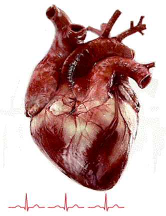
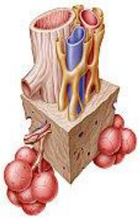
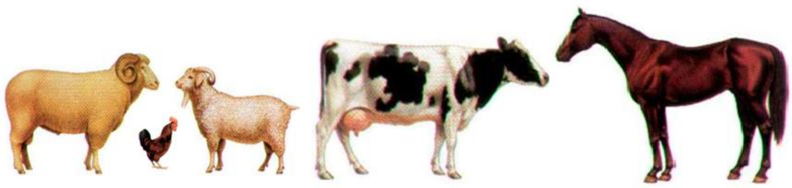
University Abdelhafid Boussouf-Mila
Life And Natural Sciences
Food Sciences


2024-2025

Animal Physiology



University of Mila

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INTRODUCTION

Physiology is the study of the normal functions of the body's molecules, cells and organ systems and the interrelationships among them.

Because the study of medicine « pathology » is the study of abnormal functions of the body or **pathophysiology**. It is essential to understand normal physiology if one is to understand the mechanisms of disease.

Physiology is vast subject and biology students are too busy to learn all that is known about it. We have to limit the concepts presented in this course according to the recommended curriculum for this specialty.

Bcause the scope of physiology encompases many scientific disciplines the authors represent the field of physiology, neurosciences, cell biology and molecular biology

I. The terminology of anatomy and physiology

In the study of any field of science it is necessary to understand the language, or specialized terminology, that is used. This is especially true in anatomy, where terms of direction, position, and movement are used to describe both the position of organs in relation to one another and the actions of muscles.

Objectives:

- Begin to learn the terminology of anatomy in order to understand the descriptions of body parts and their relative positions to one another
- Be able to locate these various anatomical areas on an animal
- Understand the terms used to describe body planes and sections in order to understand histological sections of tissues

Direction therms

Adjacent: Next to, adjoining, or close to. For example, the tongue is adjacent to the teeth.

Cranial: Pertaining to the cranium or head end of the body or denoting a position more toward the cranium or head end of the body than some other reference point (body part). For example, the head is cranial to the tail. Craniad or cranially means in the direction of the cranium or head end of the body.

Caudal: Pertaining to the tail end of the body or denoting a position more toward the tail or rear of the body than some other reference point (body part). For example, the tail is caudal to the head. Caudad or caudally means in the direction of the caudal or tail end of the body (Figure 1.1).

Cephalic: Pertaining to the head. This term is not used as frequently in veterinary medicine as cranial. For example, the top of the head is cephalic to the neck.

Rostral : Pertaining to the nose end of the head or toward the nose. For example, the nose is rostral to the eyes.

Dorsal : Pertaining to the back area of the quadruped or denoting a position more toward the back (upward) than some other reference point (body part). For example, the backbone is dorsal to the belly. Dorsum is a noun that refers to the back area of the body.

Ventral: Pertaining to the belly or underside of a quadruped or denoting a position more toward the belly (downward) than some other reference point (body part). For example, the kidneys are ventral to the backbone. Ventrum is a noun that refers to the belly area of the body.

Lateral: Denoting a position farther away from the median plane of the body or of a structure, on the side or toward the side away from the median plane, or pertaining to the side of the body or of a structure. For example, the lateral surface of the leg is the outside surface.

Medial: Denoting a position closer to the median plane of the body or of a structure, toward the middle or median plane, or pertaining to the middle or a position closer to the median plane of the body or of a structure. For example, the medial surface of the leg is the inside surface.

Oblique: At an angle or pertaining to an angle. For example, the vein crossed obliquely from the upper left side down to the lower right side.

Superficial: Near the surface; not deep. For example, the skin is superficial to the underlying muscle.

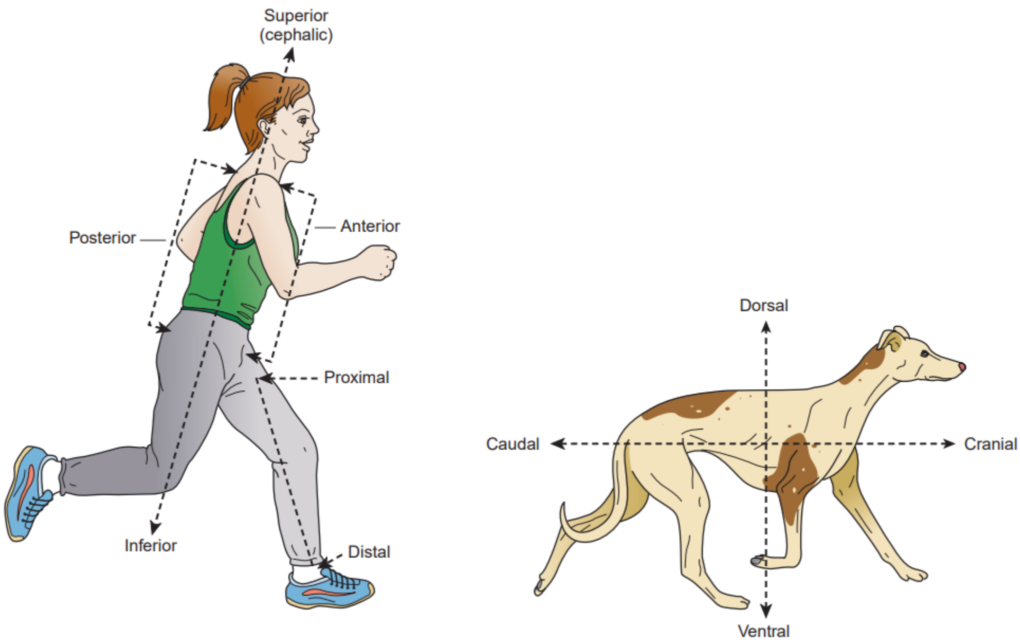


FIGURE 1.1: Anatomical terminology describing body direction: human vs. animal.

Deep: Situated far beneath the surface; not superficial. For example, the bones are deep to the skin.

Peripheral: Pertaining to or situated near the outer areas or surface of the body or a structure. For example, the subcutaneous fat is peripheral to the muscles.

Proximal: Nearest to the center of the body relative to another body part, or a location on a body part relative to another more distant location. For example, the femur is proximal to the tibia, and the upper part of the humerus is the proximal part.

Distal: Farthest from the center of the body relative to another body part, or a location on a body part relative to another closer location. For example, the tibia is distal to the femur, and the lower part of the humerus is the distal part.

Superior: Above, directed above, or pertaining to that which is above. For example, the nasal cavity is superior to the mouth.

Inferior: Below, underneath, directed below, or pertaining to that which is below. For example, the mouth is inferior to the nasal cavity.

Caudal: Pertaining to the back side of the leg above the carpus and tarsus.

Cranial: Can also be a positional term that means the front side of the leg above the carpus and tarsus.

Dorsal: Can also be a positional term that applies to the side of the leg opposite the palmar and plantar sides or, in other words, the front side of the leg from the carpus and tarsus distally (down).

Anatomical terms:

Abdominal: Pertaining to the abdomen.

Antebrachium: The distal area of the front legs of an animal, below the elbow joint.

appendicular: Related to the limbs and their attachments to the axis of the body.

Axial: Related to the head, neck, and trunk or torso, the axis of the body.

Axillary: Pertaining to the armpit area or on the medial aspect of where the front leg meets the torso

Brachial: Pertaining to the proximal area of the front legs of an animal, above the elbow joint.

Cervical: Pertaining to the neck area, the cervical vertebrae (the fi rst 7 vertebrae in the dog and cat) or the region around these vertebrae, and to the cervix in the female's reproductive system.

Coccygeal: Pertaining to the tail or vertebrae of the tail, the coccygeal vertebrae.

Cranium: The part of the skull that encases the brain.

Frontal: Pertaining to the forehead, or the area of the head above the eyes where the frontal bone and frontal sinuses are located.

Inguinal: Pertaining to the groin or the medial aspect of the rear leg where it is attached to the torso of the body.

Lumbar: Pertaining to the lumbar vertebrae (the part of the backbone between the thoracic vertebrae and the sacrum) or region around these vertebrae.

Mammary: Pertaining to the mammary glands (the milk-producing glands).

Nasal: Pertaining to the nose.

Oral: Pertaining to the mouth.

Orbital: Pertaining to the bony eye socket (the orbit).

Pelvic: Pertaining to the pelvis or hip bones (which are made up of four bones of each side of the pelvis: the ilium, ischium, pubic bone, and acetabular bone, which are joined in the middle by a symphysis of the right and left pubic bones).

Perineal: Pertaining to the region between or surrounding the anus and the external genitalia.

Peritoneal: Pertaining to the cavity inside the abdomen and the membrane (the peritoneum) that lines this cavity. The peritoneal cavity is the space inside the abdomen between the organs and the body wall.

Pleural: Pertaining to the cavity inside the chest and the membranes that line this cavity. The pleural cavity is the space inside the chest between the lungs and heart and the inside of the chest wall.

Sacral: Pertaining to the sacrum, the fused vertebrae by which the pelvis is attached to the backbone.

Scapular: Pertaining to the scapula or the shoulder blade area.

Sternal: Pertaining to the region of the sternum, or breastbone

Thoracic: Pertaining to the thorax or chest, the thoracic vertebrae (the part of the backbone between the cervical and lumbar vertebrae), or the region around these vertebrae.

Umbilical: Pertaining to the umbilicus or navel (bellybutton).

Vertebral: Pertaining to the vertebrae or spinal column

Dorsal plane: Divides the body dorsally and ventrally, not necessarily in equal divisions.

Median plane: Divides the body into left and right halves, equally.

Paramedian plane: Parallel to the median plane and also divides the body into left and right parts, but not equally.

Sagittal plane: The same as a paramedian plane. A midsagittal plane is the same as the median plane.

Transverse plane: Divides the body cranially and caudally, not necessarily in equal divisions. It also divides the leg into upper and lower parts, not necessarily in equal divisions.

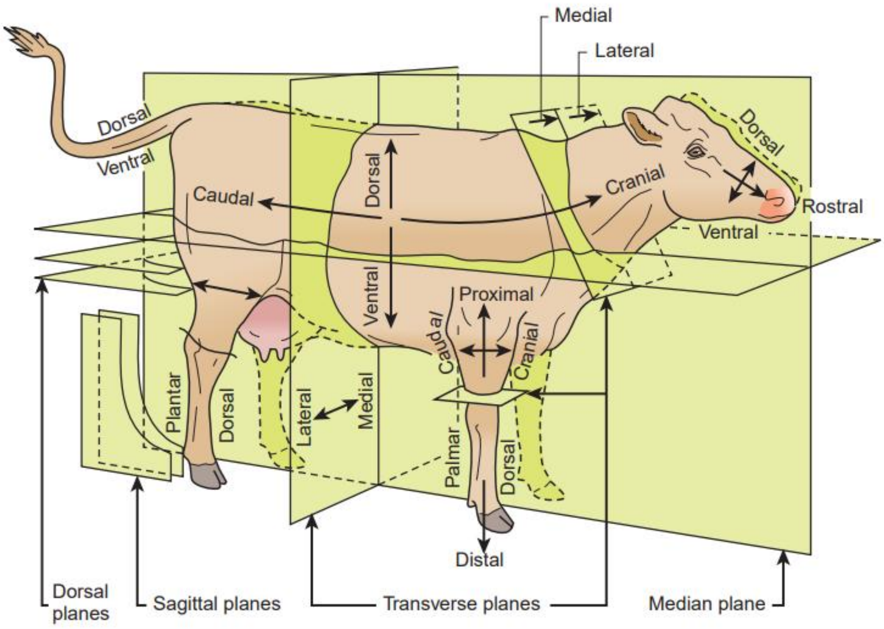


FIGURE 1.5: Planes of the body.

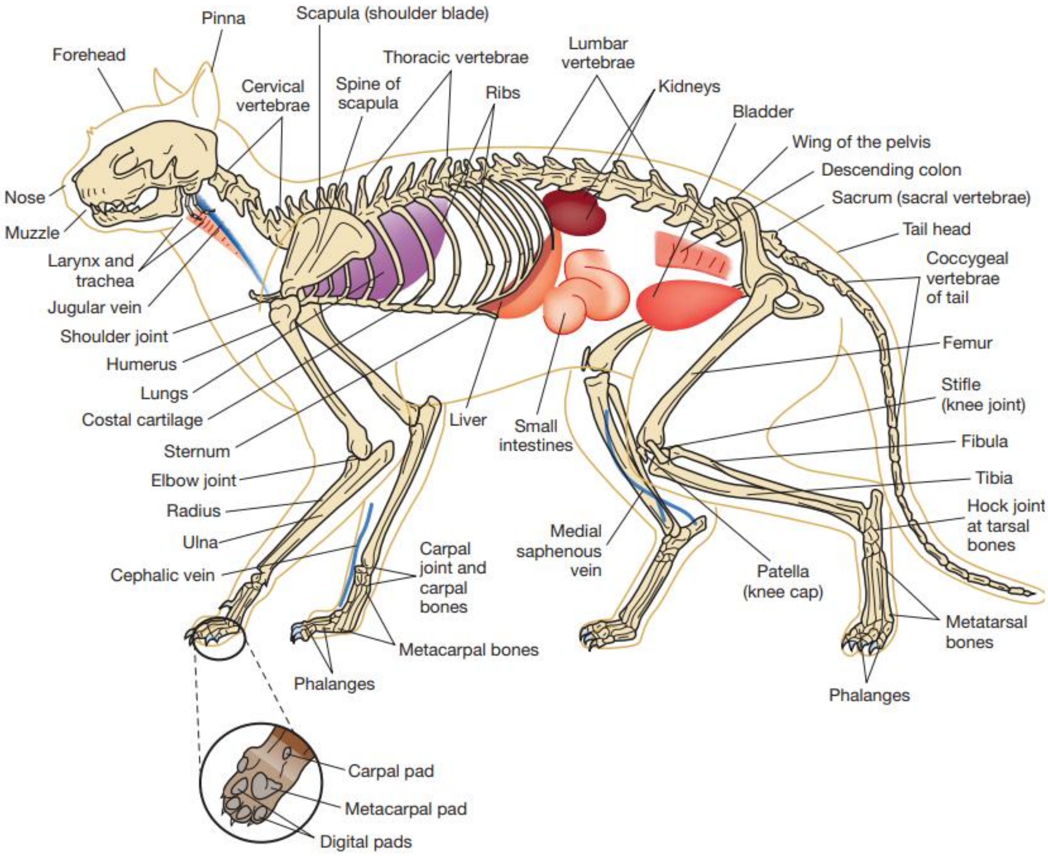


FIGURE 1.7: Parts of the cat's body.

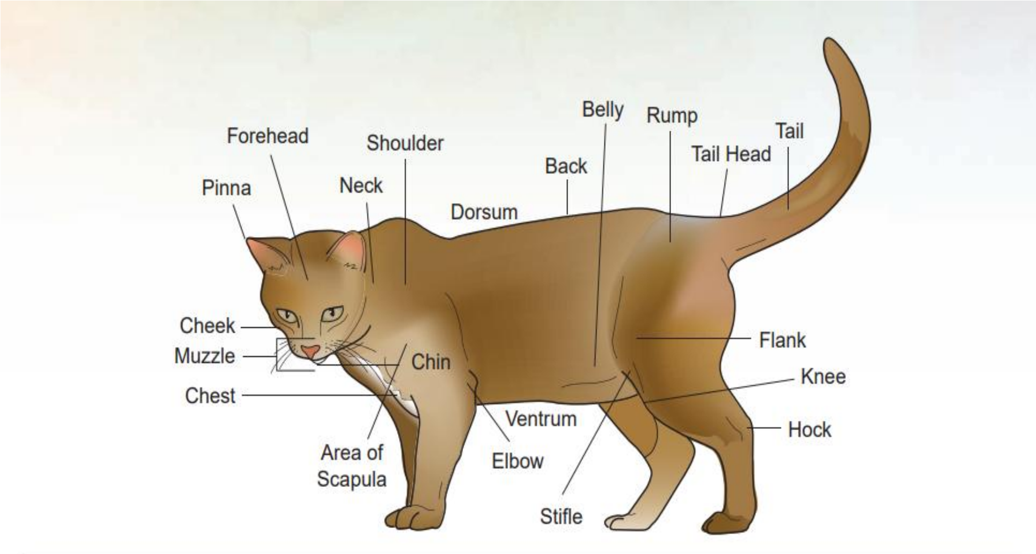


FIGURE 1.8: Common names for body areas of small animals.

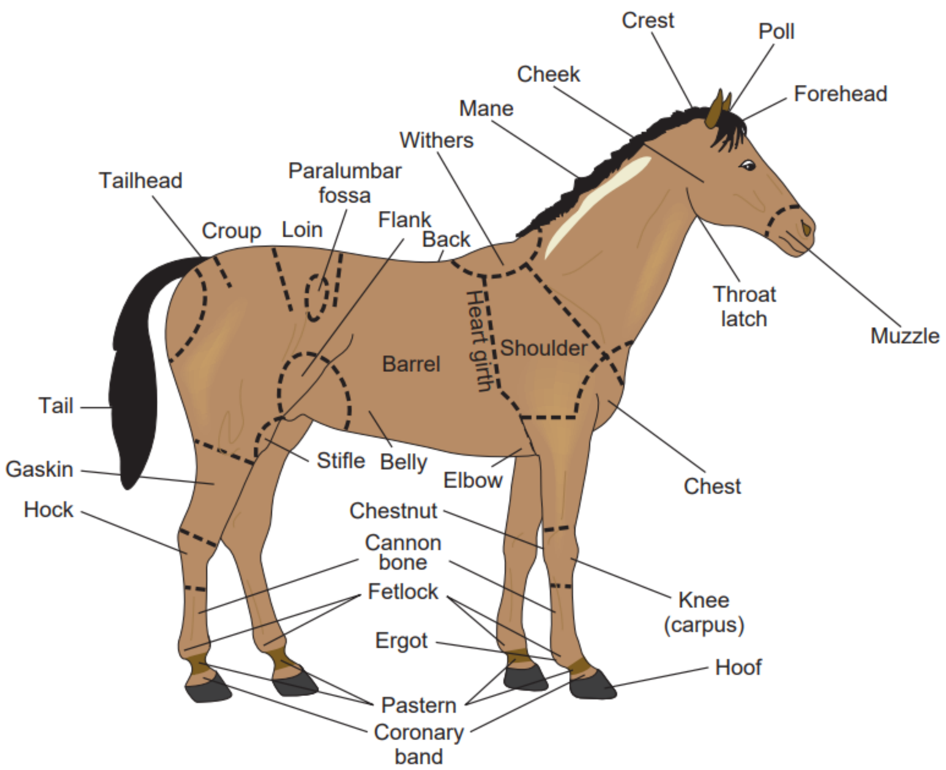


FIGURE 1.9: Common names for body areas of horses.

II. Cellular Anatomy and Morphology

1. OBJECTIVES

- define, understand, and differentiate between a cellular organelle and an inclusion body
- identify the cellular organelles in a cell model and in a diagram
- understand the structure and function of the cellular organelles
- identify the major cellular organelles using prepared slides

2. Introduction

The cell is the basic unit of organization of an animal's body. The cell may also be a singlecelled life form, or cells can combine to make up organized tissue within a more complex animal. Cells are extremely complex and are both the structural and functional unit of the tissues they form. Cells have the ability to maintain their boundaries, metabolize and digest nutrients, dispose of wastes, grow and reproduce, move, and respond to stimuli. Each cell must perform certain functions to sustain its life. Cells are highly diverse; differences in size, shape, and internal composition reflect their specific functions in the body

3. The anatomy of the cell

Generally, a cell is composed of three major parts: the plasma membrane, the nucleus, and the cytoplasm. All of these are readily observable with a light microscope. Within the cytoplasm are the organelles, which are either too small or require a special stain to be seen with ordinary light microscopy. However, since the advent of the electron microscope, even the smallest organelles have been identified. Organelles, by definition, are highly organized, living, subcellular structures, each of which has a characteristic shape and function. They are, in essence, the internal working parts of the cell. They differ from inclusion bodies, which are non-active masses within a cell.

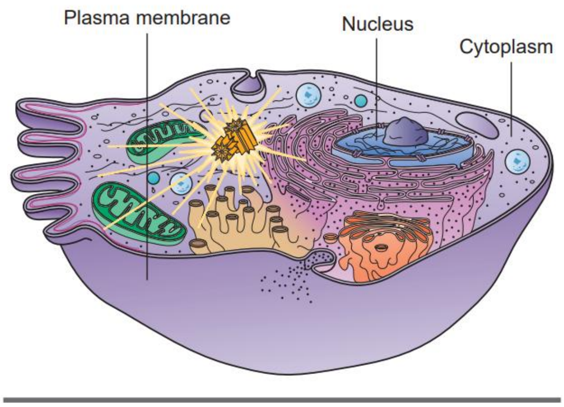


FIGURE 3.1: Structural components of a cell.

4. Identification of the Parts of a Cell

Using a cell model and Figure 3.2, identify the following parts of a cell.

1. Plasma membrane: The plasma membrane is composed of bilayer phospholipids and globular protein molecules. This arrangement of compounds is called the fluid mosaic model of the plasma membrane, and the proteins are said to be floating in a double layer of phospholipids (see Figure 3.2). Some of the externally facing proteins and lipids have sugar (carbohydrate) side chains attached to them that are important in cellular interactions. A few cholesterol molecules are also dispersed in the fluid phospholipid bilayer to help stabilize it. The proteins in the plasma membrane are also responsible for its antigenicity.

The plasma membrane is a flexible, elastic, protective barrier that separates the cell's internal components from the external environment. The plasma membrane has selective permeability and thus plays an active role in determining what enters and leaves the cell, and in what quantity. Transport through the plasma membrane can occur in two basic ways: actively and passively. In active transport, the cell must provide energy in the form

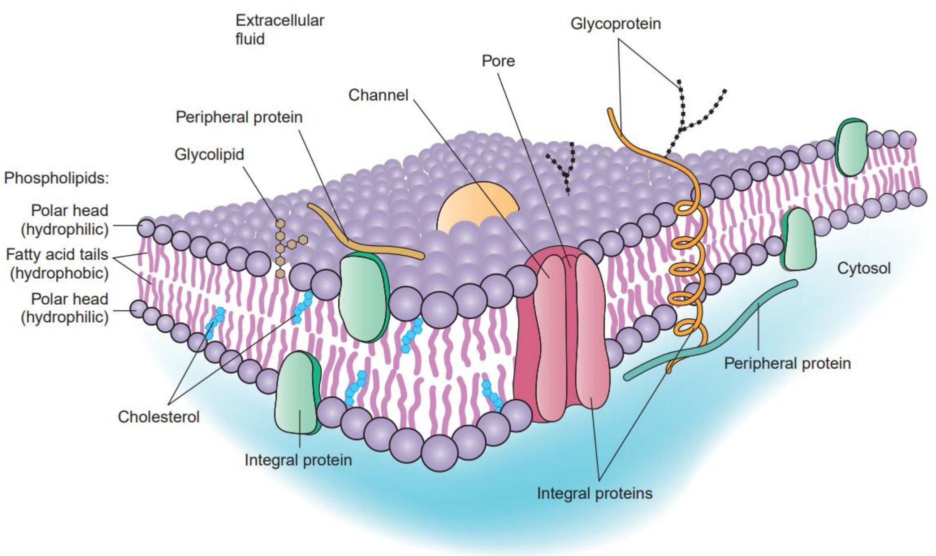


FIGURE 3.2: Structure of the plasma membrane.

of adenosine triphosphate (ATP) to power the movement of substances through the membrane. In passive transport, the movement of substances is driven by concentration or pressure differences. The plasma membrane is also able to maintain a resting potential, which is absolutely necessary for cells that are excitable, such as nerve or heart cells. The resting potential of a membrane is associated with the type and quantity of ions inside the cell and on the outside. These ions impart a potential difference across the membrane; for example, a nerve cell membrane's resting potential is about –85 mV. These characteristics play a vital role in cell signaling and cell-to-cell interactions. In addition, cells that are tightly joined together to form functional units of tissue connect to each other at cell junctions. These contact points between plasma membranes may serve one or more of the following three functions: (1) to form fluid-tight seals between cells, (2) to anchor cells together or to anchor them to extracellular material, or (3) to act as channels that allow ions and molecules to pass from cell to cell within a tissue.

2. nucleus: The nucleus is a spherical or oval structure and is the most prominent, visible feature inside the cell when viewed with a light microscope because of its contrasting, dark appearance. Nuclei usually stain a dark blue or purple (Figure 3.3). Most cells have one or more nuclei. For example, a red blood cell has a nucleus during its developmental stage, but the nucleus becomes pyknotic and disappears when the cell becomes mature. In contrast, skeletal muscle cells have numerous nuclei; in other words, they are multinucleated.

The nucleus is the control center of the cell and is necessary for cell reproduction. It is technically an organelle, but it is considered separately because of its numerous and diverse functions. On the exterior of the nucleus is the nuclear envelope. It is similar to the plasma membrane in that it is a bilayered (has two layers) lipid structure. The outer membrane of the nuclear envelope is continuous with the rough endoplasmic reticulum (ER), a membranous cytoplasmic structure that is the site of protein synthesis, and is very similar in structure

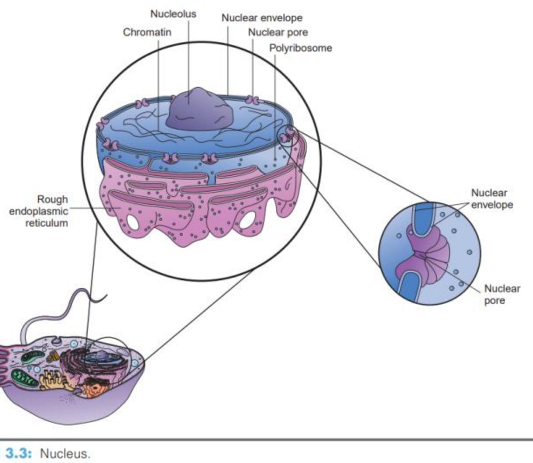


FIGURE 3.3: Nucleus.

The nuclear envelope is also perforated by numerous channels called nuclear pores. Each pore is made up of proteins arranged in a circle, forming a central channel. This channel is approximately 10 times larger than the pore within a protein in the plasma membrane. Nuclear pores control the movement of substances between the nucleus and the cytoplasm. Small molecules can pass via diffusion, but larger molecules, such as RNA and other proteins, must use active transport for passage. This permits the selective transport of proteins from the cytoplasm into the nucleus and of ribonucleic acid (RNA) molecules produced in the nucleus into the cytoplasm.

Another visible feature of the cell is the nucleolus, which is located within the nucleus. There may be one or more nucleoli per nucleus. It is spherical and is composed of a cluster of proteins, deoxyribonucleic acid (DNA), and RNA. It is not enclosed by a membrane. The nucleolus is where ribosomes, which play an important role in protein synthesis, are assembled. Thus, nucleoli are quite prominent in cells that produce large amounts of proteins, such as muscle and liver cells. The nucleoli disperse during cell division and reorganize when the new cells are formed.

The bulk of the nucleus is made up of chromatin, which may appear either diffuse or granular when viewed through a light microscope. Chromatin is the cell's genetic material, or chromosomes, and is found in a dispersed, unorganized arrangement in the non-dividing cell. The chromosomes and their component genes control cellular structure and most cellular activities. The genes, of course, are the hereditary material, and they ultimately control, among other things, the structure and appearance of the animal.

3. Cytoplasm: Cytoplasm is composed of two components: (1) cytosol and (2) organelles. The cytosol is the fluid portion of the cytoplasm and makes up 55% of the total cell volume. It varies in consistency and composition from one part of a cell to another and is composed of 75% to 90% water, with the balance consisting of various ions, glucose, amino acids, fatty acids, proteins, lipids, ATP, and waste products. Also located in the cytosol are various organic molecules that aggregate into masses that are stored and used as required for metabolism. The cytosol is the site of many chemical reactions and is the place where energy is produced and captured to drive the cellular activities necessary for life. The bulk of the cytoplasm stains pink under a microscope because of the basic (not acidic) proteins that compose the cytosol.

4. Organelles: The word organelles literally means “small organs.” These structures are the machinery of the cell and are highly specialized to carry out specific functions (Figure 3.4).

a. ribosomes: Ribosomes are densestaining, spherical bodies composed of ribosomal RNA (rRNA) and protein. They are the actual sites of protein synthesis, or the places where a new amino acid is added to the chain of amino acids in the protein being created. Structurally, a ribosome consists of two subunits, one about half the size of the other. These are formed separately in the nucleolus; then they exit the nucleus to unite within the cytosol. They may unite on the nuclear membrane or on the endoplasmic reticulum. These are called membrane-bound ribosomes. These ribosomes synthesize proteins destined for insertion into the plasma membrane or for export from the cell. Others may be free in the cytosol, unattached to any structure in the cytoplasm; these are called free ribosomes. Primarily, free ribosomes synthesize proteins used inside the cell. Ribosomes are also located within the mitochondria, where they synthesize mitochondrial proteins. Sometimes 10 to 20 ribosomes join together in string-like arrangements called polyribosomes.

b. endoplasmic reticulum (ER): The ER is a network of membranes that form flattened sacs or tubules called cisterns that extend from the nuclear envelope (as mentioned previously). The ER is so extensive throughout the cytosol that it constitutes more than half of the membranous surfaces found within the cytoplasm of most cells.

There are two forms of endoplasmic reticulum in cells: rough ER and smooth ER. They differ in structure and function. The membranous rough ER is continuous with the nuclear envelope and is studded with ribosomes. Proteins synthesized enter the rough ER’s cisterns for processing and sorting (Figure 3.5). As stated previously, these proteins will be exported from the cell or be used in the plasma membrane. In certain cells, enzymes within the cisterns attach the proteins to carbohydrates to form glycoproteins. In other cells, the enzymes attach proteins to phospholipids to form plasma membranes or the membranes of other organelles. Thus, the rough ER is responsible for synthesizing secretory proteins and membrane molecules. The smooth ER extends off of the rough ER at multiple sites to form another network of membranous tubules. It lacks the ribosomes of the rough ER, but it does contain unique enzymes that make it more functionally diverse than the rough ER. Smooth ER is able to synthesize phospholipids for membrane surfaces, and also synthesizes fats and steroids, such as estrogen and testosterone. In the hepatic cells of the liver, the enzymes of the smooth ER help release glucose into the bloodstream, and they inactivate or detoxify drugs and other potentially harmful substances, such as alcohol. In muscle cells, calcium ions are released from a form of smooth ER, called the sarcoplasmic reticulum, which triggers the contraction process.

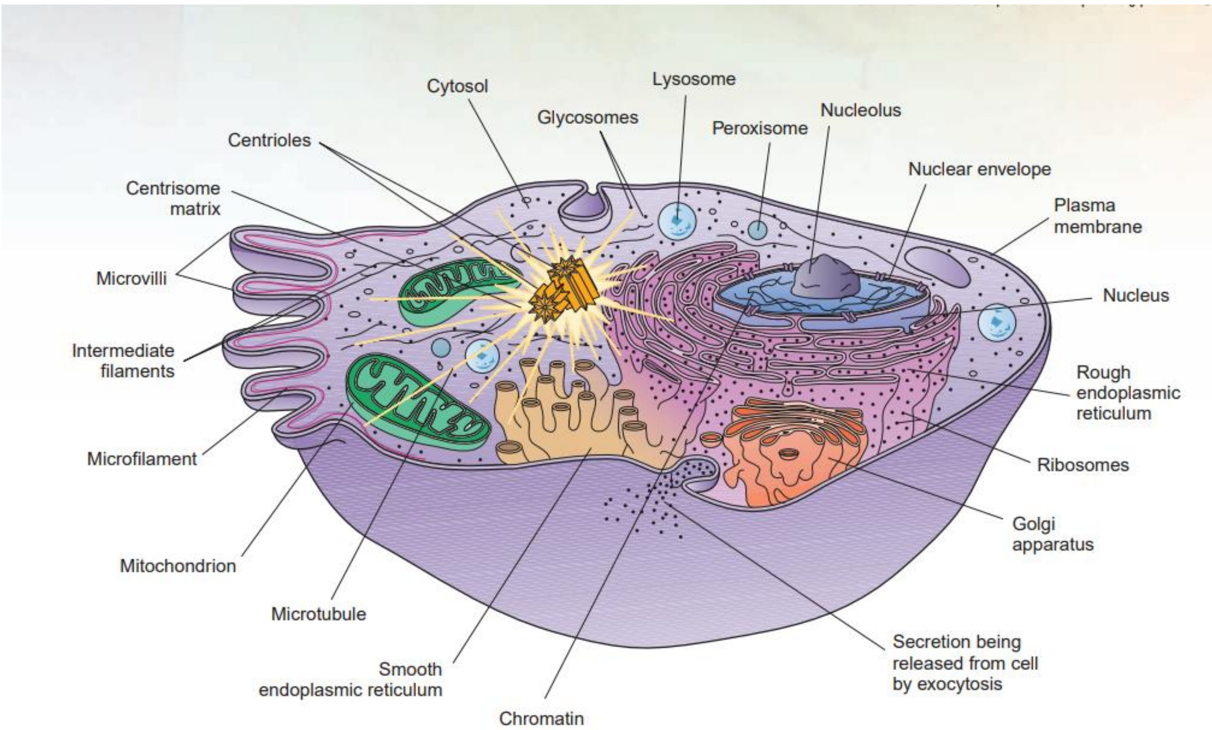


FIGURE 3.4: The cell and its organelles.

c. Golgi complex: The Golgi complex consists of 3 to 20 flattened, membranous sacs stacked on top of one another, with both ends dilated (Figure 3.6). The areas within these sacs are also called cisterns (like the similar areas found in the ER). The overall shape of the Golgi complex is cup-like because of the curvature of the cisterns. Most cells only have one Golgi complex, although some may have several. In cells that secrete many proteins into the extracellular fluid, the Golgi complex is large and extensive. Its function is to modify, sort, package, and transport products received from the rough ER and form secretory vesicles that discharge processed proteins, via a process called exocytosis, into the extracellular fluid. The Golgi complex also replaces or modifies the existing plasma membrane and forms lysosomes and peroxisomes.

d. lysosomes: Lysosomes are membraneenclosed vesicles that form in the Golgi complex (Figure 3.7). Inside the lysosomes are as many as 40 different kinds of digestive or hydrolytic enzymes capable of breaking down a variety of molecules. The enzymes tend to work best in an acidic pH, and thus the lysosomal membrane actively transports hydrogen ions ($H+$) into the lysosomes. The pH inside a lysosome is about 5.0, compared to the pH of the cytosol, which is neutral or 7.0. The lysosomal membrane also allows the final products of digestion, such as sugars and amino acids, to be transported into the cytosol. The functions of the lysosomes are to (1) digest substances that enter the cell via endocytosis, (2) digest worn-out organelles, a process called autophagy, (3) digest the entire cell if it dies, known as autolysis, and (4) occasionally conduct extracellular digestion, such as when spermatozoa release enzymes to help them penetrate the surface of an ovum.

e. peroxisomes: Peroxisome vesicles are smaller than lysosomes and contain one or more enzymes that can oxidize (by removal of a hydrogen atom) various organic substances. Peroxisomes detoxify harmful substances and are therefore abundant in kidney and liver cells. In addition to being produced by the Golgi complex, these organelles can self-replicate.

f. mitochondria: The mitochondria are the powerhouses of the cell because of their ability to produce ATP. A cell may have as few as 100 of them or as many as several thousand. Cells that have high physiologic activity, such as those in the muscles, liver, and kidneys, have many mitochondria because of their need for energy in the form of ATP. Mitochondria are found within the cytoplasm, where the need for energy is greatest, such as between the contractile proteins of muscle cells. Structurally, a mitochondrion is oval, like a small sausage. It is bounded by two membranes, similar to the plasma membrane. The outer mitochondrion layer is smooth, but the inner membrane is arranged in a series of folds called cristae. The center of the mitochondrion, bounded by the inner membrane and cristae, is fluid-filled and called the matrix. The cristae's structure provides a large inner surface area in the mitochondria for the chemical reactions in the aerobic phase of cellular respiration (Figure 3.8). The enzymes that catalyze these reactions are located on the cristae and in the matrix. To reiterate, the main product of these reactions is ATP.

g. centrioles: The paired bodies of centrioles are cylindrical and are located close to the nucleus in all animal cells capable of reproducing themselves. They lie at right angles to each other. Internally, each cylinder is composed of nine triplets of microtubules, called a 9 0 array, because there are nine sets of microtubules in a circle without any in the center. The centrioles direct the formation of the mitotic spindle during cell division. They also form the basis for cell projections called cilia and flagella. A centrosome is the pericentriolar area plus the centrioles (Figure 3.9). h. cytoskeletal elements: Inside the cell, within the cytosol, an internal scaffolding is formed that supports and moves substances within the cell. This structure is composed of several elements, including microtubules, which are slender tubules formed of proteins called tubulins. These tubulins have the ability to aggregate and disintegrate spontaneously. The centrosome serves as the initiation site for the assembly of the microtubules. They grow outward from the centrosome toward the periphery of the cell. The microtubules aid in intracellular transport of organelles, such as secretory vesicles, and form the spindle for the migration of chromosomes during cell division. They also act in the process of transporting molecules down the length of an elongated cell, such as a neuron, and they help determine and maintain cell shape by providing rigidity to the cytosol. The intermediate filaments, another component of the cell's internal scaffolding, are stable proteinaceous filaments that act as internal guy wires to resist mechanical (pulling) forces that act on the cells. Yet another component, microfilaments, are ribbon or cordlike elements within a cell formed from contractile proteins. Because they have the ability to shorten and lengthen (by relaxation), they are critical elements of cells that are mobile or cells that have the ability to contract, such as muscle cells. A cross-linked network of microfi laments braces and strengthens the internal face of the plasma membrane.

5. inclusions (inclusion bodies): Within the cytoplasm, various other substances and structures exist; these are stored foods (glycogen granules and lipid droplets), pigment granules, crystals of various types, water vacuoles, and ingested foreign materials. These are not active parts of the machinery of the cell; rather, they are passive masses and are therefore referred to as inclusions.

6. cilia and flagella: Cilia and flagella are motile, cell-surface projections composed of a 9 2 array of microtubule doublets (nine in a circle with two in the center) (Figure 3.10). Cilia are short and move fluids and debris over a cell's surface, whereas flagella are long and can propel the entire cell.

III. The cardiovascular system

III.1. OBJECTIVES

- name and describe the layers of the heart and the layers of an artery
- understand how the heart is positioned in the chest and how that relates to the sites used to auscultate the heart sounds
- understand and describe the fl ow of blood through the heart
- name and locate the major anatomical structures of the heart using models, diagrams, and a sheep's heart
- explain the operation of the atrioventricular valves and semilunar valves, and their relationship to the heart sounds
- dissect and name the arteries and veins of the cat; identify the pulmonary, systemic, and portal systems of blood flow
- understand the pathway of electrical conductivity through the heart, and how this produces the electrocardiogram
- know the various intervals, segments, and deflection waves produced during the electrocardiogram, and understand their relationship to the electrical conductivity of the heart
- understand arterial blood pressure and how to measure it

III.2. Introduction

The study of the cardiovascular system can be divided into two parts: the heart and the blood-vascular system. The cardiovascular system is the body's internal transport system. It picks up and delivers a variety of cargo, such as nutrients, hormones, antibodies, electrolytes, waste products, and drugs to and from all parts of the body. These various payloads are carried in the blood, which is pumped around the body by the heart. The cardiovascular system consists of the heart and the blood vessels that carry blood from the heart to the rest of the body and then return it. The blood vessels are named according to their positions and roles in the system. Arteries carry blood outward from the heart to the extensive network of capillaries all around the body. The capillaries deliver materials to the cells and take other materials away from the cells. The veins then return the blood to the heart. The systemic circulation is the blood flow to and from most of the parts of the body.

The pulmonary circulation is the blood flow to and from the lungs, during which the blood picks up oxygen and returns to the heart. The coronary circulation is the blood flow to the heart muscle itself, which provides it with the oxygen and nutrition it needs to do its job as a pump.

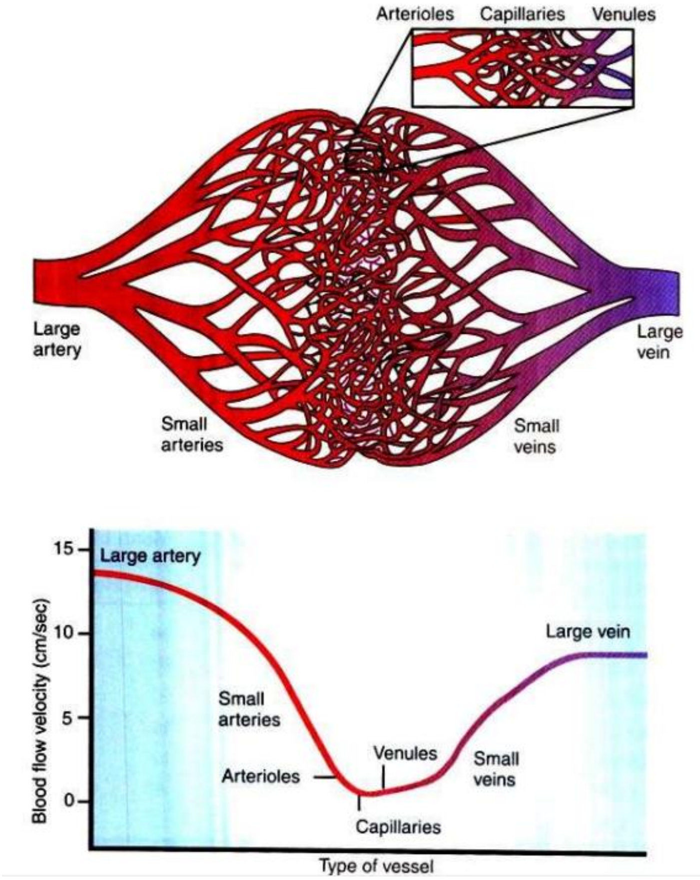
It is at the capillary level that substances are actually exchanged between the blood and the cells. However, the capillaries are simply thin, porous tubes of endothelium (simple squamous epithelium), so there is not much anatomical detail about them to learn. The heart, on the other hand, has various chambers, valves. Veins usually lie closer to the surface of the body than arteries do, and they have thin walls because the blood they carry is moving along under fairly low pressure. Arteries usually lie deeper than veins and have thicker walls because the blood they carry is under higher pressure.

The hepatic portal system is a venous system in which blood leaves the intestines and proceeds to the liver before returning to the heart. A portal system, by definition, is a series of vessels between two capillary beds. Also by definition, the venous system returns blood to the heart, and the arterial system carries blood away from the heart

The circulatory system is a closed circuit and the flow (L/min) of venous blood returning to the heart or venous return must equal the flow of blood pumped by the left ventricle into the aorta. The heart cannot pump more blood than is supplied by the venous return. The exact amount of flow around the circuit depends on the number and strength of the heart contractions, total volume of blood, and the characteristics of the vessels

The arterial system (right side of diagram) is the high- resistance, low-compliance system and distributes blood from &the left ventricle. Resistance (R)=pressure (ΔP)/flow ( ). Q 2 The venous system (left side of diagram) is the low-pressure, high-capacitance system that stores and returns blood to the atria. Capacitance (C)=volume (ΔV)/pressure (ΔP).

Capillaries connect the arteries and veins and exchange gases and small molecules by diffusion with the tissues.



III.3. ANATOMY OF THE HEART

The heart is positioned in the chest such that the base (the top part) is located just inferior to the tracheal carina (tracheal bifurcation), and in most species it angles caudoventrally until the apex (the pointed end) is resting just superior to the last few sternabrae (in the horse the apex is located mid-sternum). Because the base of the heart is oriented more cranially than the apex, the valves of the pulmonary artery and aorta are more cranial than the valves that separate the atria from the ventricles. The heart is enclosed within the pericardium or pericardial sac. The pericardium consists of the fibrous pericardium at the periphery, and a double-walled serous sac, the serous pericardium, between the fibrous pericardium and the heart. The parietal lamina of the serous pericardium intimately lines the fibrous pericardium, whereas the visceral lamina of the serous pericardium intimately covers the heart and becomes the epicardium. Between the two serous laminae is the pericardial cavity, which contains fluid that acts as a lubricant, allowing the heart to beat freely (Figure 10.4). The fi brous pericardium is covered by the pericardial pleura, the continuation of the mediastinal pleura. The mediastinal pleura was first noted when the chest was cut open in the dissection of the digestive system.

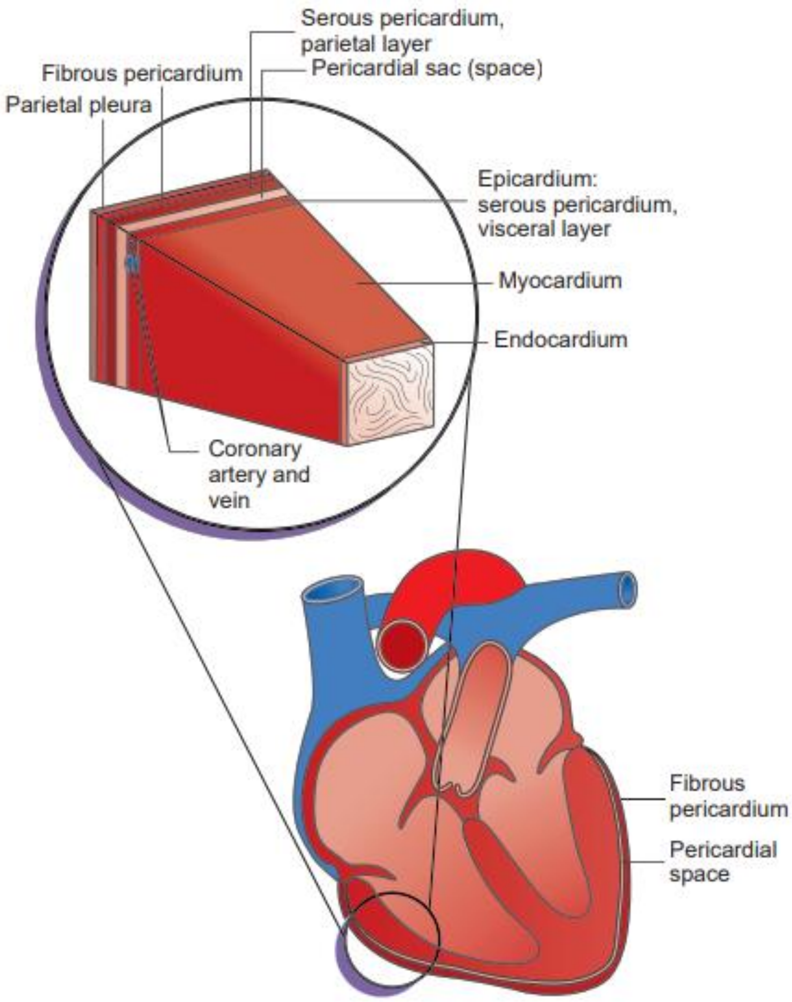


FIGURE 10.6: The layers of the heart.

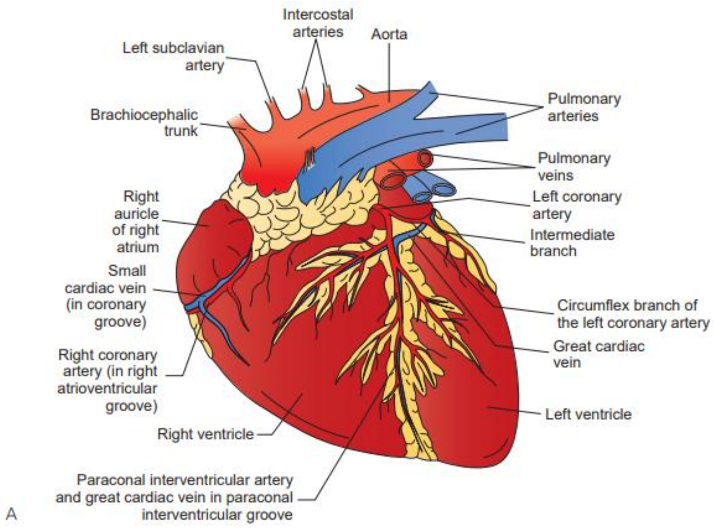


FIGURE 10.7: A. Left lateral view of the coronary circulation of the heart, all species.

- The base of the heart is where all the blood vessels enter and leave. It faces in a generally cranial direction in the living animal, tipped dorsally and to the right.
- The apex of the heart is the pointed tip. It faces in a generally caudal direction in the living animal, tipped ventrally and to the left.
- The fat-filled interventricular groove that spirals around the heart marks the location of the interventricular septum (the "wall" between the left and right ventricles).
- The left ventricle reaches all the way to the apex of the heart. The right ventricle does not.
- The right auricle, located cranial to the right ventricle, is an extension of the right atrium.
- The left auricle, located cranial to the left ventricle, is an extension of the left atrium.
- The blood vessel at the cranial end of the right ventricle near the interventricular groove is the pulmonary artery

III.4. The cardiac cycle: The heart has two phases: contraction and relaxation. Contraction, or systole, is the active phase when energy is expended; relaxation, or diastole, is the resting phase. There are four chambers of the heart: the upper chambers are the right and left atria, and the lower chambers are the right and left ventricles.

Both atria contract at virtually the same time, as do both ventricles. The cardiac cycle is illustrated in Figure 10.3. The blood enters the atria while they are relaxed. The atrioventricular valves (between the atria and ventricles), also known as the AV valves, are open, and so blood fl ows rapidly into the ventricles. Approximately 70% of the filling of the ventricles occurs during this phase. The atria then contract, which is called atrial systole, and the ventricles fill completely. Next, both ventricles begin to contract, and the atrioventricular valves are forced closed, producing an audible sound; this is called the first heart sound (the lub of the lub-dub of the heartbeat). This phase is a period of isometric contraction. As contraction continues, the pressure within the ventricles overcomes the closed semilunar valvules (the valves to the large arteries that exit off the base of the heart); the valves open, and the blood is ejected into the pulmonary artery and the aorta (the large artery that begins the systemic circulation). This contraction is called ventricular systole. As blood moves into the two arteries, they stretch, and because of their elasticity, the pressure within these vessels becomes sufficient to cause the semilunar valves to snap closed. This is the second heart sound. The cycle is repeated, starting with the period of relaxation of the heart called diastole.

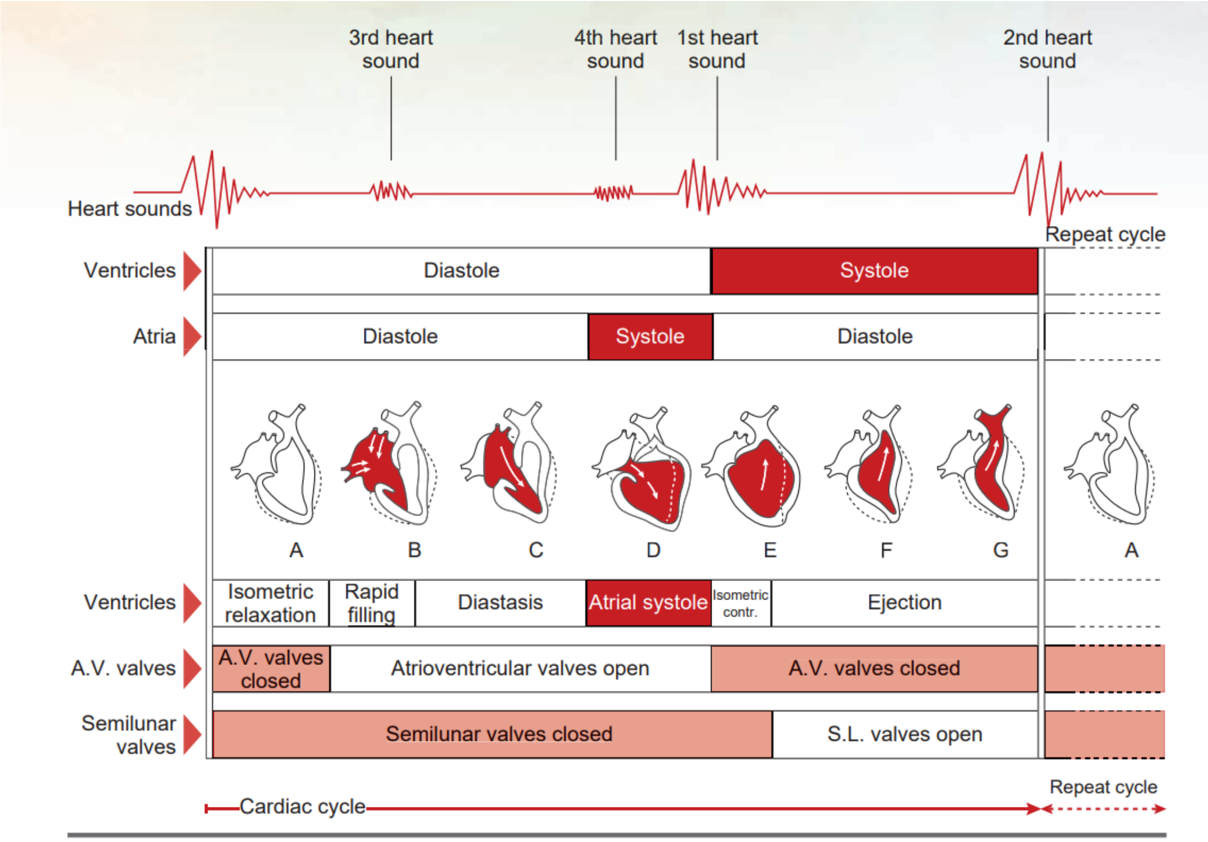


FIGURE 10.3: Events of the cardiac cycle.

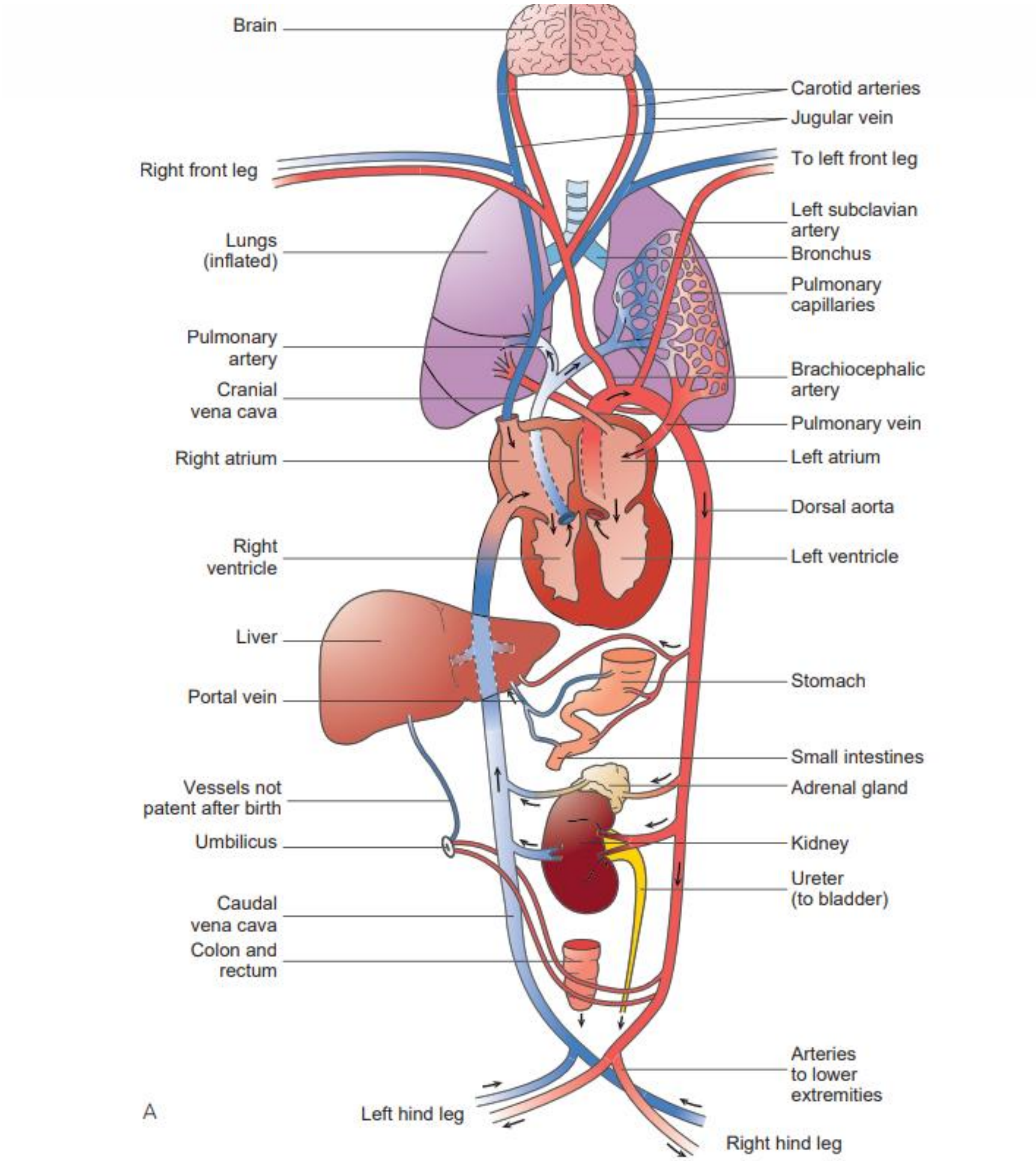


FIGURE 10.1: A. Plan of circulation in an adult animal. Red shading shows oxygenated blood and blue shading shows unoxygenated blood (opposite in the pulmonary system)

III.5. The Vascular System

The blood-vascular system is a closed transport system; blood leaves the heart in arteries and returns via veins. Veins contain venous blood, which is generally deoxygenated, and arteries contain arterial blood, which is generally oxygenated. There are two exceptions to this general rule for both the venous and arterial systems. In the venous system, the pulmonary vein(s) returning from the lungs contain oxygenated blood, as does the umbilical vein of the fetus, which returns oxygenated blood to the fetal heart. This oxygen is picked up from the mother as blood courses through the placenta (see Figure 10.1B). Conversely, in the arterial system, the pulmonary arteries taking blood to the lungs, and the umbilical artery taking blood to the placenta, contain deoxygenated blood. The flow of blood through the vascular system starts with the arteries. As the arteries branch and enter tissues, they get smaller and become arterioles, which are the smallest arteries. From there they become capillaries, and a network of capillaries within tissue is called a capillary bed. This is the site of internal respiration, where the nutrients and oxygen enter the cells of tissues, and carbon dioxide (CO2) is removed to the blood according to the following formula:

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H + CO3$

The walls of blood vessels, except for the capillaries, have three layers, or tunics (Figure 10.12).

The tunica interna (or tunica intima) lines the lumen of the vessel and is composed of a thin layer of simple squamous epithelial cells, also called the endothelium (squamous cells underlain by a scant basal lamina). It is continuous with the endocardium of the heart. The cells of this layer fi t closely together, forming an extremely smooth inner lining that helps to decrease resistance to blood flow.

The tunica media is the thicker middle layer of blood vessel walls and is composed primarily of smooth muscle and elastin. The smooth muscle is under the control of the sympathetic nervous system, a component of the autonomic nervous system. It plays an active role in regulating the diameter of the blood vessels, which controls the peripheral resistance and thus blood pressure.

The tunica externa (or adventitia) is the outermost tunic and is composed of areolar, or fibrous, connective tissue. Its function is basically support and protection. In general, the walls of the arteries are thicker than those of the veins because their tunica media have more smooth muscle and elastin. Arteries and arterioles in tissue sections appear round, whereas the venules and veins are larger and can take on a variety of elliptical shapes during the sectioning of tissues. The larger veins have valves, usually two paired cusps placed at irregular distances along the vessels. They direct blood to flow only toward the heart and prevent backflow.

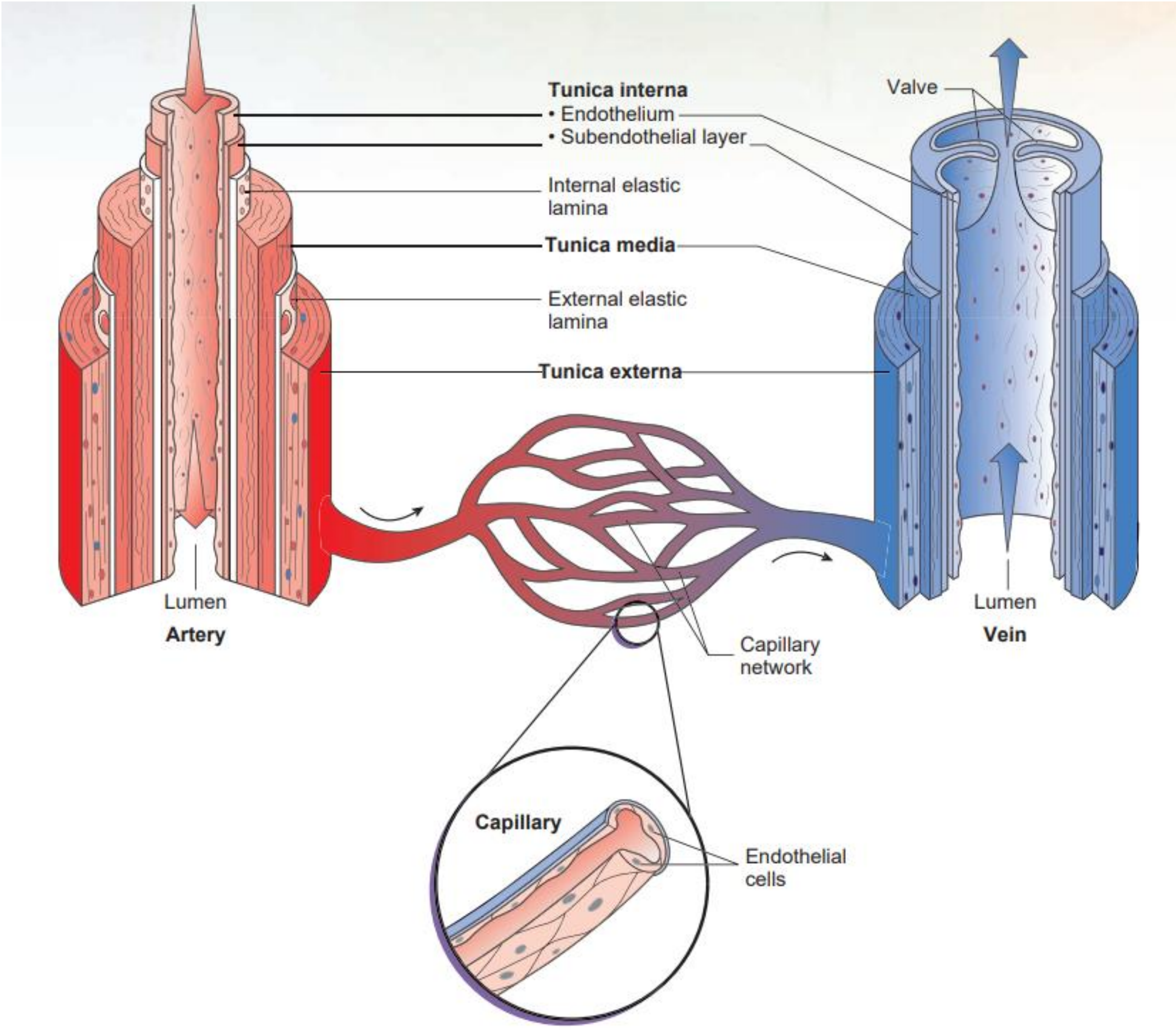


FIGURE 10.12: Structure of arteries, veins, and capillaries.

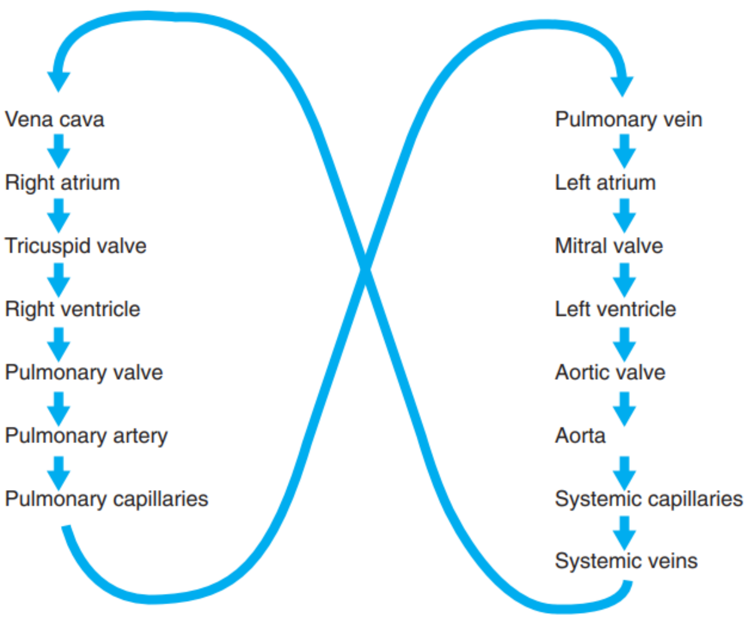


Figure 8-1 The "Figure 8" of Blood Flow Through the Heart and Blood Vessels.

III.6. The Electrocardiogram

An electrocardiogram is a recording of the electrochemical activity (depolarization waves) traveling through the heart immediately prior to each beat. The heart's ability to beat is intrinsic, and thus it does not depend on impulses from the nervous system to initiate its contraction. The heart will continue to contract rhythmically even if all nerve connections are severed. However, because it is connected to the autonomic nervous system, this system has a controlling effect on the heart and can either increase or decrease the heart rate.

Within the heart is the intrinsic conduction system, or nodal system. This system consists of specialized noncontractile myocardial tissue, called purkinje fibers of the purkinje system, that conducts the wave of depolarization through the heart in an orderly, consistent, and sequential manner that enables the heart to beat as a coordinated unit. The definition of depolarization is the state of a neuron that occurs immediately after a sufficiently strong stimulus is applied and results in an influx of sodium ions. This changes the membrane potential from approximately - 70 mV to + 30 mV. Repolarization follows depolarization; during it, potassium ions rapidly diffuse out of the neuron. This causes the membrane to return to its resting potential .

The sinoatrial node (the SA node), also called the pacemaker, has the highest rate of discharge and provides the stimulus to initiate the heartbeat. It also sets the rate of depolarization for the heart as a whole. The impulse then spreads across the both atria and is immediately followed by atrial contraction (atrial systole). The impulse then is picked up by the atrioventricular node (or AV node). At the AV node the impulse is momentarily delayed; in an animal with an average heart rate of 72 beats per minute, the delay is approximately 0.1 sec. It is shorter in animals with faster heart rates and longer in animals with slower heart rates. This allows the atria time to completely contract. From there the impulse passes through the AV bundle (or bundle of His) and splits into the right and left bundle branches as it travels down the interventricular septum. Branching off the bundle branches are numerous purkinje fibers attached to the myocardium, called terminal purkinje conducting fi bers. The impulse passes through these fibers to initiate ventricular contraction (ventricular systole; Figure 10

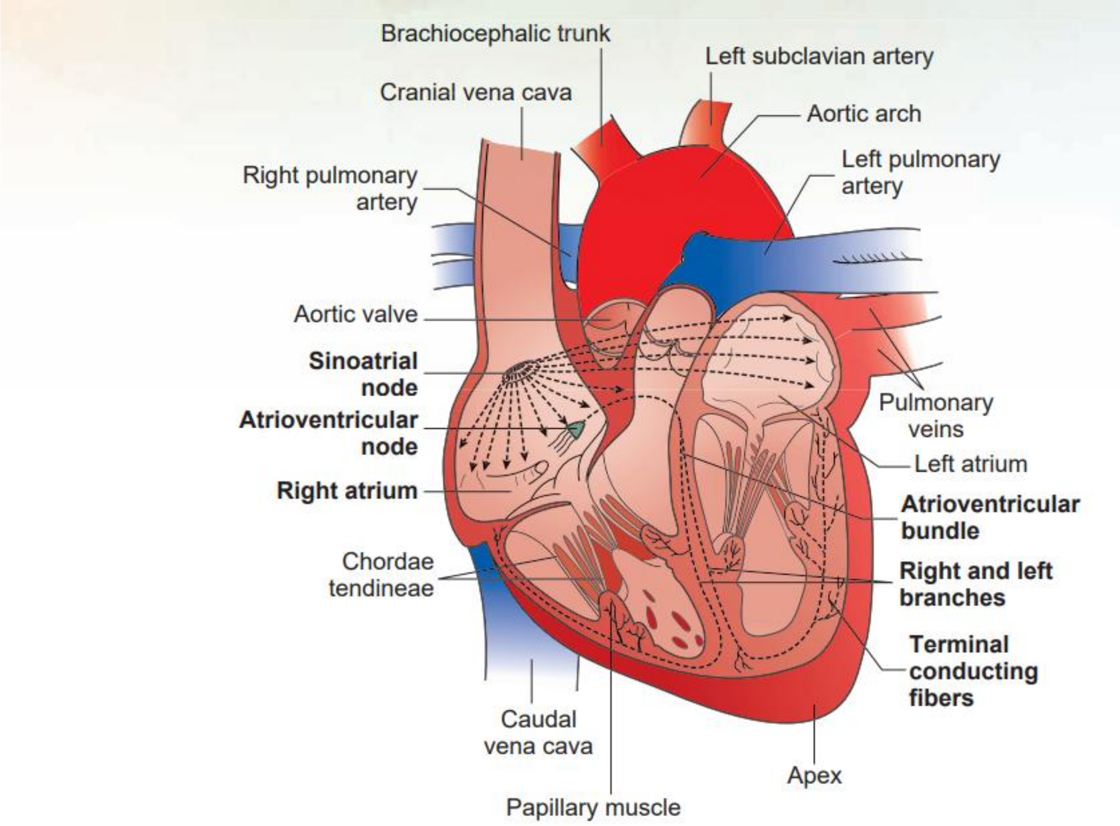


FIGURE 10.24: The intrinsic conduction system of the heart, all species.

The electrocardiograph records the electrical currents generated by the heart as they eventually spread through the body and are picked up by the machine's electrodes. The electrocardiogram (ECG or EKG) records three main recognizable waves, called deflection waves. The first is the P wave, representing depolarization of the atria, which occurs immediately prior to atrial systole. The next is the QRS complex, representing ventricular depolarization, and it is immediately followed by ventricular systole. The third wave is the T wave, representing ventricular repolarization. A small atrial repolarization wave occurs at the same time as ventricular depolarization, and thus this wave is buried within the QRS complex (Figure 10.25).

The direction of the ECG deflection waves (up or down) depends on where the positive and negative electrodes are attached on the limbs of the patient. Traditionally, a dog lies in right lateral recumbency and has electrodes attached at the elbows and knees. The right knee is the ground electrode. Cats may be positioned like dogs or sternally. The electrocardiograph machine is able to change the polarity of the electrodes without having to move them. A typical ECG records three standard limb leads, three augmented limb leads, and four or more chest leads. The three standard limb leads—Leads I, II, and III—record two of the electrodes during a reading. Lead I is positive on the left front leg and negative on the right front leg; Lead II is positive on the left hind leg and negative on the right front leg; and Lead III is positive on the left hind leg and negative on the left front leg.

The augmented or unipolar leads, known as aVR, aVL, and aVF, compare the positive electrode to each of the standard limb leads. The chest leads are placed at various locations on the external chest wall.

In a normal animal, the lead that usually gives the P wave and R wave in a positive deflection is Lead II because of the heart's position in the chest. As the wave of depolarization moves toward the positive electrode, it will record it as a positive deflection. If the wave moves directly toward the lead, it will be a strong positive deflection; if it is moving 45° obliquely toward the positive electrode, it will be a small positive deflection; if it is moving 90° to the positive electrode, the deflection will usually be minimal and be as much positive as negative. If the wave moves 45° away from the positive electrode and toward a negative electrode, it will be a small negative deflection; and finally, if the wave moves directly away from the positive electrode and directly toward the negative electrode, it will be strongly negative. If the QRS complex's wave deflections are equally positive and negative, this lead is called the isoelectric lead. The size of the atria or ventricles also affects the size of the wave deflection, giving veterinarians an indication of whether there is heart enlargement. Therefore, measurements of the P wave and R wave are performed as follows (see also Figure 10.25). The units of the following are all in millivolts (mV).

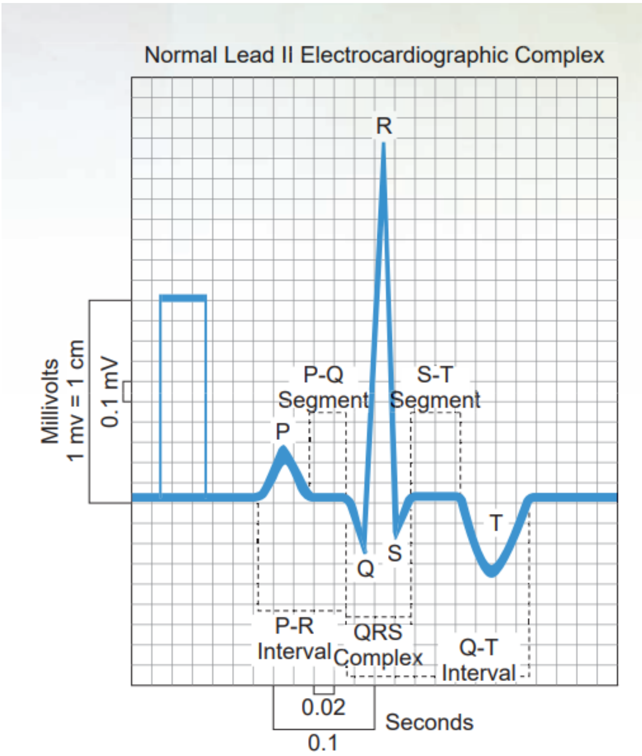


FIGURE 10.25: The normal Lead II electrocardiogram pattern. The machine appears standardized at 1 cm = 1 mV, and the tract would normally be recorded at 50 mm/sec paper speed

P wave: Measure from the baseline to the top of the P wave.

R wave: Measure from the baseline to the top of the R wave. (Note: it is measured not from the bottom of the Q or S waves to the top of the R wave, but from the baseline.)

Along the horizontal axis of the ECG, certain measurements are taken. Remember, intervals include the wave deflections; segments do not. The units of the following are in seconds (sec).

P-R interval: Measure from the start of the P wave to the start of the Q wave. This interval is misnamed and should be called the P-Q interval, but it is so named because the Q wave is often absent. This represents the time for atrial depolarization.

P-Q segment: Measure from the end of the P wave to the start of the Q wave. This represents the time the wave is within the AV node.

QRS complex: Measure from the start of the Q wave to the end of the R wave. This represents the time for ventricular depolarization.

S-T segment: Measure from the end of the S wave to the start of the T wave. This represents the time period between the end of depolarization of the ventricles and the initiation of repolarization.

Q-T interval: Measure from the start of the Q wave to the end of the T wave. This represents the length of time for ventricular contraction and repolarization.

Note that the measure along the horizontal axis is time in seconds, and that the vertical is measured in millivolts (mV). The standard measurements are taken at 50 mm/sec, and 1 mV = 1 cm on the vertical axis. This makes each small box equal to 0.02 sec horizontally and 0.1 mV vertically.

IV. The nervous system

IV. 1. Objectives

- describe the anatomy of a neuron and a nerve using diagrams or a prepared slide
- understand the reflex arc from the sensory afferent nerve fibers, through the spinal cord, to the efferent nerve fibers
- understand the mechanism of a nerve impulse
- locate and name the major anatomical structures of the sheep's brain and meninges
- explain the function of each part of the brain
- locate and name the major nerves of the peripheral nervous system
- understand the transmission of an impulse across a synapse
- understand and describe the flow of cerebrospinal fluid from its origin
- name the cranial nerves and describe their functions

IV. 2. Introduction

The nervous system is the master integrating and coordinating unit of the body. It is continuously monitoring sensory input from internal systems and from the external environment, then processing this information. All thoughts, actions, and perceived sensations are a reflection of the nervous system's activity. The nervous system can be divided into two parts: the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS consists of the brain and spinal cord, whereas the PNS consists of the spinal nerves from the spinal cord and the cranial nerves from the brain. The PNS can also be divided functionally into the autonomic nervous system, which acts automatically, and the somatic nervous system, which involves controlled muscular action. Nervous tissue has just two different classes of cells: neurons and their supporting cells. The supporting cells of the CNS are usually referred to as neuroglia, or glial cells. These cells include astrocytes, oligodendrocytes, microglia, and ependymal cells (Figure 15.1). They hold the neurons and their processes in place and have been described as nerve glue, which is the meaning of the word neuroglia. Supporting cells of the PNS are Schwann cells and satellite cells. They serve neurons by acting as phagocytes and by bracing, protecting, and myelinating the neurons' tiny, delicate fi bers. In addition, these support cells play a role in the exchange between local capillaries and neurons to control the surrounding chemical environment. Although the neuroglia resemble the neurons (because of their fibrous cellular extensions), they cannot generate or transmit nerve impulses.

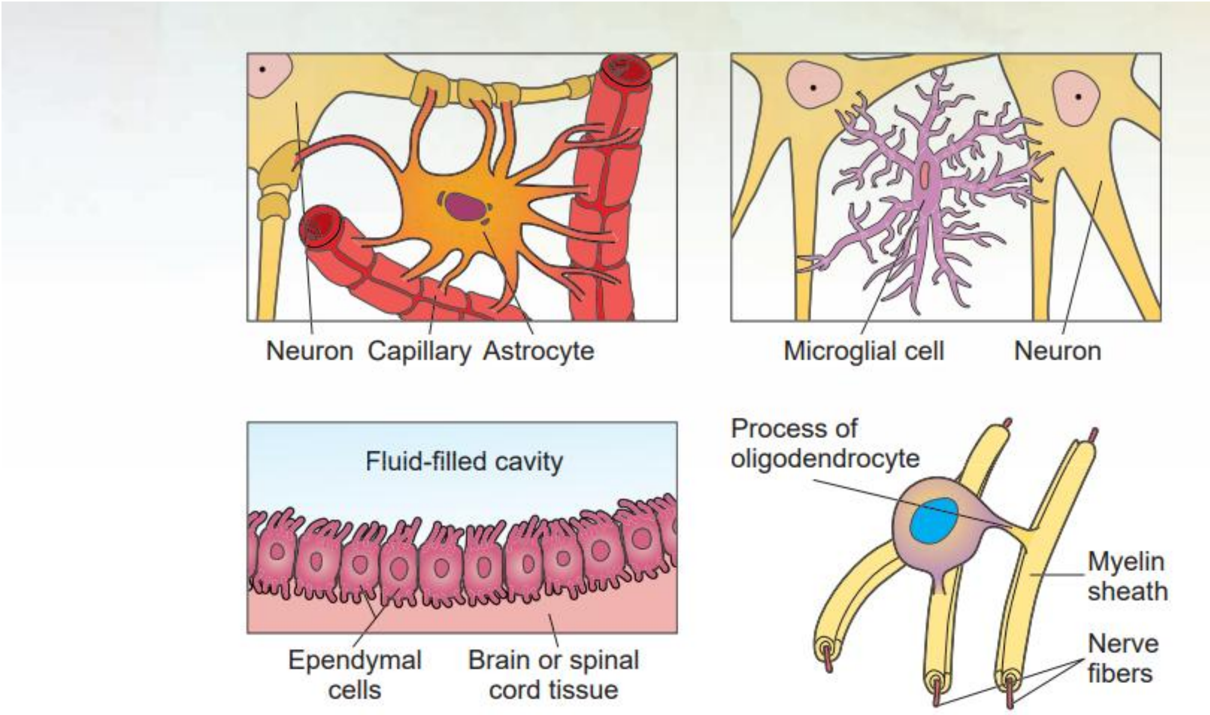


FIGURE 15.1: Supporting cells of the nervous system (all species).

IV. 3. The neuron

The neuron is the basic structural unit of nervous tissue. Neurons transmit messages as nerve impulses from one part of the body to another. Although neurons in different parts of the body differ structurally, they have a number of commonly identifiable features.

The cell body is where the nucleus is located, and the slender processes, or fibers, extend from it. The cell bodies can be found within the CNS or outside of it. Ganglia (singular: ganglion) are small masses of nervous tissue, containing primarily the cell bodies of neurons, that are located outside the brain and spinal cord. Collections of nerve cell bodies within the CNS constitute the gray matter.

Within the cell body of a neuron, neurofibrils can be found in the cytoplasm. These are the cytoskeletal elements of the neuron that help with support and intracellular transport. Also visible are Nissl (chromatophilic) bodies, which are elaborate types of endoplasmic reticulum involved in the metabolic activities of the cell.

Extending from the cell body are the neuron's processes, or fibers, which can take a variety of forms. Dendrites are the receptive region of the neuron, as they bear receptors for neurotransmitter substances released from adjoining axons and conduct the nerve impulse toward the cell body. Neurons have many dendrites. Axons are another type of process. Generally axons carry impulses in one direction only: away from the cell body. However, we now know that some axons transmit impulses both to and from the cell body. Therefore, axons are now defined as nerve impulse generators and transmitters

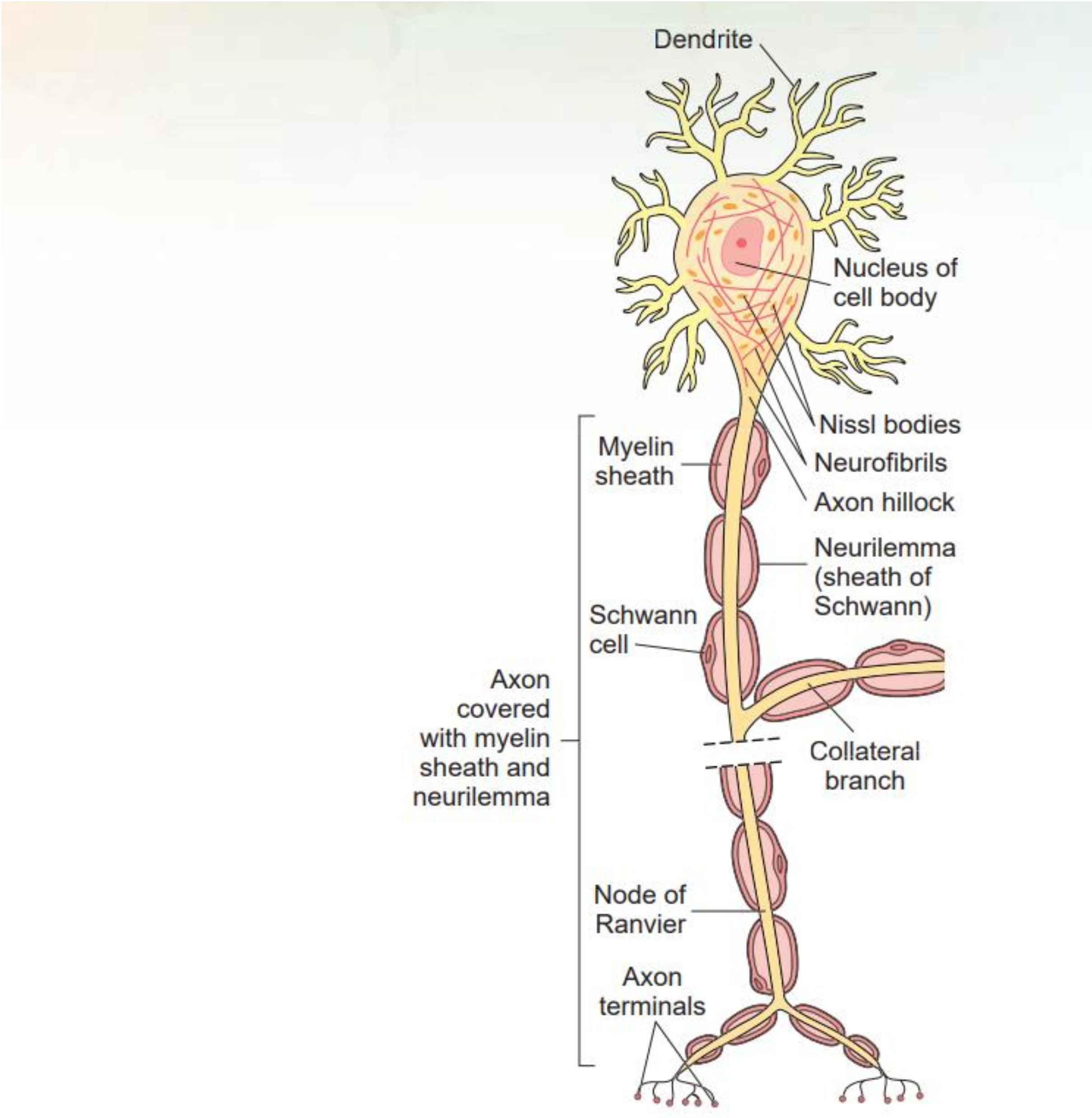


FIGURE 15.2: The structure of a neuron (all species).

IV. 4. Types of The neuron

Neurons are classified as unipolar, bipolar, and multipolar (Figure 15.3). Unipolar neurons are sensory neurons that originate in the embryo as bipolar neurons. During development, the axon and dendrite fuse to form a single process that divides into two branches a short distance from the cell body. Both branches function together as an axon. The branch that extends to the periphery at its distal tip has unmyelinated dendrites attached. The other branch extends into the CNS and synapses with other neurons.

Bipolar neurons have one main dendrite and one axon. They are found in the retina of the eye, in the inner ear, and in the olfactory area of the brain. **Multipolar** neurons usually have several dendrites and one axon. Most neurons of the brain and spinal cord are of this type. Even though multipolar neurons have only one axon, the axon may branch into collaterals. Note that the term nerve fiber is a synonym for axon and is thus quite specific.

Neurons communicate with one another or with cells of other tissues (such as muscle) by transmitting impulses from the terminal end of the axon (axon terminal) to another neuron's dendrite (Figure 15.4) or to another type of cell. The terminal end of an axon meets a dendrite at a synapse. These axon terminals have synaptic vesicles containing the **neurotransmitter substance**, and numerous mitochondria for energy. The membrane of the axon terminal is called the presynaptic membrane. When the nerve impulse reaches the axon terminals, some of the vesicles release the neurotransmitter substance to diffuse across the synaptic cleft (the tiny gap between the presynaptic membrane of an axon and the postsynaptic membrane of the dendrite). This substance then stimulates the dendrite, and thus the impulse is picked up and carried to the receiving nerve's cell body. It was long thought that each type of axon produced only one neurotransmitter, but we now know that axons may produce two or three different types of neurotransmitter substances, each with its own specific synaptic vesicle.

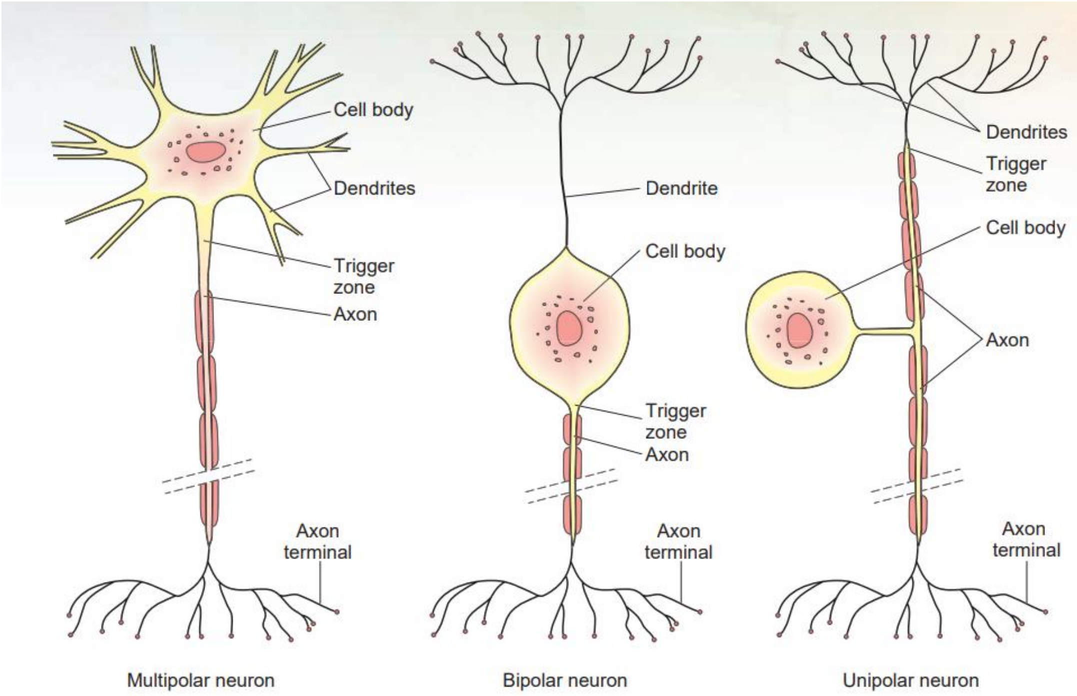


FIGURE 15.3: Structural classification of neurons.

IV. 5. The Nerve Impulse

Neurons have two major physiological properties: They are excitable (can convert stimuli into a nerve impulse), and they are conductive (can transmit the impulse). The following characteristics differentiate a nerve impulse from an electric impulse that runs through a wire: 1. Nerve impulses are based on ion move￾ment rather than electron movement. 2. Nerve impulses are slower than electric impulses. 3. Nerve impulses are active and self-propagating. 4. Nerve impulses require energy in the form of ATP. 5. Nerve impulses move at a constant amplitude and velocity

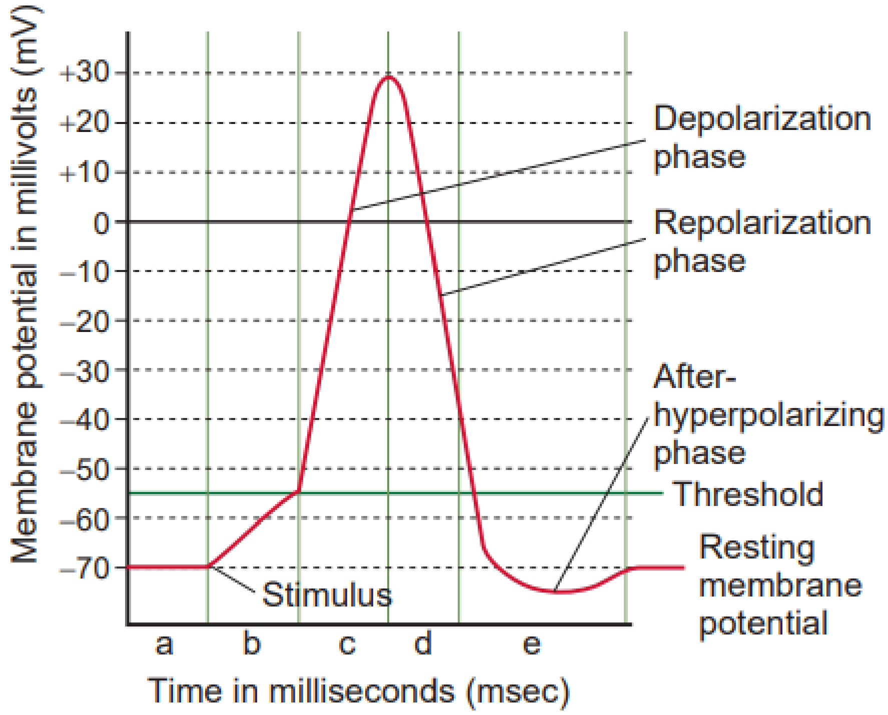


FIGURE 15.6: The action potential, or nerve impulse, and its phases. A. During resting membrane potential the voltage-gated Na^+ channels are resting and volt￾age-gated K^+ channels are closed. B. Rise to threshold potential: Sufficient stimulus causes depolarization to the threshold potential. C. Depolarization: The voltage￾gated Na^+ channels' activation gates are open. Part C represents the absolute refractory period. D. Repolarization: The Voltage-gated K^+ channels are open; Na^+ channels are inactivating. E. After hyper-polarization: voltage-gated K^+ channels are still open; Na^+ channels are in a resting state. Parts D and E represent the relative refractory period

A nerve impulse is described as an action potential (Figure 15.6). The difference in charge on two sides of a cell membrane results in a volt￾age known as the resting membrane potential, and a neuron in this state is polarized. This resting potential, measured across the axonal cell membrane, is approximately –70 millivolts (mV). The value is negative because the inside of the nerve cell membrane is negatively charged relative to the exterior because of an excess of cations in the extracellular fluid (ECF), especially sodium (Na^+).

At rest, the plasma membrane is virtually impermeable to sodium. A balance is maintained (by an active sodium-potassium pump) in which there are more potassium ions (K^+) inside the cell and more sodium ions (Na^+) outside the cell. When an axon receives a stimulus, the plasma membrane briefly becomes more permeable, and sodium rushes into the cell, resulting in more positive ions inside the cell (the chloride ions [Cl^-] in the extracellular fluid stay outside the cell). Thus, the interior of the cell starts to become less negative, and the outside less positive. This process is called depolarization.

If the stimulus is strong enough to depolarize the membrane to a critical level, called a threshold (approximately –55 mV), voltage-gated Na^+ channels (special gates that open and close to allow ions to pass) rapidly start to open. Both the electrical and chemical gradients favor inward diffusion of Na^+ ; this initiates the depolarizing phase of the action potential. The inflow of Na^+ becomes so large that the membrane potential passes 0 mV and rises to +30 mV. Action potentials arise according to the all-or-none principle: Once depolarization reaches the threshold an action potential occurs that is always the same size in terms of amplitude. Different neurons may have different thresholds for the generation of action potentials, but the threshold in any one neuron is usually constant.

When the voltage-gated Na^+ channels close, the voltage-gated K^+ channels are opening. This produces the repolarizing phase of the action potential and a process called repolarization. With the slowing of Na^+ influx and the acceleration of K^+ outflow, the membrane changes from +30 mV to –70 mV. However, the voltage-gated K^+ channels continue to allow K^+ to flow out; this overshoot is called after-hyperpolarization of the action potential. As the voltage-gated K^+ channels close, the membrane potential returns to –70 mV. In a typical neuron, the entire action potential lasts about 1 msec, or 0.001 seconds.

When the Na^+ is rushing in, the neuron is totally insensitive to additional stimuli and is said to be in an absolute refractory period. During the period of repolarization, it is nearly insensitive to further stimuli; however, a very strong stimulus may reactivate it. This period is called the relative refractory period. The sodium-potassium pump reestablishes the ionic balance soon after the action potential is completed, and because only minute amounts of sodium and potassium ions change places, once repolarization is completed, the neuron can quickly respond again to a stimulus.

Once generated, the action potential is self-propagating: It spreads along the entire length of the nerve fiber. It is never partially transmitted but is an all-or-none response (see previous discussion of this concept). The nerve impulse is the propagation of the action potential in which the disruption of the membrane permeability in one area of the axon causes disruption of the membrane permeability of the distal adjacent axonal area. This initiates another action potential in that axonal area, which stimulates the next axonal area, and so on down the axon. Because these axonal areas are small, propagation (and thus nerve impulse conduction) is slow under these circumstances.

As an animal develops and grows, either in utero or early in life, the nerves become myelinated. This results in faster nerve transmission and increased coordination. Animals that need to run immediately after birth to survive are born with fully myelinated nerves; others, such as kittens, do not complete myelination of motor neurons until 4 to 6 weeks of age. Figure 15.7 shows a myelin sheath around an axon. Myelin is a fatty substance within Schwann cells that segmentally envelopes the axon for its entire length. The areas between the Schwann cells are called nodes of Ranvier (or neurofi bril nodes). In myelinated nerves, these nodes act as the adjacent axonal area in which propagation occurs. In other words, the impulse jumps from node to node, progressing down the axon at a very fast rate, especially when compared to an unmyelinated nerve fiber.

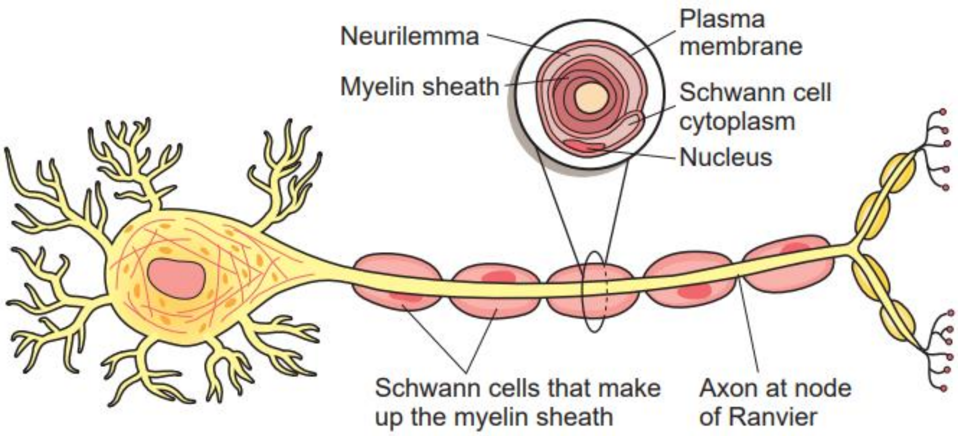


FIGURE 15.7: Axon with Schwann cells.

IV. 6. The peripheral nerves

There are approximately 38 pairs of spinal nerves in the cat. There are usually eight cervical, 13 thoracic, seven lumbar, three sacral, and seven coccygeal nerves. The first pair of cervical spinal nerves exits the atlas through the lateral vertebral foramina; the second pair exits between the atlas (C1) and the axis (C2). Each spinal cord segment produces a pair of spinal nerves; for example, cord segment C6 produces spinal nerve pair C6. Within the seven cervical vertebrae are eight cord segments producing eight pairs of spinal nerves. From T1 to L2 in the dog, and to L3 in the cat, the cord segment is located entirely within its associated vertebrae; in other words, inside the seventh thoracic vertebra is cord segment T7 that produces spinal nerve pair T7. From C1 caudally, each spinal nerve emerges from the intervertebral foramen between its associated vertebra and the next one or, in other words, just caudal to its associated vertebra. Continuing with the previous example, T7 exits the vertebral column just caudal to the seventh thoracic vertebra (between the seventh and eighth thoracic vertebra). Caudal to L2, more than one cord segment can be found within the vertebral bodies (Table 15.1). Even though the cord segments lie within a more cranial vertebra, their spinal nerves still exit caudal to the associated vertebral body. This means the nerves travel down the vertebral canal to reach the proper intervertebral foramen. Collectively, these spinal nerves come off the end of the spinal cord to form the cauda equina, so named for its resemblance to a horse's tail (Figure 15.8).

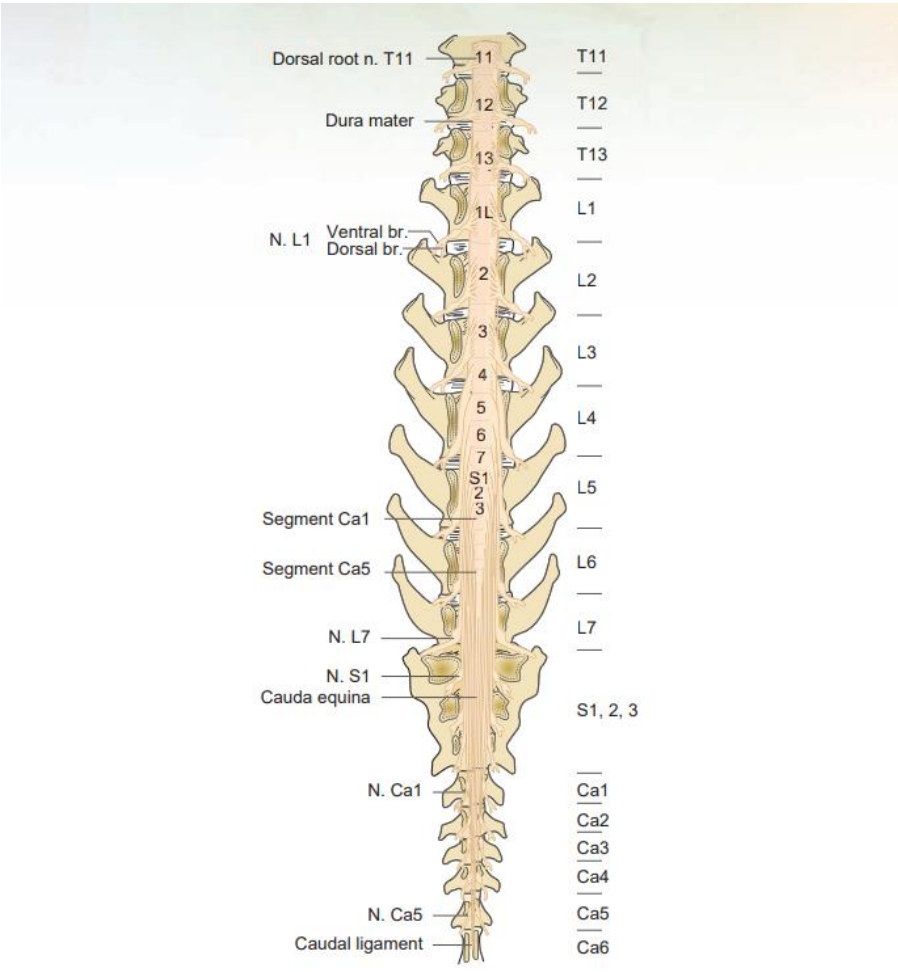


FIGURE 15.8: Spinal cord segment's placement within the spinal vertebrae and the cauda equina

IV. 7. The Cranial Nerves

The cranial nerves are the nerves of the peripheral nervous system that come from the brain and the brain stem. Each of these nerves is either sensory, motor, or both (if they have multiple functions). They may have autonomic function or may be voluntary. Table 15.2 lists the numbers and corresponding names of each of these nerves, its type, and its key function(s). Table 15.3 has two mnemonic devices for remembering the name and type of each nerve.

TABLE 15.2: Names and Functions of the 12 Cranial Nerves

Number	Name	Type	Key Function
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Motor	Eye movement, pupil size, focusing lens
IV	Trochlear	Motor	Eye movement
V	Trigeminal	Both	Sensations from the head and teeth, chewing
VI	Abducens	Motor	Eye movement
VII	Facial	Both	Face and scalp movement, salivation, tears, taste
VIII	Vestibulocochlear	Sensory	Balance and equilibrium, hearing
IX	Glossopharyngeal	Both	Tongue movement, swallowing, salivation, taste
X	Vagus	Both	Sensory from GI tract and respiratory tree; motor to larynx, pharynx; parasympathetic motor to the abdominal and thoracic organs
XI	Accessory	Motor	Head movement
XII	Hypoglossal	Motor	Tongue movement

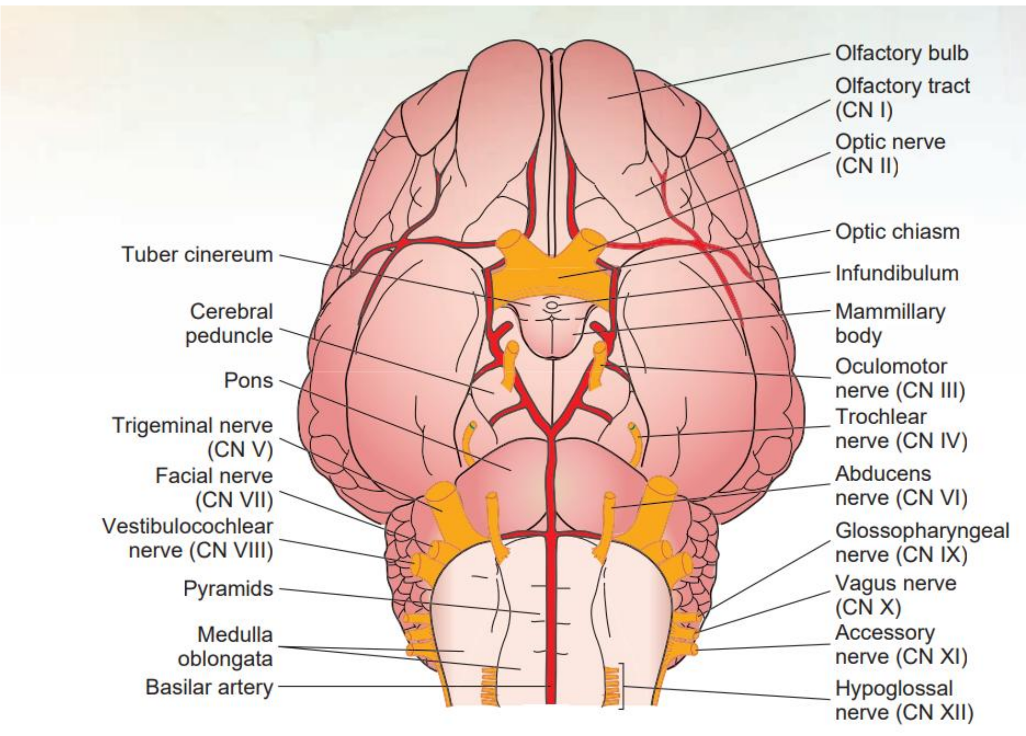
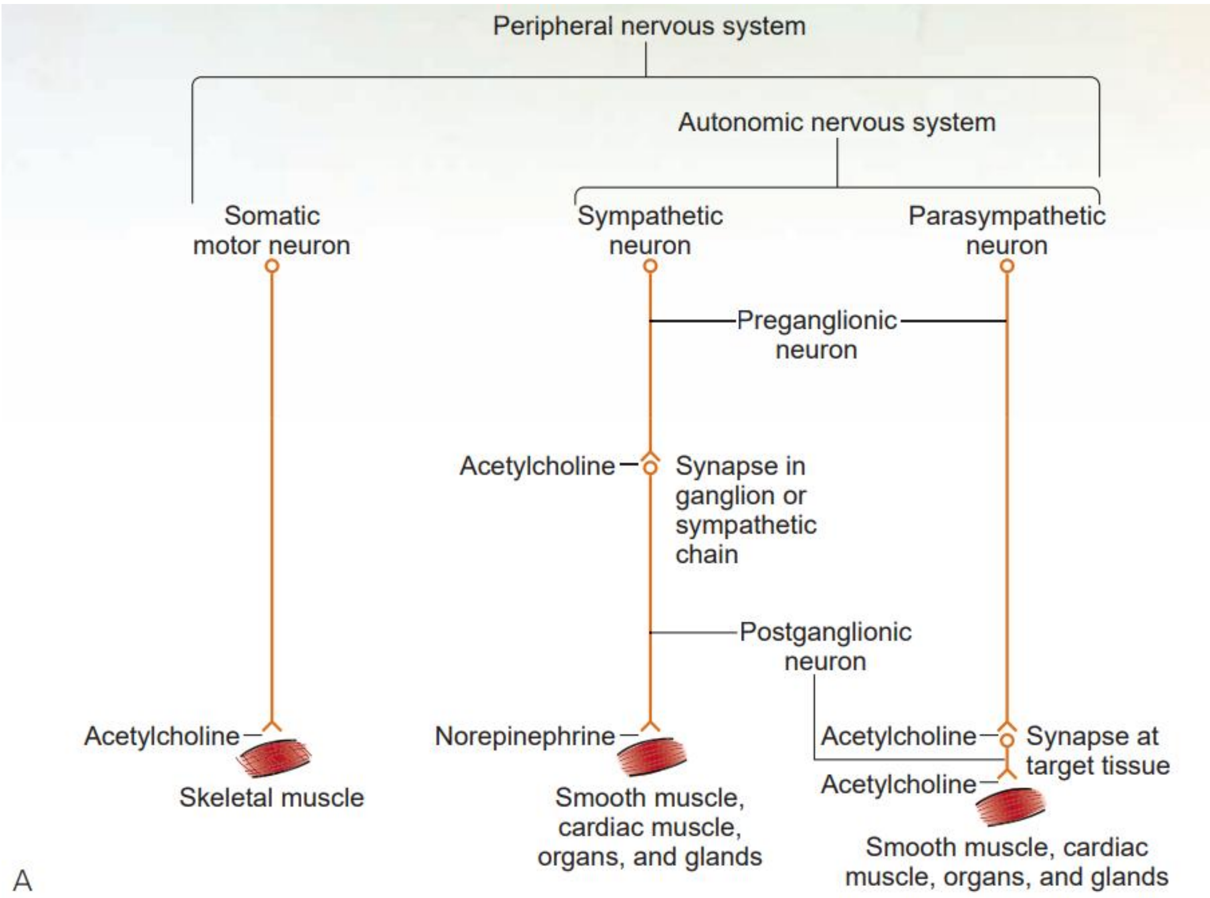


FIGURE 15.22: Diagram of the ventral view of the sheep's brain.

IV. 8. The Autonomic Nervous System

The autonomic nervous system is divided into the sympathetic and parasysmpathetic nervous systems. Figure 15.15A illustrates the neuronal arrangement of the somatic, sympathetic, and parasympathetic nerves. The parasysmpathetic nerves arise from the cranial nerves and sacral nerves. The sympathetic nerves arise from the thoracic and lumbar spinal nerves (Figure 15.15B). The sympathetic nerves' presynaptic fi bers syn apse at the sympathetic chain or other ganglia, and use acetylcholine as the neurotransmitter at this junction (see Figure 15.15A). The postsynaptic fi bers innervate organs of the chest and abdomen and use norepinephrine as the neurotransmitter. The parasympathetic nerves' presynaptic fi bers are long and synapse at or just below the surface of the organ they innervate. A short postsynaptic fi ber innervates the organ. Both use acetylcholine as the neurotransmitter.



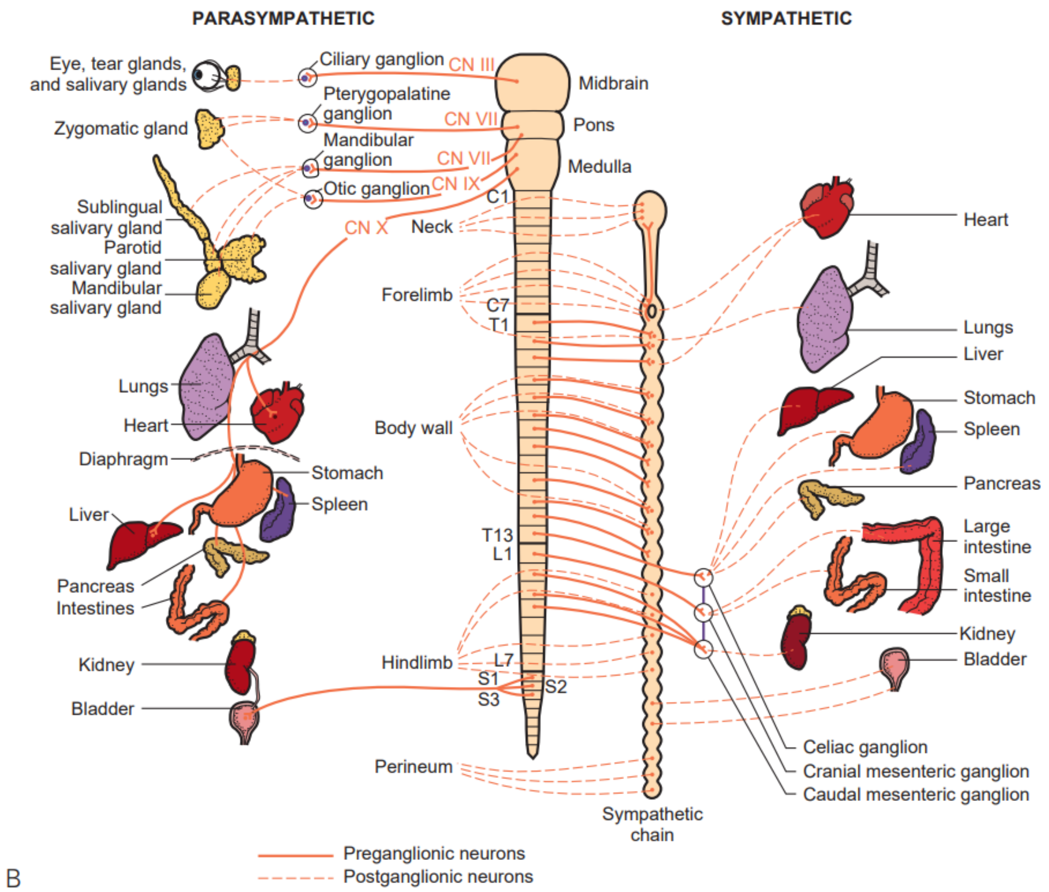


FIGURE 15.15: A. The peripheral nervous system. B. Sympathetic and parasympathetic preganglionic

IV. 9. Anatomy and Physiology of the Brain

The regions of the brain originate in the embryo. They are discussed in the following text. The telencephalon is composed of the cerebrum, or cerebral hemispheres. These are divided into functional lobes, which roughly correspond to the area of the cerebrum underlying the bone of the same name.

1. The frontal lobe contains the part of the motor cortex associated with voluntary movement, as well as areas associated with psychomotor skills

2. The parietal lobe also contains part of the motor cortex, as well as the somesthetic interpretation center, which controls conscious perception and localization of pain, touch, and temperature.

3. The occipital lobe is associated with visual interpretation.

4. The temporal lobe is associated with auditory function, behavior, and memory.

5. The piriform lobe is found on the ventral surface of the cerebrum and is associated with olfaction (Figure 15.16).

The major connection between the right and left cerebral hemispheres is the corpus callosum. Ventral to the corpus callosum and septum pellucidum is the body of the fornix. The fornix is the white matter connection between the hippocampal gyrus and nearby areas, such as the mammillary body and the brain stem. Other areas of the brain include the diencephalon, which consists mainly of the thalamus but also includes smaller areas of the epithalamus, subthalamus, metathalamus, and hypothalamus. The thalamus functions as a sensory relay center; it receives general sensory impulses and transmits them to the telencephalon. The other parts of the diencephalon also act as relay centers. The hypothalamus consists of the optic chiasm, tuber cinereum, mammillary body, infundibulum, and hypophysa. The functions of the hypothalamus were discussed in Chapter 13 on the endocrine system. The diencephalon and telencephalon together may be referred to as the forebrain.

The mesencephalon, or midbrain, is located immediately caudal to the diencephalon and consists of the corpora quadrigemina (made up of the rostral and caudal colliculi) and the paired cerebral peduncles. The rostral colliculi are associated with vision, and the caudal colliculi with hearing. The cerebral peduncles are essentially the continuation of the right and left halves of the spinal cord and brain stem into the respective cerebral hemispheres. They contain nerve fiber tracts and nuclei.

The embryonic rhombencephalon (hindbrain) develops into the metencephalon and myelencephalon. The metencephalon consists of the cerebellum dorsally and the pons ventrally. The cerebellum has a cortex and a medulla made up of white matter, which, on a cut surface, has a branching appearance and is called the arbor vitae. The cerebellum is connected by the rostral, middle, and caudal cerebellar peduncles to the cerebral peduncle, pons, and brain stem, respectively. The cerebellum coordinates motor activity. The pons is visible on the ventral surface, rostral to the brain stem. It is a mixture of white matter and gray matter and contains the ascending reticular activating system (ARAS). The ARAS maintains alertness or awareness by way of the cerebrum, and it controls the apneustic center and pneumotaxic center (for respiration), the nuclei of the vestibular apparatus, and the motor nucleus of cranial nerve 5 (CN V). The myelencephalon is the medulla oblongata, or brain stem. It contains the center for heart functions, as well as centers for respiration, swallowing, and vomiting

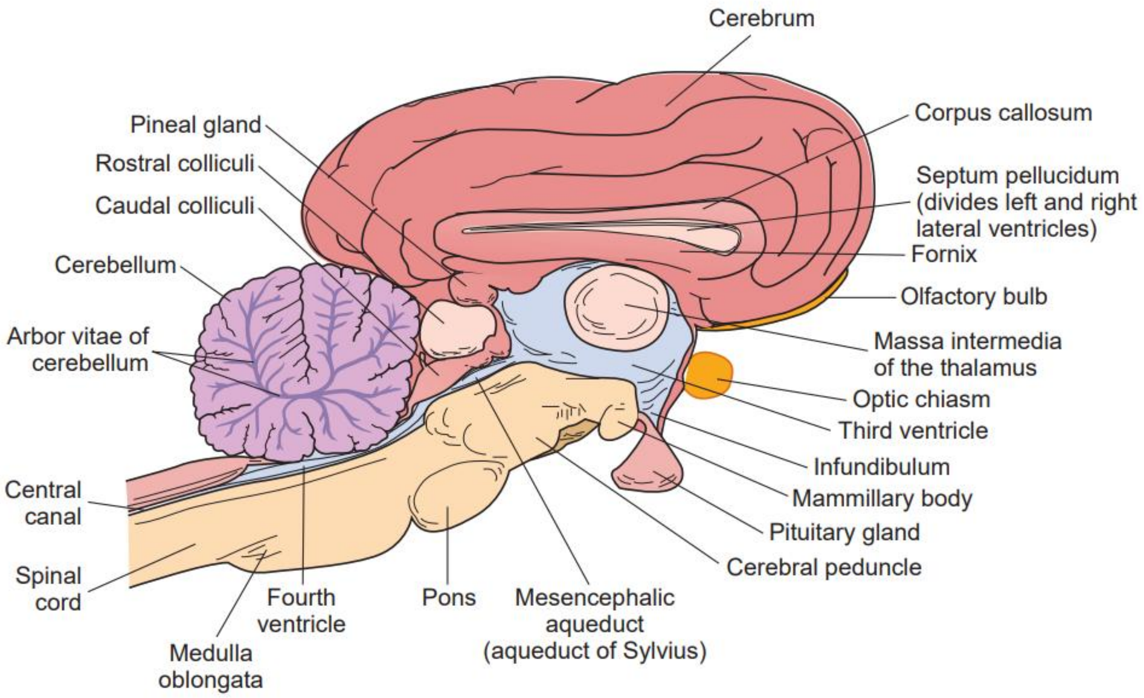


FIGURE 15.24: Diagram of the sagittal view of the sheep's brain.

IV. 10. The cross section of the spinal cord

1. A cross-sectional view of mammal spinal cord (Figure 15.26).

2. The spinal cord is divided into two mirror halves, right and left. The two halves are divided dorsally by a sulcus, the dorsal median sulcus, and ventrally by a fissue, the ventral median fissure. The gray matter is located centrally on both sides, surrounded by white matter peripherally. The gray matter contains nerve cell bodies, both in the brain and in the spinal cord.

3. The white matter contains the white tracts, or columns, that communicate with the brain stem, cerebellum, and cerebrum. It is white because these nerve fi bers are myelinated. The dorsal white column is called the dorsal funiculus; the lateral column, the lateral funiculus; and ventral column, the ventral funiculus.

4. In the center is the central canal, which communicates with the fourth ventricle

IV. 11. Spinal reflex

A spinal reflex arc is a pathway of a nerve impulse. A sensory afferent neuron extends to the spinal cord, synapses there with an interneuron (also called an internuncial neuron or Renshaw cell), and synapses again with a motor efferent neuron (Figure 15.27).

The neurotransmitter at the efferent motor neuron is excitatory. It establishes an excitatory post-synaptic potential in the efferent motor neuron that goes to the agonist muscle. This neurotransmitter is acetylcholine. Simultaneously, another interneuron establishes an inhibitory postsynaptic potential to the efferent motor neuron of the antagonist muscle by releasing an inhibitory neurotransmitter, glycine, at the spinal cord level. Gamma-amino butyric acid (GABA) is the inhibitory neurotransmitter in the brain. As a result, the agonist muscle is contracting while its opposing muscle, the antagonist, is relaxing, thus allowing easy movement of a limb or other body part. The excitatory neurotransmitter is removed from the synaptic cleft by the release of an enzyme—in this case, acetylcholinesterase.

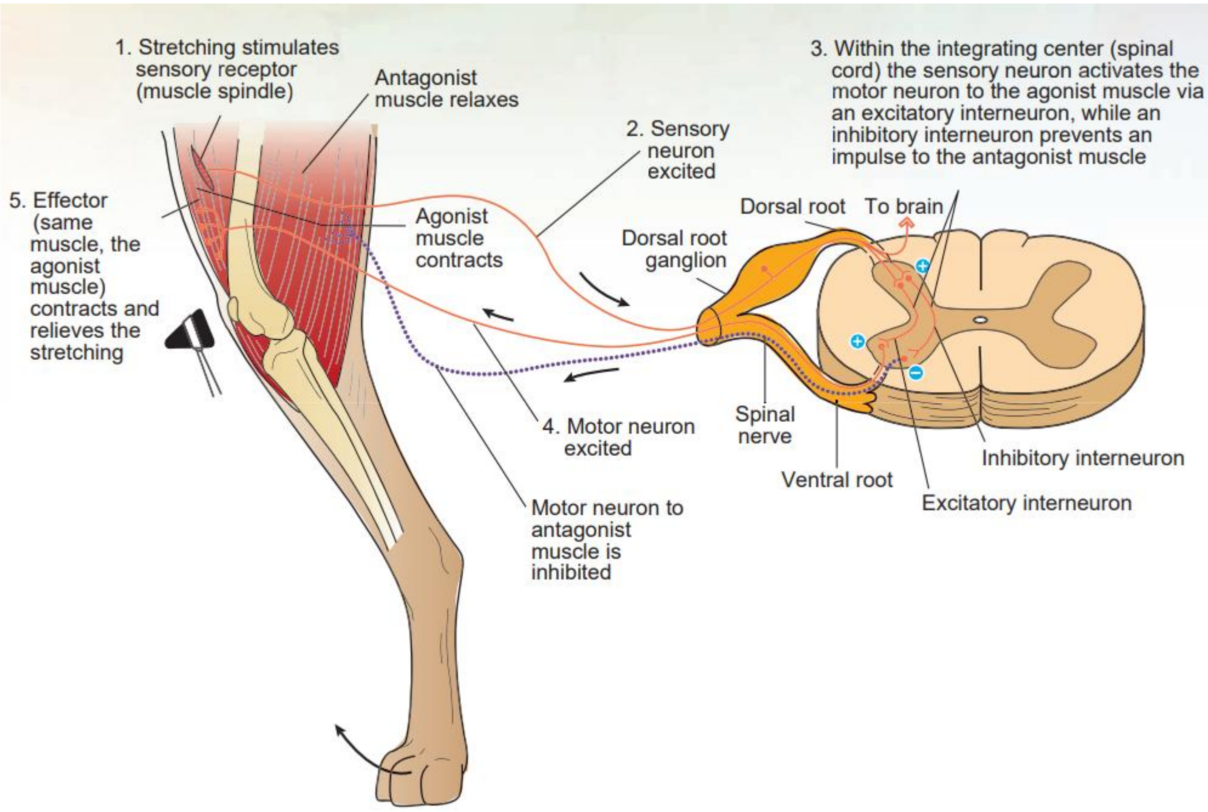


FIGURE 15.27: The spinal reflex arc in a dog.

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