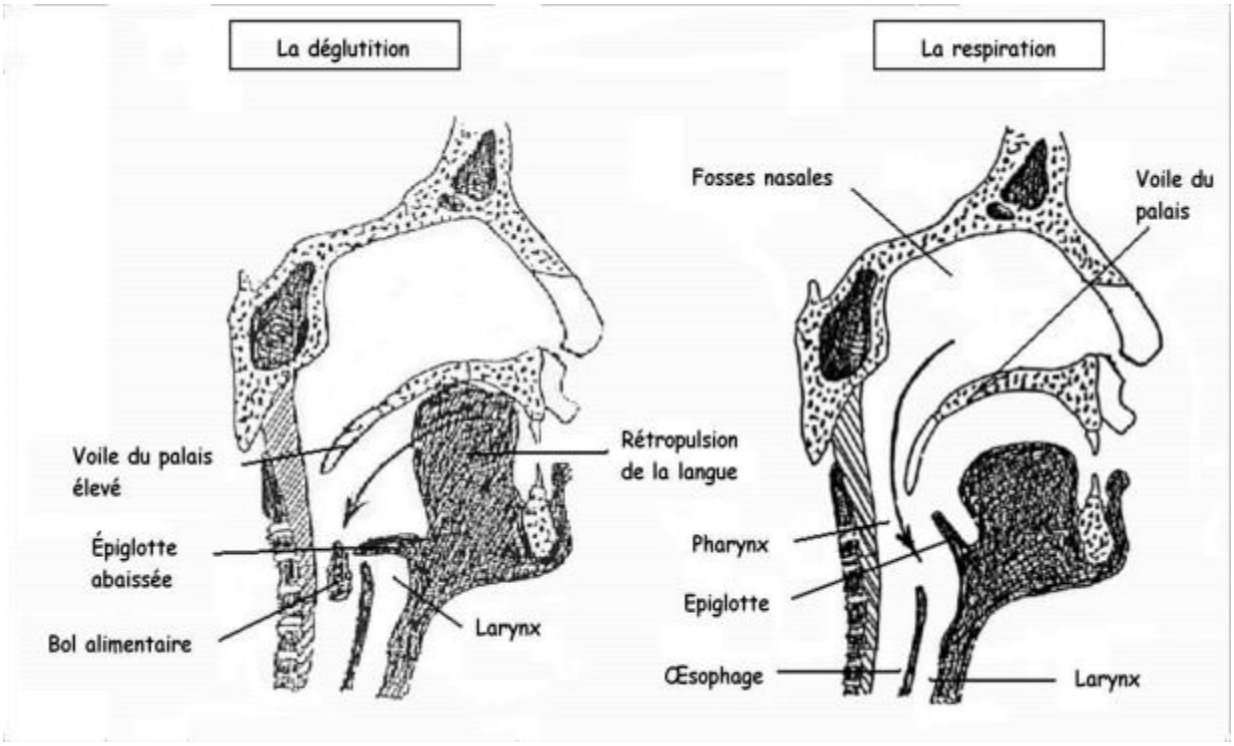


Figure 43: Safety Reflexes (Swallowing)

IV.3.2. The Cough

Second protection of the tracheobronchial tree. It expels irritating gases or particles of any kind that may be present in the airways. Rapid expulsion of alveolar gas at very high speed and with strong turbulence.

Combined action of diaphragmatic contraction with a closed glottis, followed by the sudden opening of the upper airways.

IV.4. The Physiology of the Respiratory System

The main functions of the respiratory system are:

- To provide oxygen to the body.
- To remove carbon dioxide.

This is possible through respiration, which requires four essential phenomena:

- Pulmonary ventilation.
- External respiration.
- The transport of respiratory gases.
- Internal respiration.

IV.4.1. Pulmonary Ventilation (respiration)

Pulmonary ventilation or respiration is the renewal of the air contained in the lungs by the action of the respiratory muscles of which the main one is the diaphragm. In medicine and biology, the term "respiration" referring to energy production by cells, the term pulmonary ventilation is preferred to avoid any confusion. It includes two phases: the entry of air into the lungs during inhalation and the exit of air during exhalation.

IV.4.2. External Respiration

Refers to the gas exchange that occurs between the capillaries of the lungs and the pulmonary alveoli.

IV.4.3. The Transport of Respiratory Gases

This refers to the entry of oxygen and carbon dioxide into the lungs and tissues, and their exit through the bloodstream.

IV.4.4. Internal respiration(cellular respiration): it is the exchange between cells and blood.

IV.4.5. The Mechanics of Ventilation

IV.4.5.1. Inspiration

Inspiration is one of the phases of respiration consisting of absorbing air, as opposed to expiration.

Active phenomenon, entry of air. Action of the diaphragm, which contracts between two fixed points. Increase in the volume of the thoracic cage with a decrease in intrathoracic pressure. Air penetration into the airways, the lungs expand and air enters (figure 44).

IV.4.5.2. Expiration

A phase of respiration consisting of expelling air, as opposed to inspiration. Passive phenomenon, exit of air. Elasticity of the thoracic cage with a return to the normal volume of the thoracic cage. Expired air exits and relaxation of the muscles. The thoracic cage lowers and the diaphragm relaxes and rises and the lungs contract and air exits (figure 45).

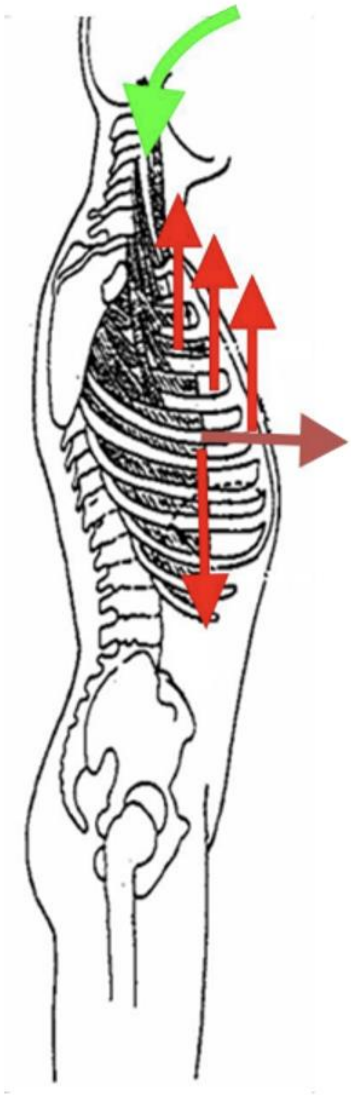
IV.5. Alveolar-Capillary Exchanges

IV.5.1. Oxygen

Arrives with ambient air in the pulmonary alveolus during inhalation. Passes through the alveolar-capillary membrane by diffusion and enters the blood, binding to the hemoglobin of the red blood cell (figure 46).

IV.5.2. Carbon Dioxide

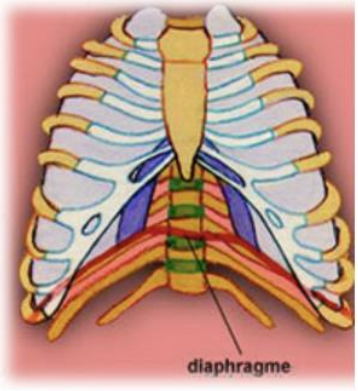
Transported by plasma and red blood cells, it passes through the alveolar-capillary membrane by diffusion. Expelled from the airways during exhalation.



Inspiration: active phenomenon

Contraction of the diaphragm,

the elevating muscles of the ribs and the intercostals

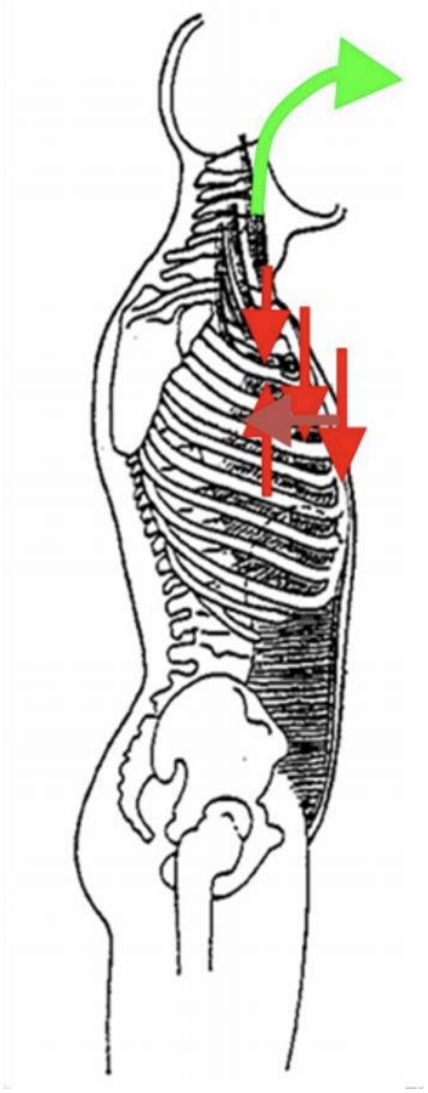


Increase in the volume of the thoracic cage

The lungs, extensible, attached to the thoracic cage by the pleura, increase in volume

Entry of air

Figure 44: Inspiration

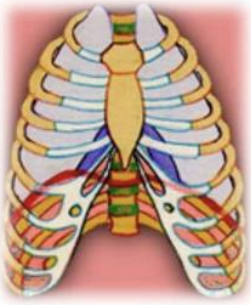


Expiration: passive phenomenon

Relaxation of the diaphragm,

the elevating muscles of the ribs and the interco-stals; the diaphragm rises

The lungs, elastic, return to their initial volume by pulling on the rib cage



Decrease in the volume of the rib cage

Expulsion of air

Figure 45: Expiration

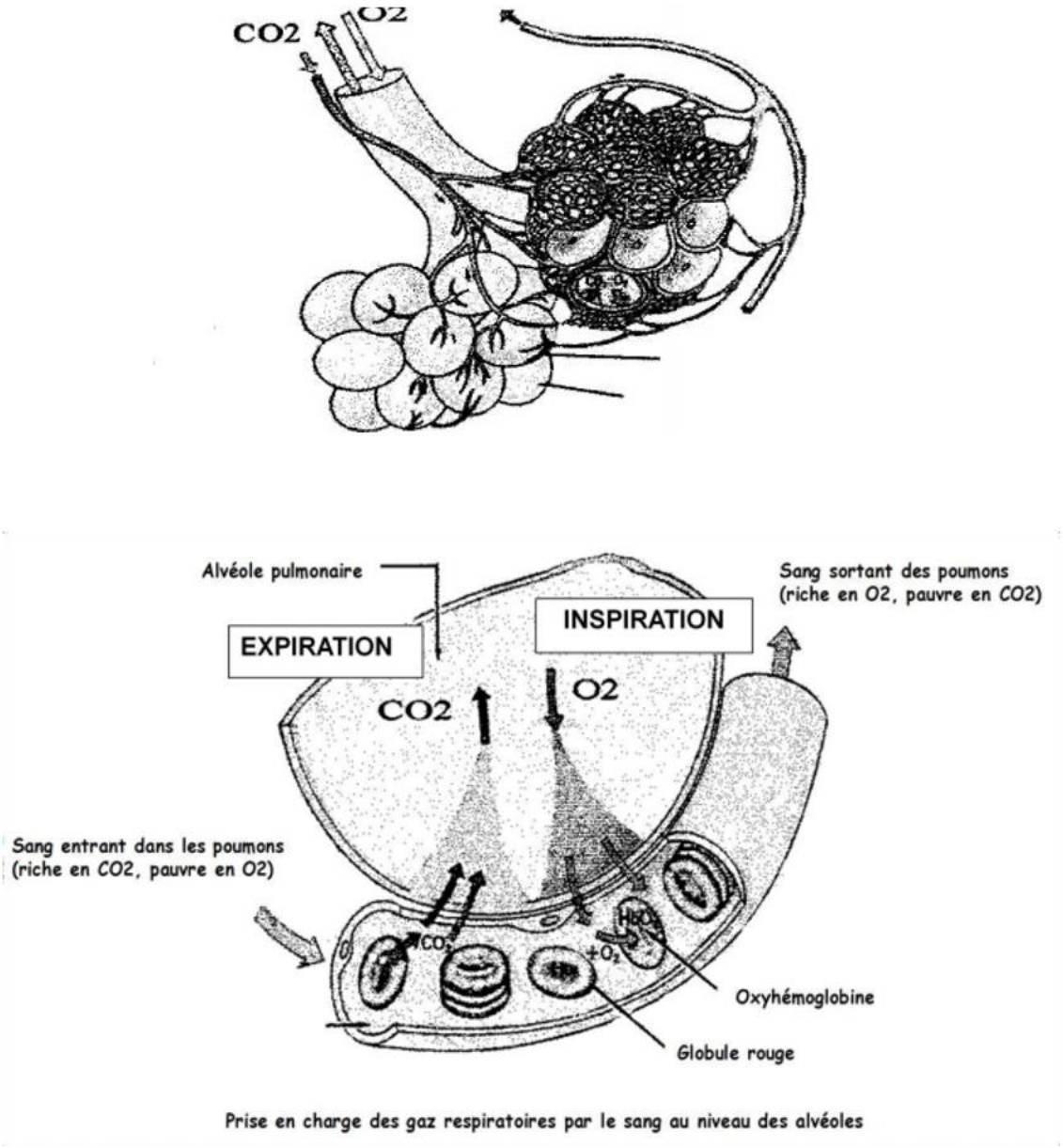


Figure 46: Alveolar-Capillary Exchanges

The respiratory rate in adults is 15 to 20 cycles/min

IV.6. Respiratory Regulation

IV.6.1. Carbon Dioxide

Main stimulus for respiration. It is the excess of carbon dioxide that kills the patient first. An increase in CO2 causes an increase in heart rate.

IV.6.2. Oxygen

Second stimulus for respiration. A decrease in O2 causes an increase in heart rate.

IV.6.3. Other Stimuli

Pain, stress, fever, effort, emotion, will increase heart rate. Disorders of consciousness, certain medications or toxins, will decrease heart rate.

IV.7. Factors Influencing Respiratory Performance:

- Lung capacity
- Muscle strength
- The available energy
- The medications
- Nutrition status
- Metabolic situation

IV.7.1. Lung Capacity

Lung capacity is the volume of air that can be inhaled. It is measured with a spirometer. Generally, three types of breathing are measured:

- Normal, calm breathing, which gives the resting volume used of about 0.5 liters.
- Forced breathing, which gives the maximum capacity (vital capacity) of about 5 liters.
- A sudden expiration, which provides information about the bronchioles, particularly in the context of a search for asthma.

The capacity of our lungs increases until adulthood and decreases with old age. Men have a greater lung capacity than women (about double). The reason is simple: they are larger in size.

- Tidal volume (TV): the volume of air inhaled and exhaled during normal breathing.

- Inspiratory reserve volume (IRV): the volume of air that can be inhaled in addition to the tidal volume.
- Expiratory reserve volume (ERV): the volume of air that can be exhaled in addition to the tidal volume.
- Vital capacity (VC): the total volume of exchangeable gas (figure 47).
- Residual volume (RV): the amount of gas that remains in the lungs and airways after a complete expiration.

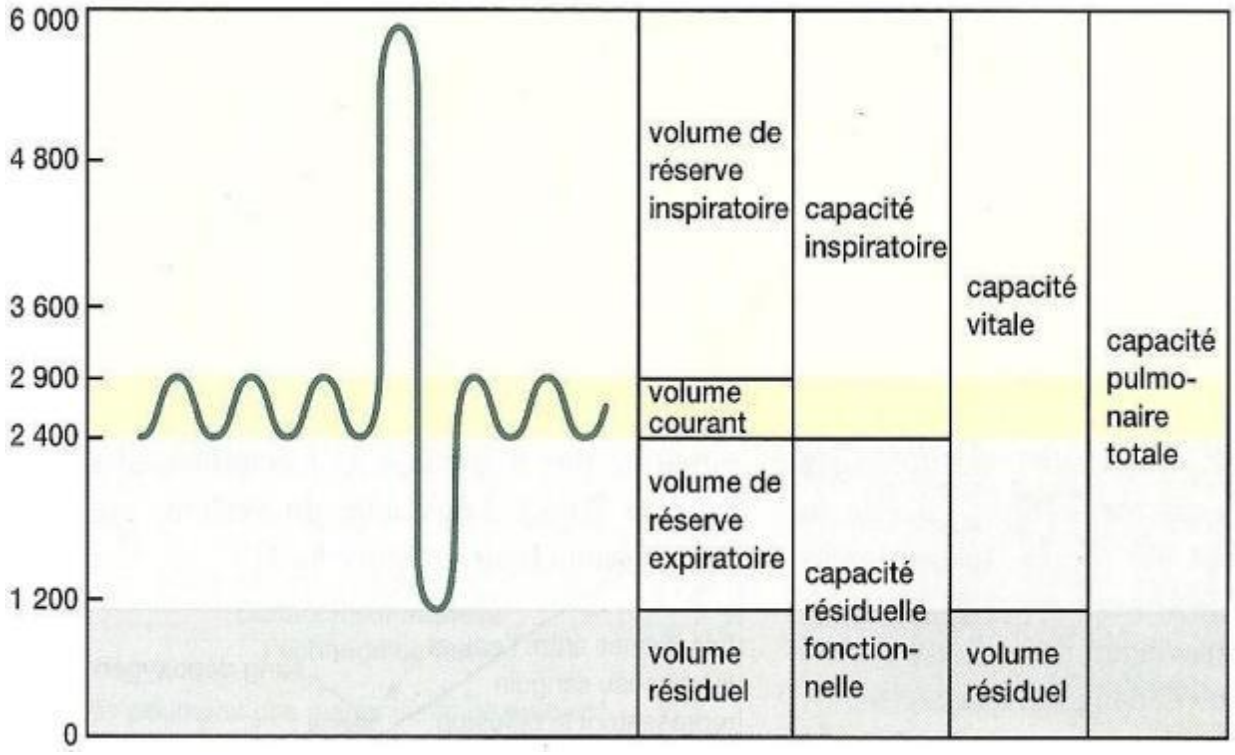


Figure 47: Vital Capacity

This diagram, called "Spirogram", represents the maximum amount of air that can be exchanged during a breath, that is to say, the vital capacity.

Chapter V: Urinary System

V.1. Anatomy of the Urinary System

V.1.1. The Kidney

Retroperitoneal organ (behind the peritoneal cavity), it is a vital organ. The right kidney is located behind the liver, the left kidney behind the lower pole of the spleen and the tail of the pancreas. The kidney measures 12 cm in height and 6 cm in width. It has the shape of a bean (figure 48). The adrenal gland rests on the upper pole of the kidney.

V.1.2. The Urinary Tract

V.1.2.1. The Ureter

In human anatomy, the ureters are the two conduits that transport urine from the renal pelvises to the bladder. The ureters are muscular tubes that push urine through peristaltic movements. In adults, they usually measure between 25 and 35 cm long.

V.1.2.2. The Bladder

The bladder is a hollow muscular organ pelvic in the shape of a pyramid whose apex is stretched upwards and forwards. The usual maximum filling of the bladder has a physiological capacity of 300 to 600 ml in adults. Beyond that, its filling is pathological and the bladder can take on a globular shape, hence the name vesical globe (it can hold more than a liter before rupture). Physiologically, the capacity of the bladder is on average higher in women (350-600 cm 3) than in men (250-500 cm 3). The sensation of needing to urinate is felt from about 300 ml.

In men, it is caudally related to the prostate, and dorsally with the rectum and the seminal vesicles. In women, it has posterior relations with the vagina and cranially with the uterus.

V.1.2.3. The Urethra

In anatomy, the urethra is the outlet canal of the bladder. It has an excretory function in both sexes (outlet of urine) and additionally in men a reproductive function (passage of sperm).

In women, the urethra is very short (about 3.5 cm), with a diameter of approximately 6 mm, and opens onto the vulva between the clitoris and the opening of the vagina through the urinary meatus.

In men, the urethra measures about 15 cm and opens at the end of the penis. It is longer than in women, and it is composed of several parts, each having a function. Due to this size difference, women are more prone to lower urinary tract infections (cystitis).(figure 49).

V.2. Nephrons

The nephron is the structural and functional unit of the kidney (figure 50). It allows for the formation of urine.

The nephron is generally composed of two structures:

- A renal corpuscle.
- A tubular system.

The renal corpuscle is the initial portion of the nephron, spherical in shape, where plasma filtration occurs. This filtration is not selective regarding the nature of the solutes present in the plasma, although it does not allow proteins and molecules weighing more than 3.6 kDa to pass. The resulting liquid is the ultrafiltrate (also called primitive urine), the content of which is conditioned through the tubular system with which it is contiguous.

The renal corpuscle is the meeting of a vascular component and an epithelial component: on one side is the vascular pole, which contains a high-pressure tuft-shaped capillary bed called the glomerulus, and on the other side, the urinary pole, where the ultrafiltrate passes, consisting of Bowman's capsule. Bowman's capsule is lined with two epithelial layers separated by a space called the urinary chamber, through which the ultrafiltrate passes, to then integrate into the tubular system.

The tubular system consists of a succession of straight and convoluted tubules. It is made up of several parts:

- The proximal convoluted tubule.
- Henle's loop, located in the medulla, shaped like a U, it forms a loop and thus contains a descending part and an ascending part.

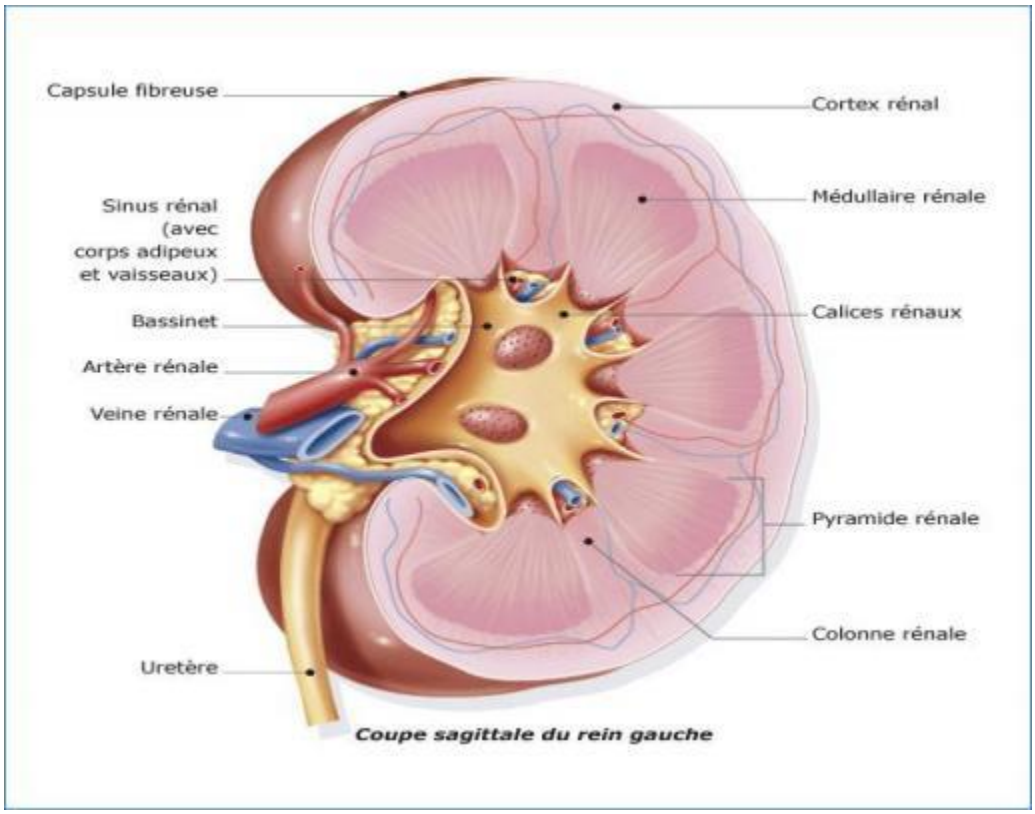


Figure 48: Sagittal Section of the Kidney

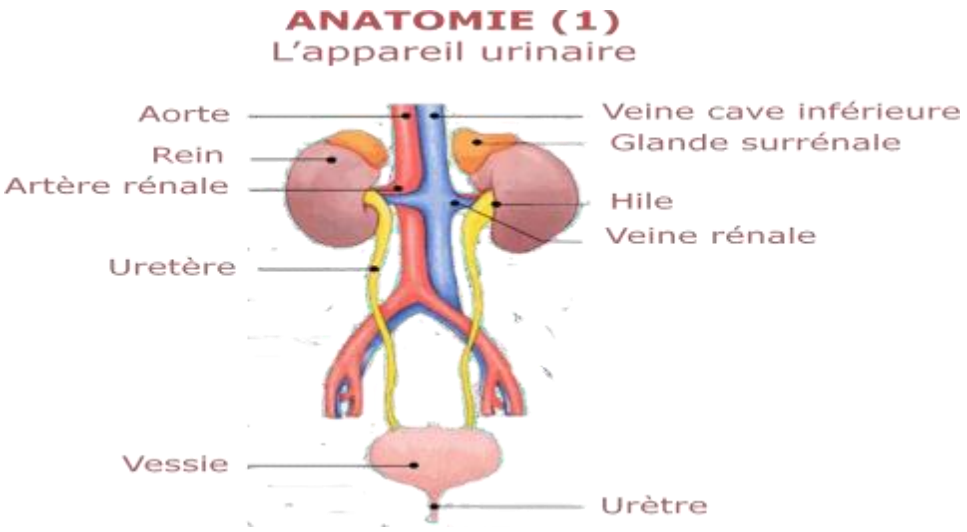


Figure 49: the Urinary Tract

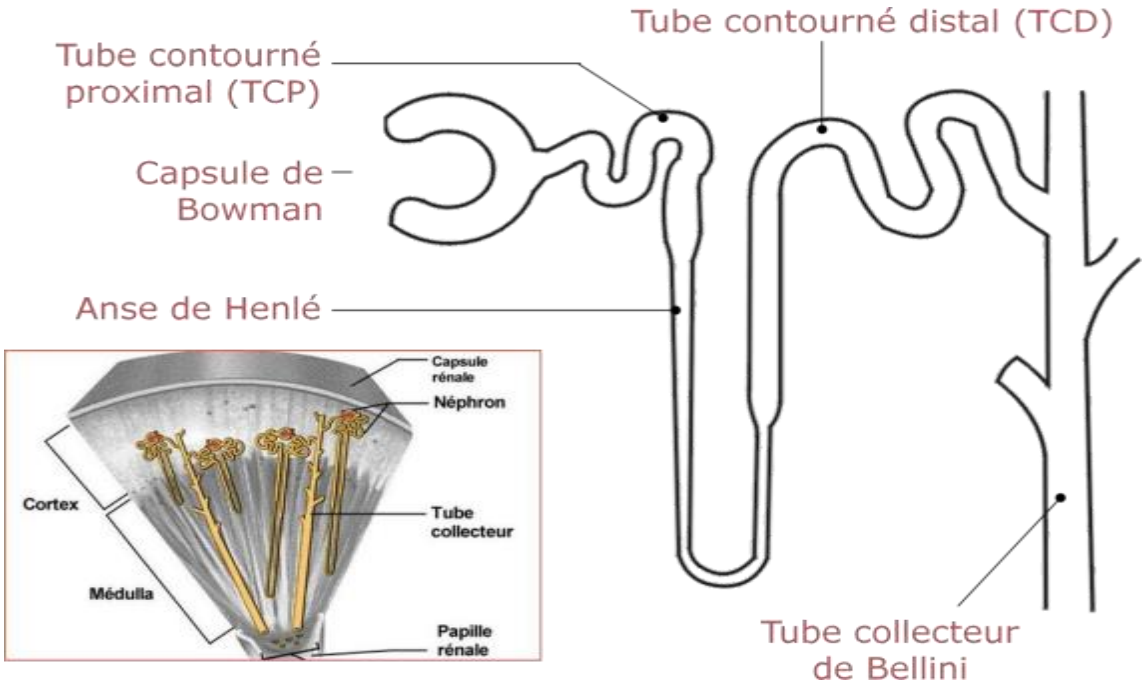


Figure 50: the Functional Unit of the Kidney (Nephron)

- The Distal Convoluted Tubule.

The distal convoluted tubule empties into the collecting duct. The nephron and collecting duct together form a unit called the uriniferous tubule. Some nephrons empty into the collecting system via an additional segment, the connecting tubule.

The renal corpuscles are located only in the renal cortex, where they are responsible for its granular appearance.

V.2.1. Types of Nephrons According to the Location of the Renal Corpuscle

- Superficial/cortical nephrons: Their renal corpuscle is located in the outer or middle part of the cortex, they are referred to as "short nephrons" because their loops of Henle (part of the nephron located in the medulla) are short and do not reach the inner medulla.
- Juxtamedullary nephrons: Their renal corpuscle is located near the cortico-medullary junction, close to the arcuate arteries. They are referred to as "long

nephrons" because their loops of Henle are long and reach the inner medulla. Their physiological role is crucial as they allow for the formation of hypertonic urine and thus the reabsorption of water at the level of their descending loops.

- Intermediate nephrons

V.2.2. The Renal Corpuscle

V.2.2.1. Structure of the Renal Corpuscle

Globular in shape, it measures between 200 and 300 µm and is formed from the following structures:

- The glomerulus, a ball of capillary blood vessels from the afferent arteriole. The glomerulus allows for the filtration of blood and the formation of primitive urine. The capillaries then gather to form the efferent arteriole.
- The Bowman capsule, a blind sac formed of two layers of cells, surrounding the glomerulus, collecting the'primitive urine'and opening at its other end into the proximal convoluted tubule.
- The mesangium, interstitial tissue composed of cells called mesangial cells and a matrix intercellular. The mesangial cells are specialized fibroblasts. They have contractile properties,macrophagic and can synthesize extracellular matrix and collagen.

They also secrete prostaglandins, endothelins, and cytokines. By contracting, under the influence of endothelins, mesangial cells control blood flow in the capillaries and thus influence glomerular filtration.

- The podocytes,cells forming the inner layer of Bowman's capsule. They surround the cells of the glomerular capillaries, notably through cytoplasmic extensions or feet. The dense network formed by these extensions represents an important structure of the glomerular filter.

V.2.3. The Glomerular Filter

The function of the glomerulus is to filter blood from the glomerular capillaries and to form primitive urine, also called ultrafiltrate.

The filtration barrier of the glomerulus is composed of three layers :

- The fenestrated endothelium of the capillaries, equipped with small pores of 50 to 100 nms in diameter, which allows the passage of substances such as water,sodium,urea, glucose, and small proteins, but prevents the passage of blood cellular elements (leukocytes,erythrocytes,etc.) and macromolecules with a molecular weight equal to or greater than 68,000 Da.
- The basement membrane(with a thickness of 240 to 340 nm), preventing the passage of large proteins.
- The filtration slits (with a thickness of 25 nm) formed by podocytes and covered with a thin diaphragm of 4 nm thickness. These slits prevent the passage of small proteins.

V.2.4. Formation of Primitive Urine

The filtration of blood occurs at the level of the capillaries of the glomerulus. This filtration, passive, is due to the gradient of pressure that exists between the arterial pressure of the afferent arteriole and the lower pressure of the glomerulus itself.

The glomerular filtration rate (volume of primitive urine from all glomeruli per unit of time) is normally 100 to 120 ml/min. In adults, about 180 liters are filtered every day, but the primary urine is subsequently reabsorbed at 99% in the tubules, leading to a final urine production of about 1.5 liters per day (figures 51, 52).

- Active tubular reabsorption(cotransport with Na+at the level of the PCT + loop of Henle) :
  - Some ions (Na+, H+)
  - Glucose
  - Amino acids
  - Lactic acid
  - Vitamins

There is a maximum reabsorption rate related to the number of available transporters (e.g.: glucose).

- Passive Tubular Reabsorption
    - Anions (HCO3-, Cl-)
    - Water (follows Na+by osmosis = mandatory reabsorption).

Waste is eliminated in urine: creatinine, urea, excess potassium, toxins, medications. The reabsorption of water and sodium allows for the regulation of blood pressure.

The functioning of the tubules depends on hormones that have a diuretic or water retention effect, depending on blood pressure: aldosterone (adrenal), ADH (pituitary), renin (kidney) (figure 53).

V.2.5. The Renal Tubules

The tubular system is a succession of tubules that conduct urine from the glomerulus to the collecting duct. The passage through the renal tubules allows for the reabsorption of a large part of the water filtered by the glomerulus as well as the secretion and reabsorption of certain molecules. The tubular system can be divided into several parts. This division is not arbitrary but takes into account the differences in histological structure and function of the concerned segments.

Figure 51: Filtration

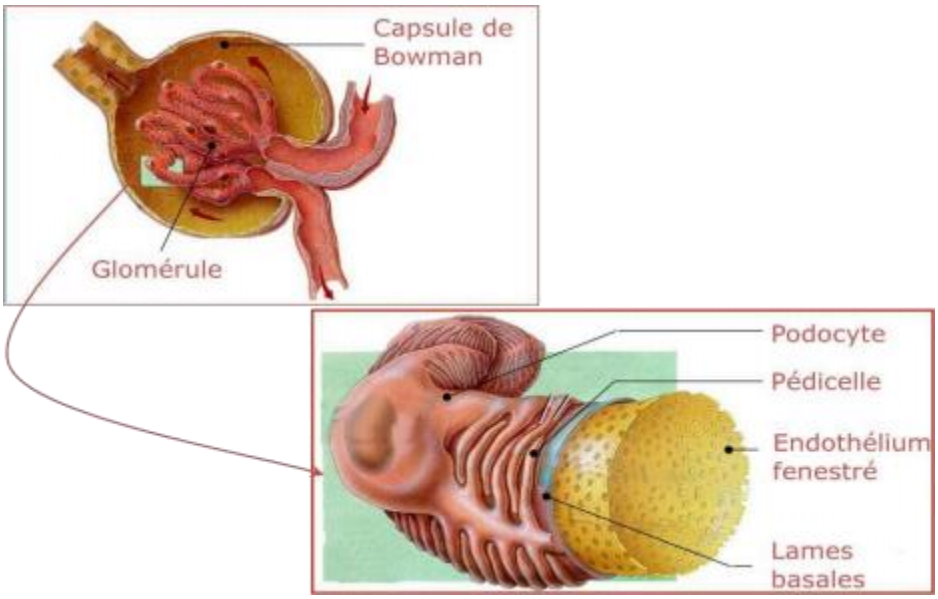


Figure 52: Structure of the Filtration Membrane

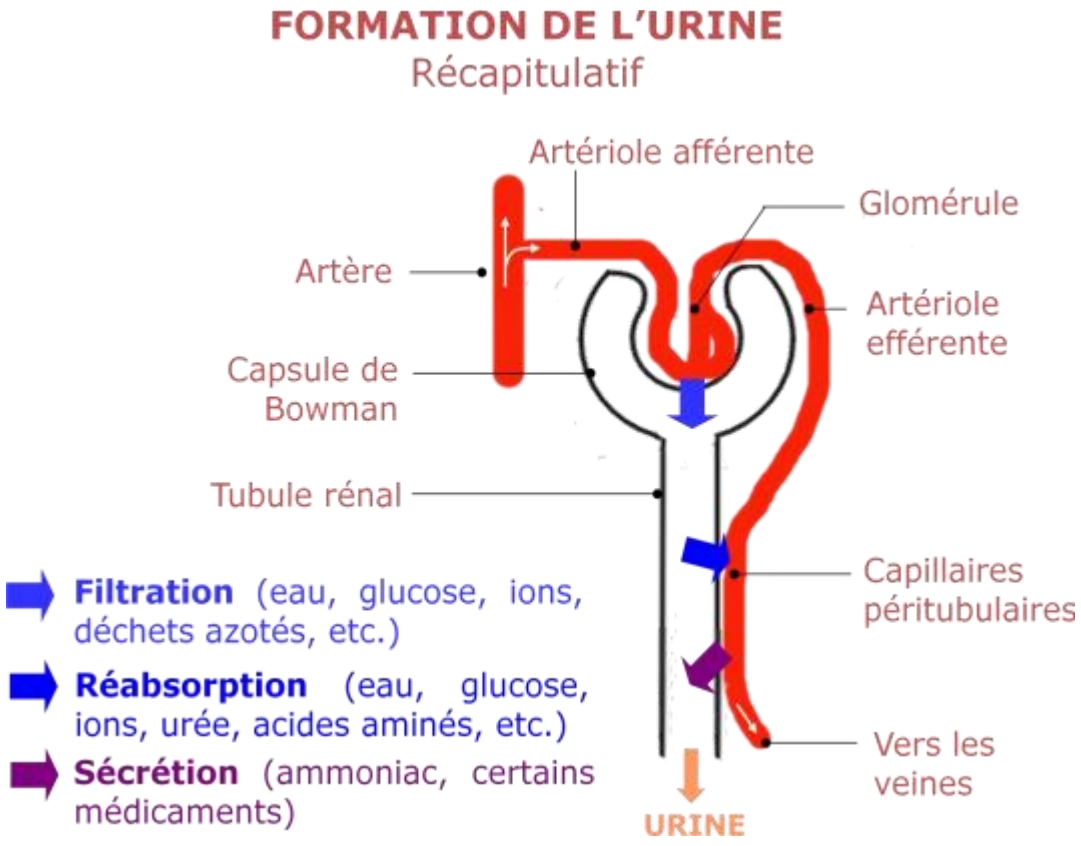


Figure 53: Formation of Urine

V.2.5.1. Proximal Tubule

This is the longest segment of the nephron. It is located only in the renal cortical area and measures 12 to 14 mm. With a diameter of 50 to 60 µm, it is also the widest.

It is lined by a single-layered cuboidal epithelium, whose apical pole has a brush border (microvilli). It also features numerous basolateral folds containing mitochondria, responsible for the eosinophilia of the cytoplasm.

70 % of water,glucose,sodium,potassium, and chloride present in the primary urine are reabsorbed at this level.

V.2.5.2. Loop of Henle

The Henle loop is the straight segment of the nephron that allows for the formation of hypertonic urine. It is predominantly present in the medulla, but part of it is located in the cortex, also straight, and forms with the collecting system the medullary radiations. The Henle loop has a U shape and forms a loop in the medulla; it starts from the proximal convoluted tubule in the cortex, descends into the medulla, makes a loop, and ascends back towards the distal convoluted tubule present in the cortex. Thus, we distinguish a descending part and an ascending part. Each of these parts has a thick segment and a thin segment (slender). Some authors refer to the descending thick part of the Henle loop as the proximal straight tubule. The thick parts of the Henle loop have an ultrastructure very similar to that of the convoluted tubules. The length of the Henle loop depends on the type of nephron; juxtamedullary nephrons have a long Henle loop that penetrates into the inner medulla, while cortical nephrons have a short Henle loop that does not extend beyond the outer medulla.

V.2.5.3. Intermediate Tubule

Those of the nephrons located in the superficial cortex and middle are very short, while those of the juxtamedullary nephrons (close to the medulla) are long. Their epithelium is squamous, meaning very flattened with an oval nucleus.

V.2.5.4. Distal Straight Tubule

With a diameter of 25 to 35 µm, it begins in the outer medulla and ascends into the cortex.

Its epithelium, simple cuboidal, shows a near absence of morphological differentiation of its apical pole, with only a few microvilli, short and irregular.

V.2.5.5. Distal Convoluted Tubule

With a diameter of 40 µm, it is entirely located in the renal cortex. It is histologically identical to the distal straight tubule.

In its initial part, the reabsorption of sodium occurs via sodium-chloride cotransport sodium-chloride. In the second part, it is regulated by aldosterone, and thus occurs through sodium channels, in exchange for potassium. The distal tubule is impermeable to water. It empties into the collecting duct.

V.3. How Renal Failure Kills

If the kidney no longer functions:

Either there is no urine: asphyxiation due to pulmonary edema. Or there is still urine but the nephron is not functional.

Waste products are no longer eliminated: creatinine and urea increase in the blood (diagnosis). Mineral salts are no longer regulated: cardiac arrest due to hyperkalemia (too much potassium: toxic to the heart).

Solution: dialysis.

V.4. The Exocrine Function of the Kidney

The formation of urine allows for the regulation of the internal environment:

- Excretion of waste, toxins.
- Ensures the stability of mineral concentrations (sodium, potassium).
- Maintains fluid volumes, thus maintaining blood pressure.

The exocrine function is dependent on hormones, notably ADH (pituitary), aldosterone (adrenals), renin.

V.5. The Endocrine Function of the Kidney

Several hormones are produced by the kidney:

- Erythropoietin: stimulates the production of red blood cells by the bone marrow.
- Vitamin D: the kidney ensures its transformation into active form. It is involved in the absorption of calcium and phosphorus.
- Renin: a hormone acting on blood pressure: vasoconstrictor, reabsorption of sodium by the tubules.

V.6. Homeostasis

Homeostasis is the set of mechanisms that allow the stability of the physicochemical parameters of the internal environment.

V.6.1. Regulation of Renal Function

Water excretion: mandatory reabsorption of water (figure 54), represents about 80% of the water reabsorbed. Especially in the proximal convoluted tubule (PCT), is a consequence of the reabsorption by active transport of Na+at the level of the PCT (almost all Na+is reabsorbed at this level).

Reabsorption of Na+, the environment around the tubule becomes hypertonic. Water follows by osmosis. Optional reabsorption of water, represents about 20% of the water reabsorbed. Occurs at the level of the distal convoluted tubule (DCT) and the collecting duct (especially), under the control of the antidiuretic hormone or ADH (or vasopressin) secreted by the pituitary gland.

ADH Increases the Permeability to Water of the Collecting Tubule

ADH → reabsorption □ □ less abundant and more concentrated urine.

ADH → reabsorption □ □ abundant and diluted urine.

V.6.2. Mechanism of Obligatory Water Reabsorption

Mineral excretion: the juxtaglomerular apparatus (figure 55)

The cells of the juxtaglomerular apparatus are sensitive to 3 factors:

- Decrease in Na+levels in the DCT (a sign of decreased filtration rate).

- Influx of the autonomic nervous system.

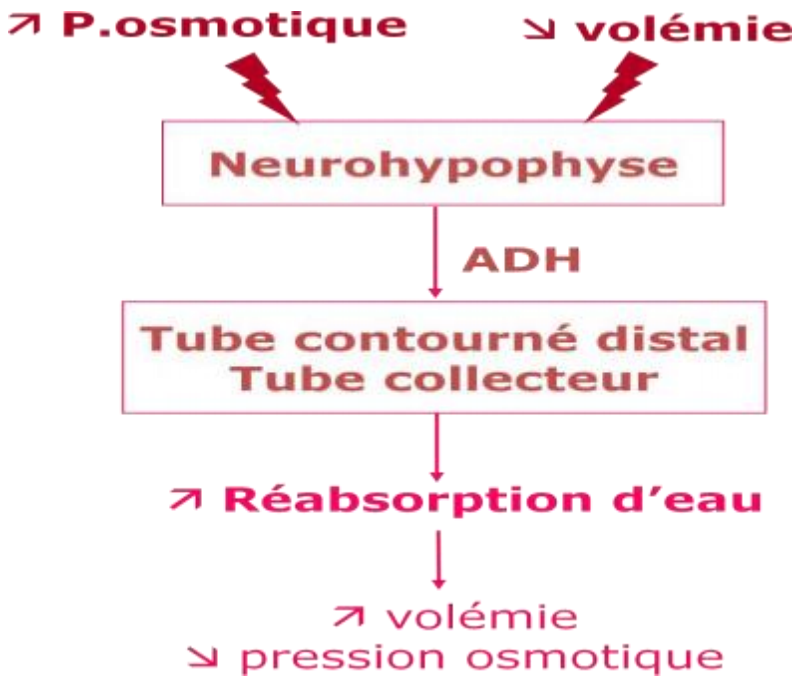


Figure 54: Mechanism of the Mandatory Reabsorption of Water

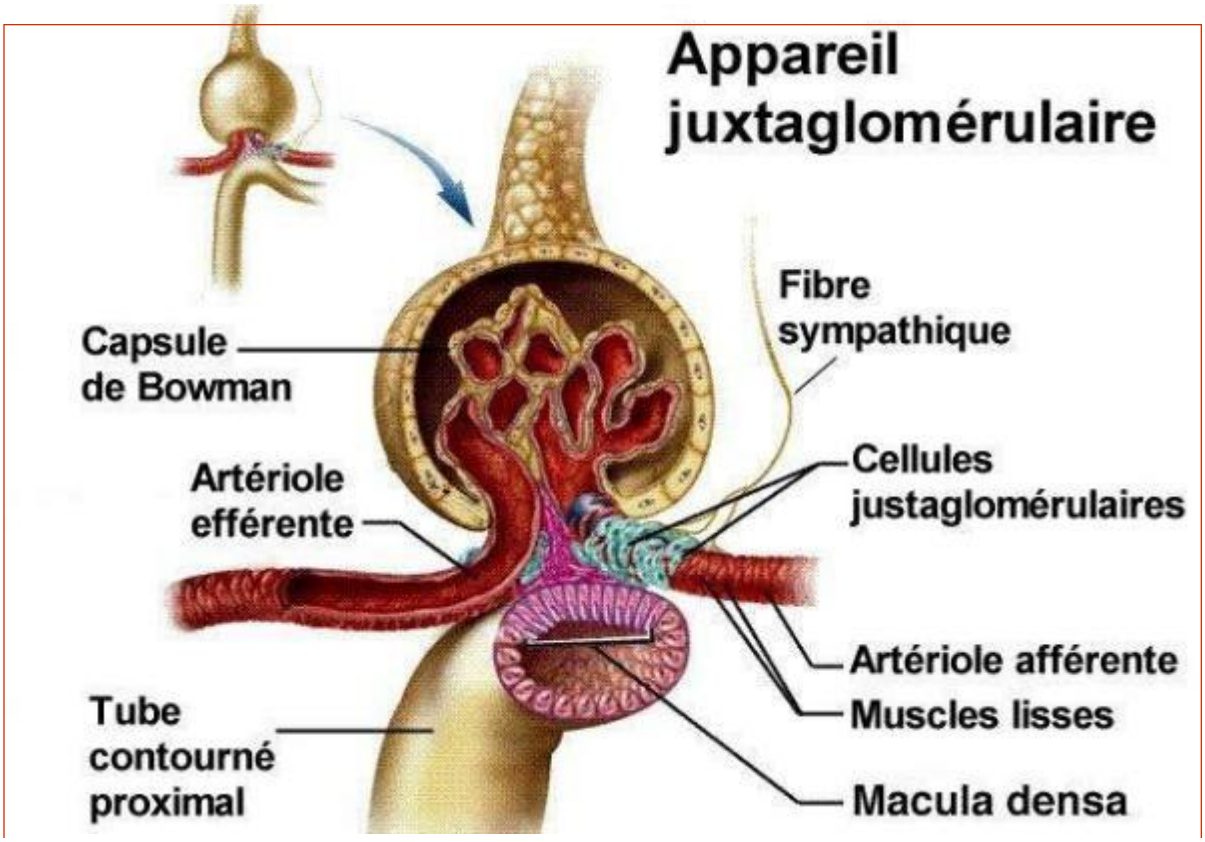


Figure 55: the Juxtaglomerular Apparatus

- Decrease in blood pressure in the afferent arteriole.

The juxtaglomerular cells respond to these factors by secreting a hormone: renin (figures 56, 57).

V.7. Renin

Renin (also called angiotensinogenase) is a enzyme of the renin system angiotensin-aldosterone.

The synthesis of renin by the juxtaglomerular cells of the renal apparatus occurs in response to:

- A decrease in blood perfusion pressure,
- To a hyperkalemia,
- To a hyponatremia.

Renin is a protein consisting of 340 amino acids and has a molecular weight of 37 kDa.

Renin is first synthesized in the form of prorenin, which is released into the plasma. This prorenin is cleaved into active renin at the level of the renal juxtaglomerular apparatus. It can also be activated without cleavage by binding to a specific receptor, resulting in a conformational change. This receptor allows for the activation of angiotensinogen but also has other roles by inducing the production of other molecules (transforming growth factor (TGF)- ß and plasminogen activator inhibitor (PAI)-1) whose roles remain to be determined. Its role is to catalyze the transformation of angiotensinogen(protein synthesized by the liver) into angiotensin I, which itself will produce angiotensin II, a peptide that leads to an increase in blood volume by affecting the sensation of thirst, the secretion of aldosterone, and the caliber of blood vessels.

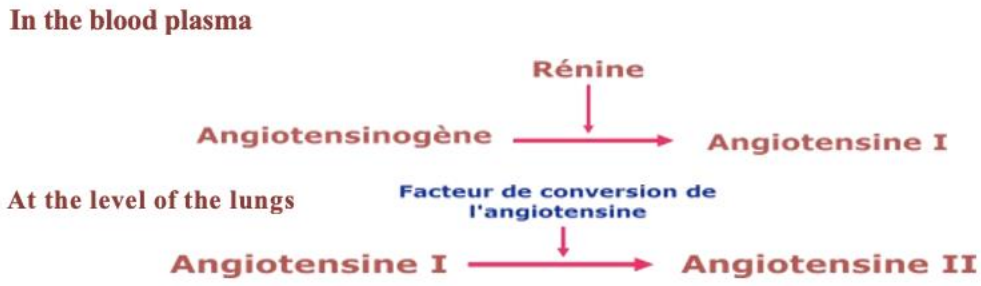


Figure 56: Mechanism of Mineral Excretion

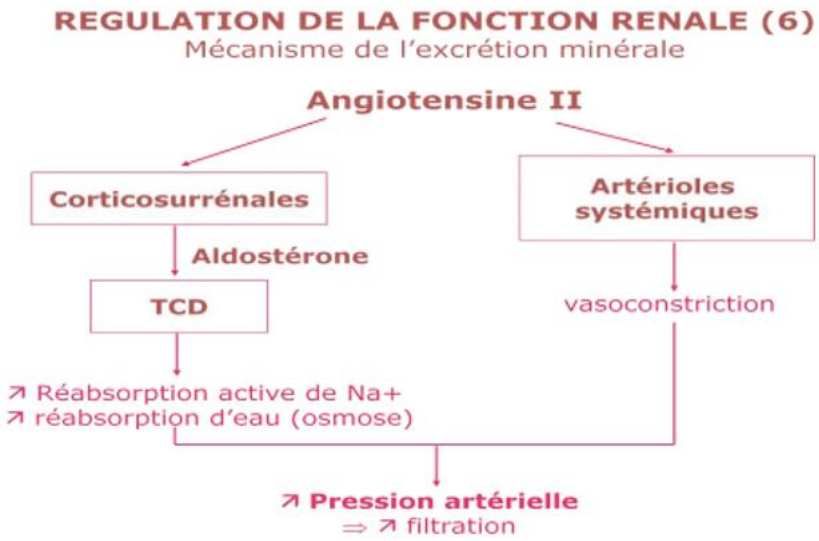


Figure 57: Regulation of Renal Function

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