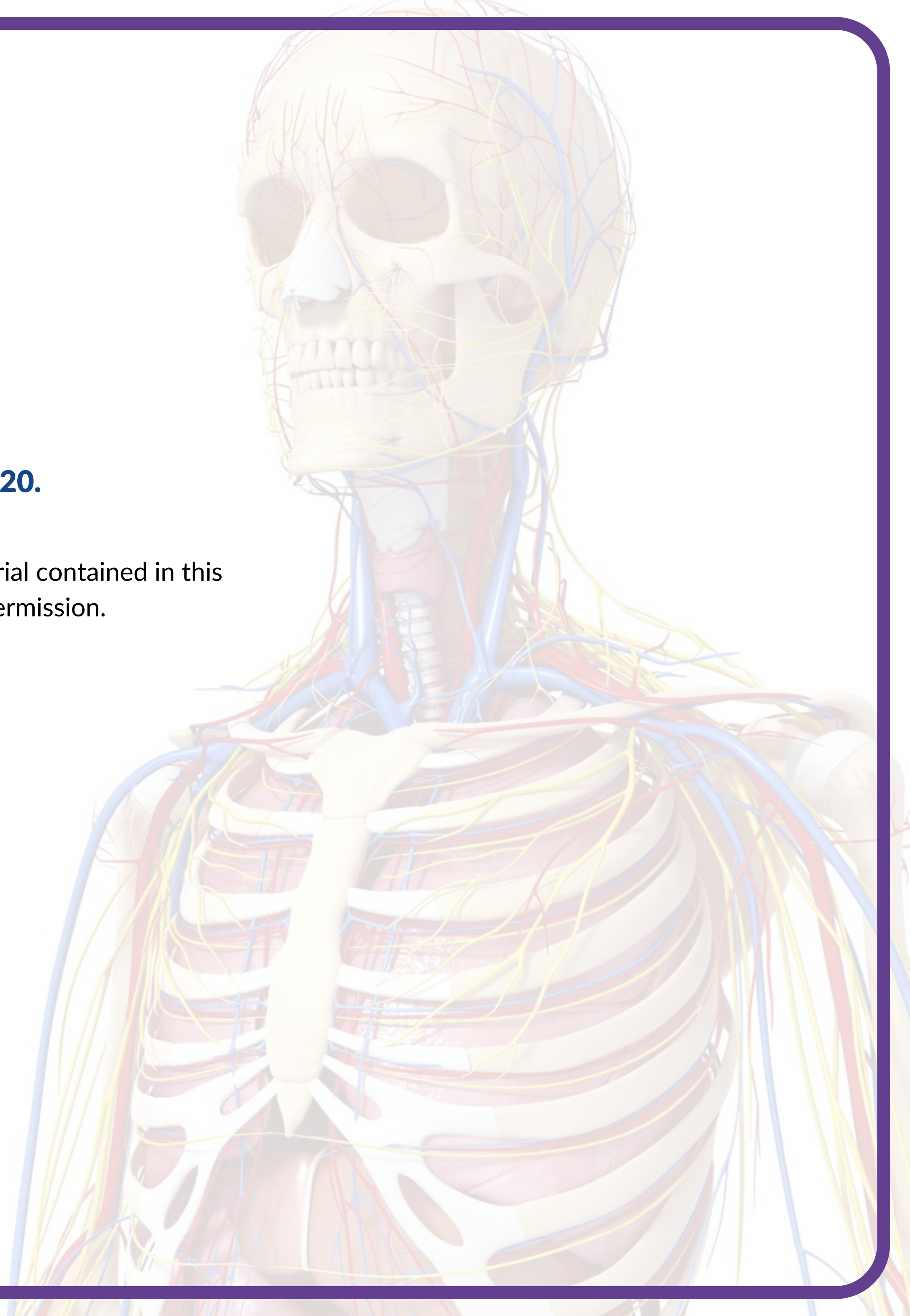
Nervous System Workbook

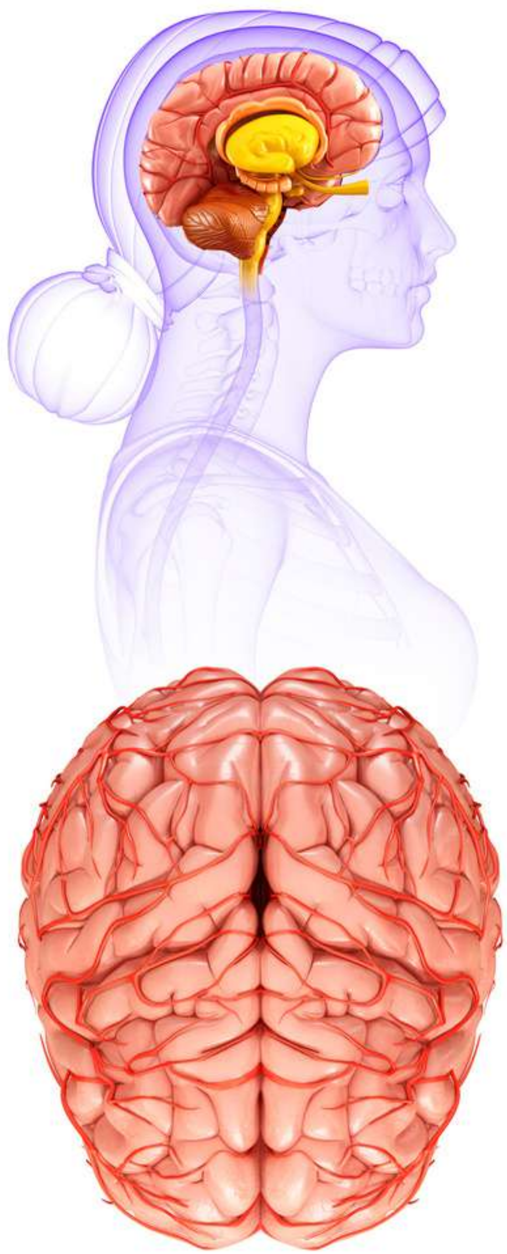


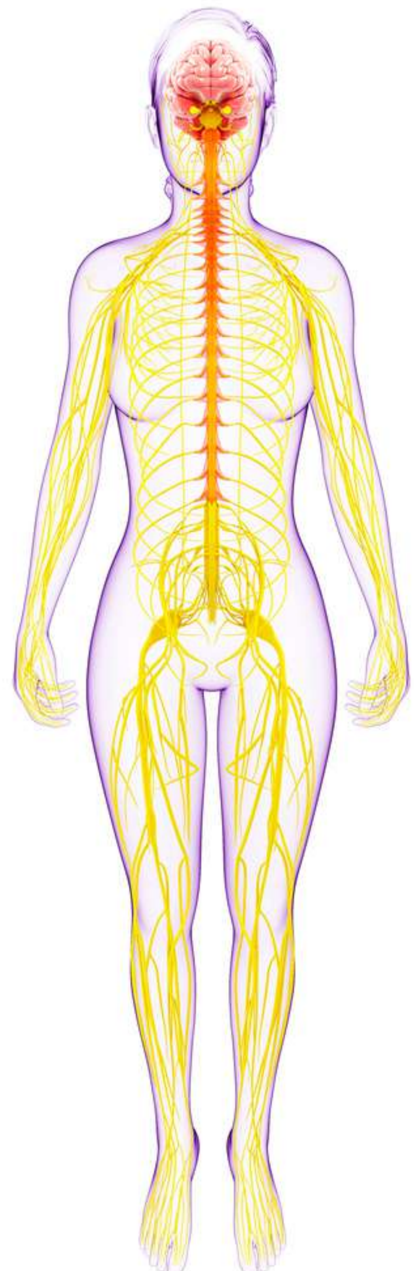
Contents

Learning Objectives

- Describe the function of the nervous system and its major components.
- Describe the relationships between the different components of the nervous system.
- Explain how the nervous system is interdependent with other organ systems.
- Explain how the nervous system maintains homeostasis in the body

Nervous System Overview





The nervous system is involved in **receiving information** about the environment around us (sensation) and **generating responses** to that information (motor responses). The nervous system can be divided into regions that are responsible for sensation (sensory functions) and for the response (motor functions).

COMPONENTS

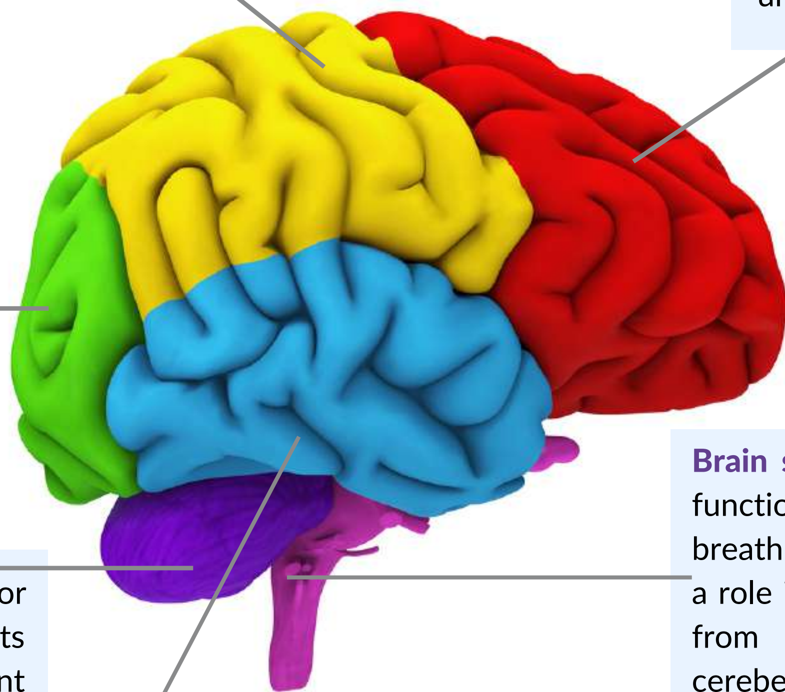
Brain
Spinal Cord
Nerves
Neurons

Brain Anatomy: External

Parietal lobe: Integrates sensory information. Includes areas for visuo-spatial processing.

Frontal lobe: Responsible for higher mental functions, including ability to determine similarities and differences, recognize consequences from actions, and to suppress unacceptable societal responses.

Occipital lobe: Contains the visual processing centre. Has specialized areas for different visual tasks, including visuo-spatial processing, motion perception and colour differentiation.



Cerebellum: Has anterior and posterior lobes. Controls fine motor movements and is involved in planning movement that is about to occur.

Brain stem: The brainstem has many basic functions, including regulation of heart rate, breathing, sleeping, and eating. It also plays a role in conduction. All information relayed from the body to the cerebrum and cerebellum and vice versa must traverse the brainstem.

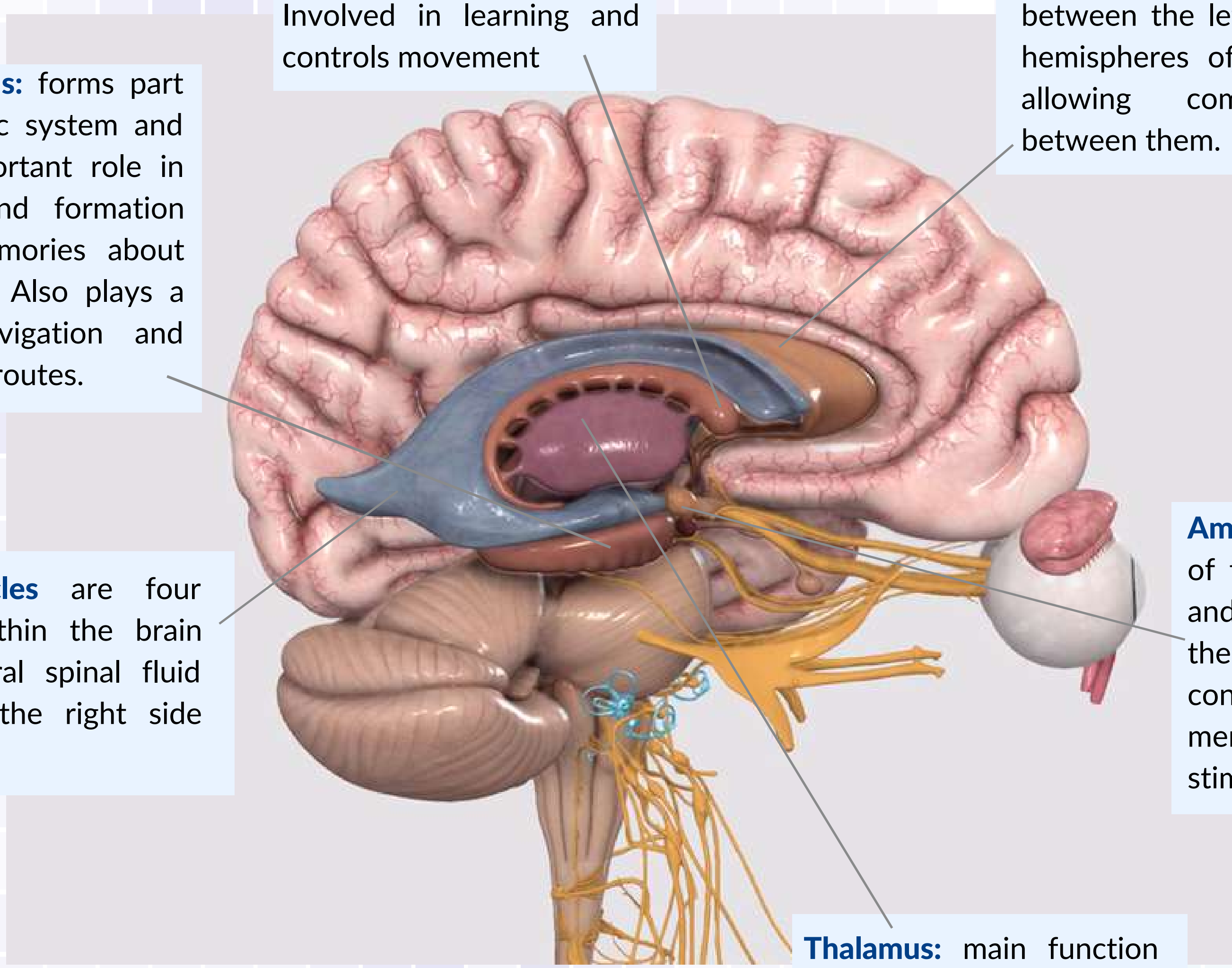
Temporal lobe: the primary auditory cortex is found here and is involved in auditory perception. This lobe also contains the hippocampus.

Brain Anatomy: Internal

Caudate nucleus: forms past of the basal ganglia. Involved in learning and controls movement

Corpus callosum: forms a white matter bridge between the left and right hemispheres of the brain, allowing communication between them.

Hippocampus: forms part of the limbic system and has an important role in screening and formation of new memories about experiences. Also plays a role in navigation and finding new routes.



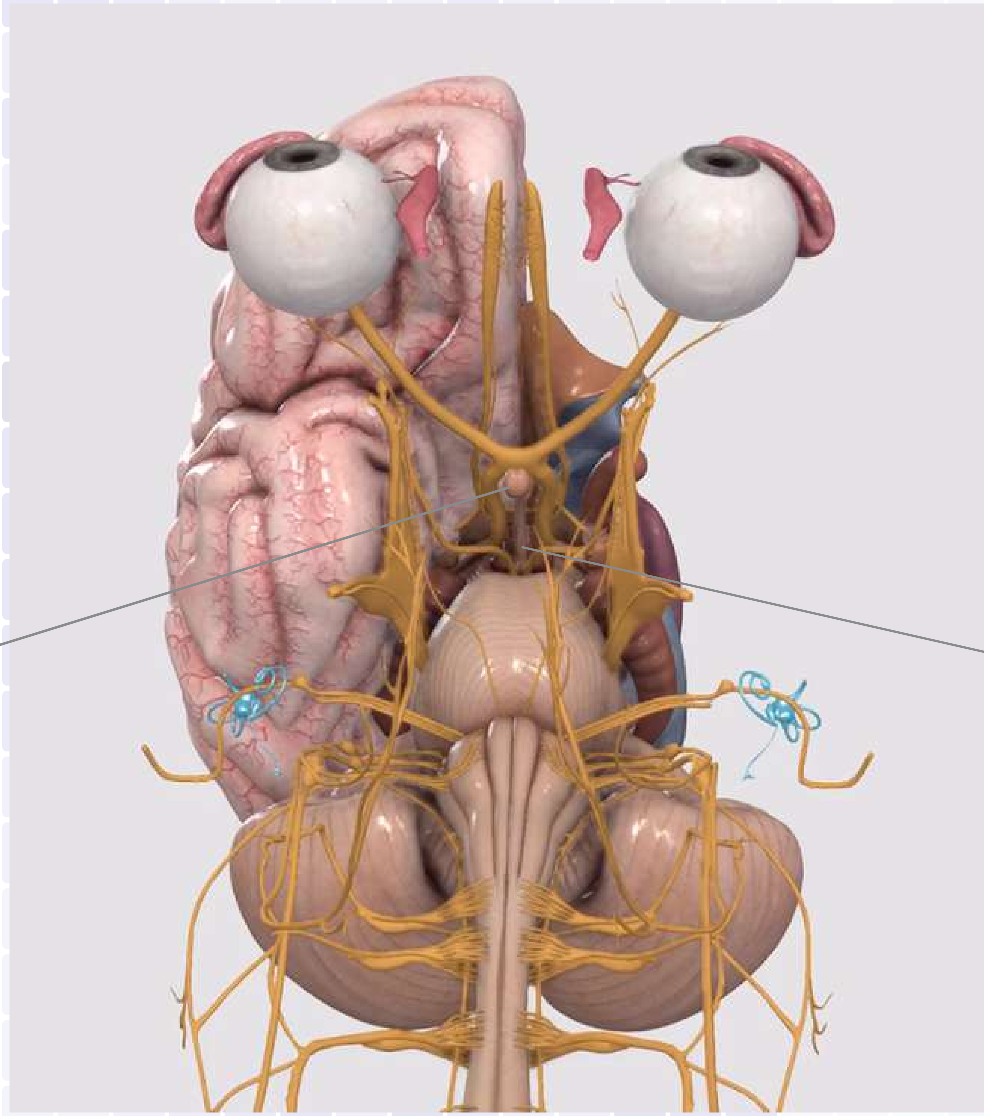
The brain **ventricles** are four cavities located within the brain that contain cerebral spinal fluid (CSF). Pictured is the right side **lateral ventricle**.

Amygdala: forms part of the limbic systems and has a major role in the processing and consolidation of the memory of emotional stimuli.

Thalamus: main function is to relay motor and sensory signals to the cerebral cortex.

Brain Anatomy: Internal

Pituitary Gland:
secretes 9 endocrine hormones

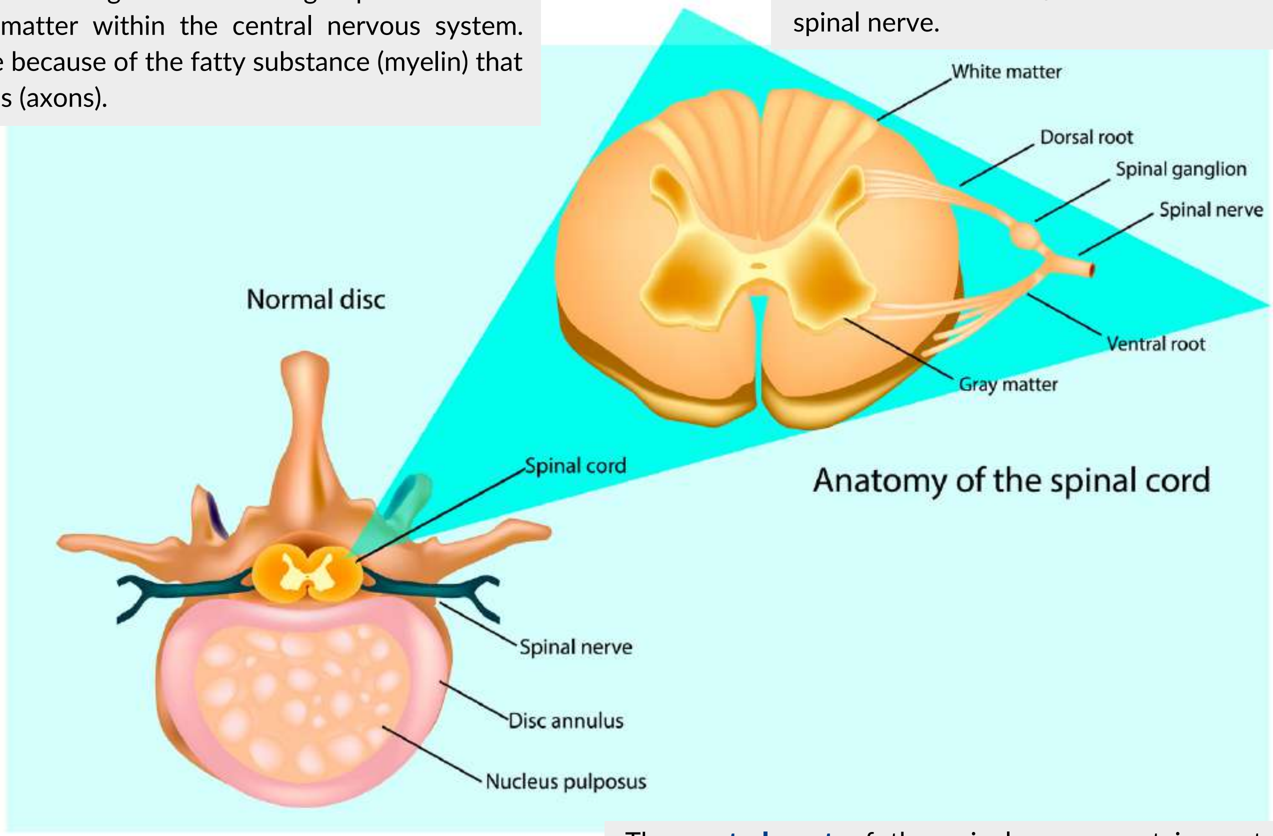


Hypothalamus:
secretes important endocrine hormones, and is the centre for feelings, instincts, motivational states, and emotional reactions.

Spinal Cord Anatomy

The **dorsal root** of spinal nerve (or posterior root of spinal nerve) is one of two "roots" which emerge from the spinal cord. It emerges directly from the spinal cord, and travels to the **dorsal root (spinal) ganglion**. The dorsal root transmits sensory information, forming the afferent sensory root of a spinal nerve.

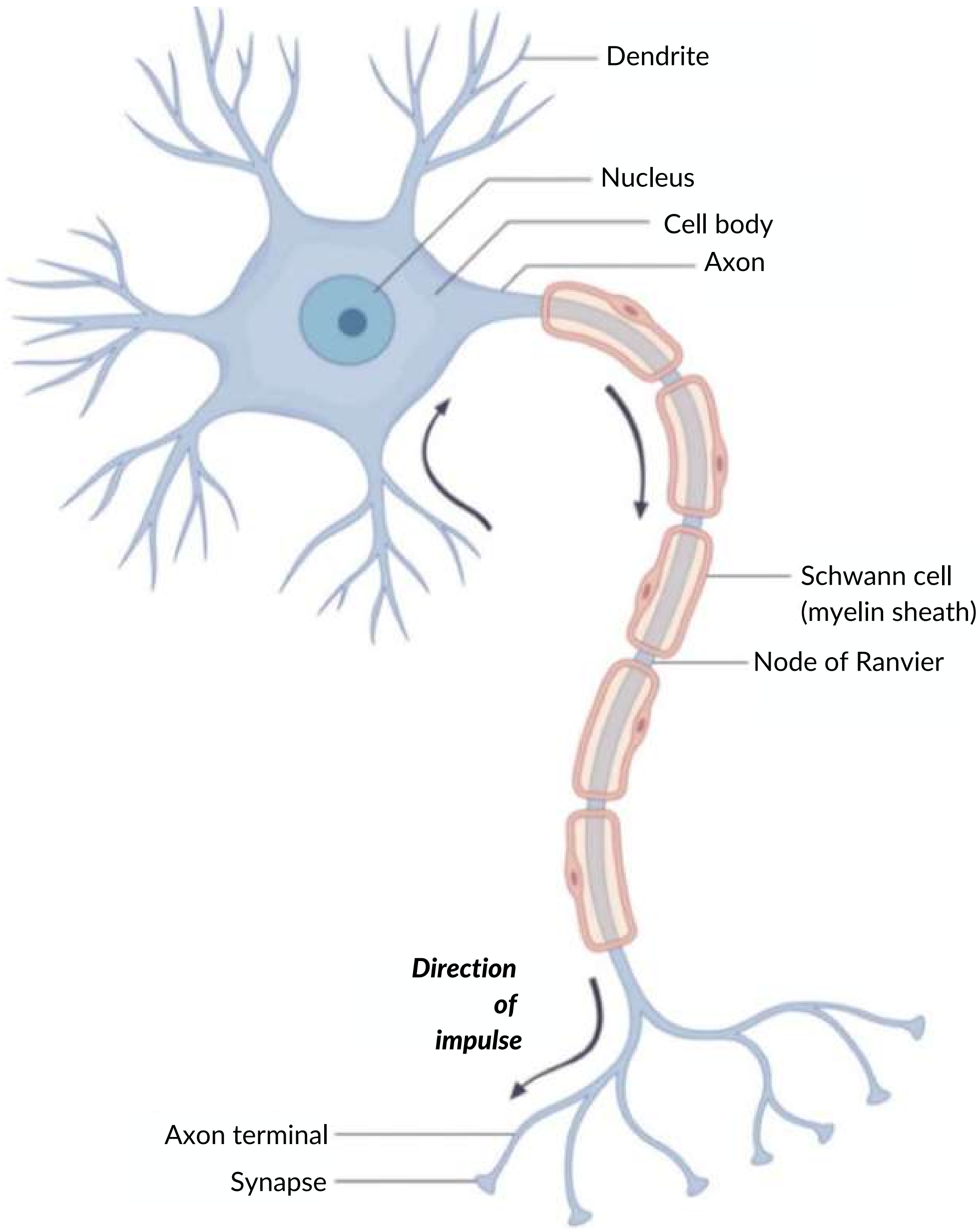
White matter is the tissue through which messages pass between different areas of grey matter within the central nervous system. The white matter is white because of the fatty substance (myelin) that surrounds the nerve fibres (axons).



The **ventral root** of the spinal nerve contains outgoing, efferent (meaning to "bear away from") fibres that carry information destined to control motor or glandular function. The cell bodies of these motor neurons are located in the ventral horns of the spinal cord's central grey region.

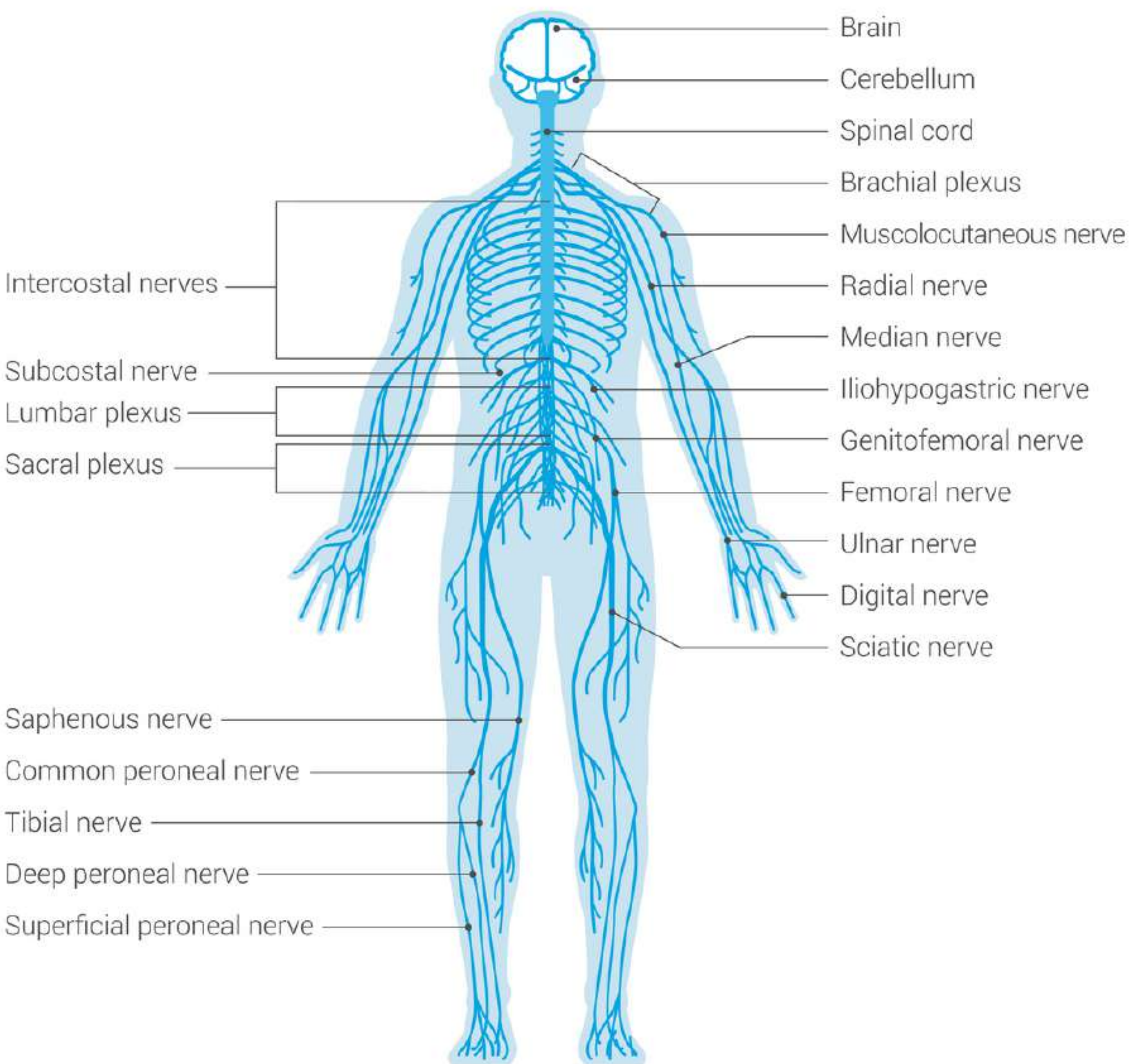
Grey matter is a major component of the central nervous system, consisting of neuronal cell bodies, neuropil (dendrites and unmyelinated axons), glial cells (astrocytes and oligodendrocytes), synapses, and capillaries.

Neuron Anatomy



Dendrites receive electrical impulses from upstream neurons across a special gap between neurons called a **synapse**. The electrical impulse (**action potential**) travels along the **axon** of the neuron, away from the cell body. Special cells called **Schwann cells** produce a white, fatty substance called **myelin**, which acts as an insulator. Schwann cells wrap around the axon to create a **myelin sheath**. Gaps between the Schwann cells called **Nodes of Ranvier** propagate the action potential - the electrical impulse "jumps" from node to node along the axon. The axon branches into **axon terminals** to create synapses (also called synaptic junctions) with dendrites of other downstream neurons. Neurons don't actually touch each other - action potentials are carried across synaptic junctions by special chemical messengers called **neurotransmitters**.

Peripheral Nervous System



The **peripheral nervous system** refers to parts of the nervous system outside the brain and spinal cord. It includes the **cranial nerves**, **spinal nerves** and their roots and branches, **peripheral nerves**, and **neuromuscular junctions**. In the peripheral nervous system, bundles of nerve fibres or axons conduct information to and from the central nervous system.

Autonomic Nervous System

The **autonomic** nervous system regulates certain body processes, such as blood pressure and the rate of breathing. This system works **automatically** (autonomously), without a person's conscious effort. Disorders of the autonomic nervous system can affect any body part or process. Autonomic disorders may be reversible or progressive.

Anatomy of the autonomic nervous system

The autonomic nervous system is the part of the nervous system that supplies the internal organs, including the blood vessels, stomach, intestine, liver, kidneys, bladder, genitals, lungs, pupils, heart, and sweat, salivary, and digestive glands.The autonomic nervous system has two main divisions:

- **Sympathetic**
- **Parasympathetic**

After the autonomic nervous system receives information about the body and external environment, it responds by stimulating body processes, usually through the sympathetic division, or inhibiting them, usually through the parasympathetic division. An autonomic nerve pathway involves two nerve cells. One cell is located in the brain stem or spinal cord. It is connected by nerve fibres to the other cell, which is located in a cluster of nerve cells (called an **autonomic ganglion**). Nerve fibres from these ganglia connect with internal organs. Most of the ganglia for the sympathetic division are located just outside the spinal cord on both sides of it. The ganglia for the parasympathetic division are located near or in the organs they connect with.

Function of the autonomic nervous system

The autonomic nervous system controls **internal body processes** such as the following:

- Blood pressure
- Heart and breathing rates
- Body temperature
- Digestion
- Metabolism (thus affecting body weight)
- The balance of water and electrolytes (such as sodium and calcium)
- The production of body fluids (saliva, sweat, and tears)
- Urination
- Defecation
- Sexual response

Many organs are controlled primarily by either the sympathetic or the parasympathetic division. Sometimes the two divisions have opposite effects on the same organ. For example, the sympathetic division increases blood pressure, and the parasympathetic division decreases it. Overall, the two divisions work together to ensure that the body responds appropriately to different situations.

Autonomic Nervous System

Generally, the sympathetic division does the following:

- **Prepares the body for stressful or emergency situations**—fight or flight

Thus, the sympathetic division increases heart rate and the force of heart contractions and widens (dilates) the airways to make breathing easier. It causes the body to release stored energy. Muscular strength is increased. This division also causes palms to sweat, pupils to dilate, and hair to stand on end. It slows body processes that are less important in emergencies, such as digestion and urination.

The parasympathetic division does the following:

- **Controls body process during ordinary situations.**

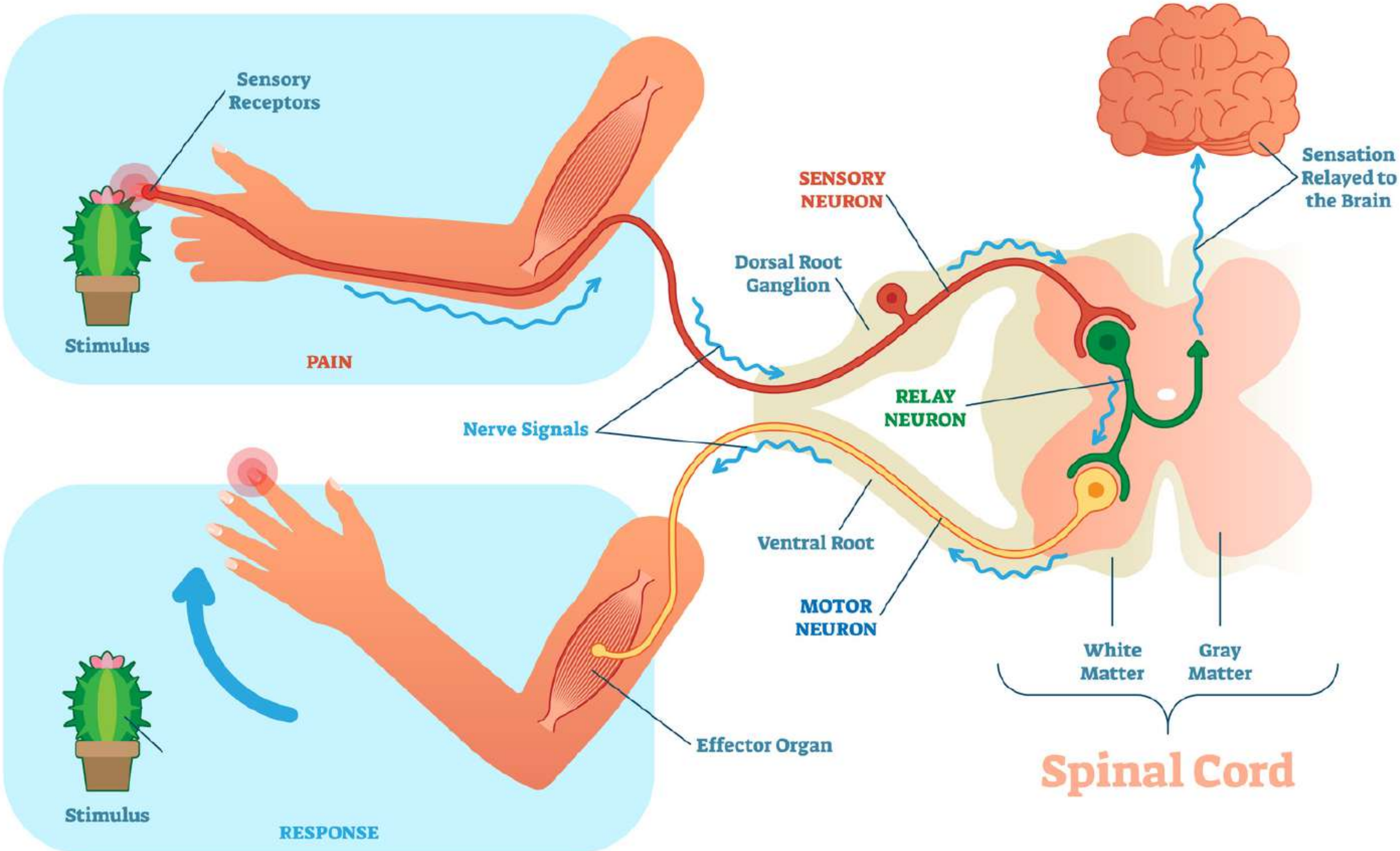
Generally, the parasympathetic division conserves and restores. It slows the heart rate and decreases blood pressure. It stimulates the digestive tract to process food and eliminate wastes. Energy from the processed food is used to restore and build tissues.
Both the sympathetic and parasympathetic divisions are involved in sexual activity, as are the parts of the nervous system that control voluntary actions and transmit sensation from the skin (somatic nervous system).

Two chemical messengers (neurotransmitters) are used to communicate within the autonomic nervous system:

- **Acetylcholine**
- **Norepinephrine**

Nerve fibres that secrete acetylcholine are called **cholinergic fiberes**. Fibres that secrete secrete norepinephrine are called **adrenergic fibres**. Generally, acetylcholine has parasympathetic (inhibiting) effects and norepinephrine has sympathetic (stimulating) effects. However, acetylcholine has some sympathetic effects. For example, it sometimes stimulates sweating or makes the hair stand on end.

Reflex Arc



Sensory Receptors
Stimulus
PAIN
SENSORY NEURON
Dorsal Root Ganglion
Sensation Relayed to the Brain
Nerve Signals
RELAY NEURON
Ventral Root
MOTOR NEURON
White Matter
Gray Matter
Spinal Cord
Effector Organ
Stimulus
RESPONSE

Reflex Arc

5 Parts of a Reflex Arc

First Part of a Reflex Arc: **Sensor**

Reflexes start in structures called **sensors**. These structures detect one kind of **energy** such as touch, stretch, heat, light, smell, and vibration. Some sensors are **neurons**, and they fire nerve impulses when stimulated. Other sensors are not neurons but can signal nearby sensory neurons when they detect their specific **stimuli**. All information about the world inside and outside your body has to be changed into **nerve impulses** before that information can be used by the circuits of your nervous system. When you tap your knee, you stretch the tendon that connects your quadriceps muscle to your tibia, the largest bone in your lower leg. Stretching the tendon stretches the muscle, and stretch sensors in the muscle detect this change. The stretch sensors are not neurons. They are special muscle cells that stimulate the sensory nerves to fire impulses.

Second Part of a Reflex Arc: **Sensory Neuron**

Each reflex has a **sensory neuron**. The sensor may be the nerve endings of the sensory neuron, or the sensor is another kind of cell that signals the sensory neuron. The sensory neuron begins a nerve impulse that travels to the **spinal cord** or the **brain**. Sensory neurons take messages to the spinal cord or brain from sensors in the eyes, ears, muscles, skin, and other body parts. The sensory neuron in the knee jerk reflex sends its messages to the spinal cord.

Third Part of a Reflex Arc: **Control Center**

In the spinal cord, the sensory neuron splits into at least three branches. Each branch forms a **synapse** with one of three different kinds of cells. In the case of the knee jerk reflex, one branch connects to a cell called an **interneuron**. The interneuron sends a message up the spinal cord to let the **cerebral cortex** know what is happening. Another branch goes to the **motor neuron** for the quadriceps muscle on the front of the thigh. The third branch goes to another interneuron that makes a connection to the motor neuron going to the biceps femoris muscle on the back of the thigh. Neurons in the brain and spinal cord control **reflexes** by receiving information and deciding if the stimulus is strong enough to command a **response**. Sometimes the neurons in the brain and spinal cord combine information from different sources. That is why you can sometimes hold back a reflex like a cough or keep your eyes open when the eye doctor asks you to, even though an instrument is close to your eye. Information from the cortex tells the controlling neuron in the reflex arc not to respond. The cerebral cortex is an important control centre. Messages come from your eyes, ears, skin, and muscles. These messages travel along sensory neurons to get to the **cortex**. The cortex processes all these messages in networks of interneurons that decide how to respond. In making these decisions, the cortex also uses information from memory. The cerebral cortex is not involved, however, in completing a simple reflex like the knee jerk reflex.

Reflex Arc

Fourth Part of a Reflex Arc: **Motor Neuron**

The fourth part of the knee jerk reflex arc is called the **output phase.** Three things happen at once during the output phase. The nerve impulse to the **motor neuron** travels out to the quadriceps. The nerve impulse is carried along an **interneuron** a short distance to the motor neuron for the biceps femoris muscle on the back of your leg. A message traveling along interneurons starts its long trip to the **cerebral cortex.**

Fifth Part of a Reflex Arc: **Muscle**

A message from a **motor neuron** tells your muscles to **contract**. In the knee jerk reflex, the muscle contracts when the nerve impulse reaches your quadriceps muscle. This muscle contraction should move your leg forward. But your leg won't move forward if the opposing biceps femoris muscle is also contracted. An **interneuron** tells the biceps motor neuron not to send nerve impulses to keep the biceps muscle relaxed. As the quadriceps muscle contracts, the biceps relaxes, and your leg moves forward. All these events occur before the message about what is happening arrives in your cortex. **Reflex arcs need an interneuron to turn off one reflex to make room for another.** An interneuron that turns off, or inhibits, a reflex is called an **inhibitory interneuron**. In the vomiting reflex, inhibitory interneurons keep you from breathing at the wrong time. Other inhibitory interneurons keep your hand from squeezing a hot grill, as muscles on the back of your hand contract to pull the hand away. Reflexes protect your body. Inhibitory interneurons help reflexes work the right way every time.

Nervous System & Other Organ Systems

Muscular System

- Receptors in muscles provide the brain with information about body position and movement.
- The brain controls the contraction of skeletal muscle.
- The nervous system regulates the speed at which food moves through the digestive tract.

Integumentary System

- Receptors in skin send sensory information to the brain.
- The autonomic nervous system regulates peripheral blood flow and sweat glands.
- Nerves control muscles connected to hair follicles.

Digestive System

- Digestive processes provide the building blocks for some neurotransmitters.
- The autonomic nervous system controls the tone of the digestive tract.
- The brain controls drinking and feeding behavior.
- The brain controls muscles for eating and elimination.
- The digestive system sends sensory information to the brain.

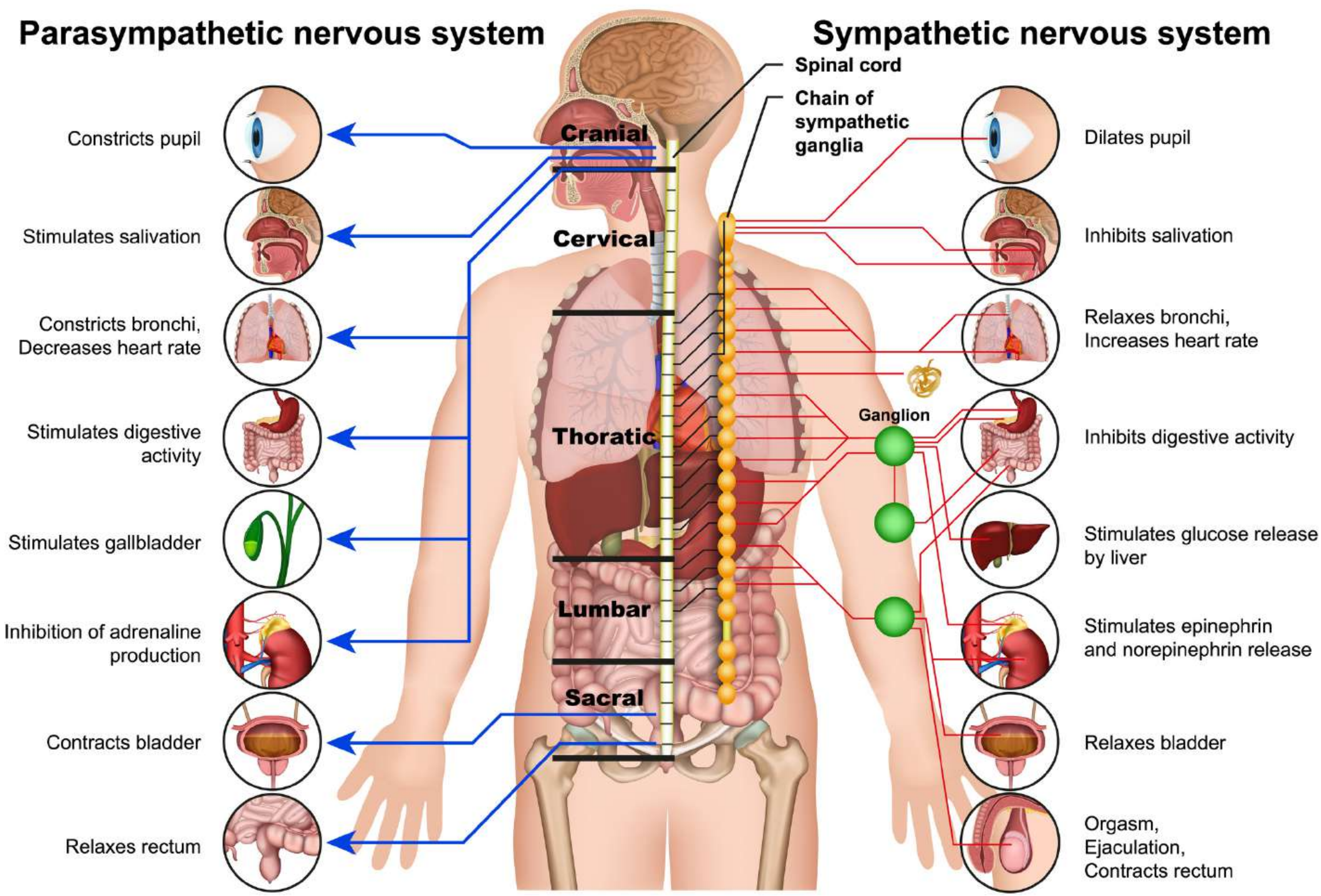
Cardiovascular System

- Endothelial cells maintain the blood-brain barrier.
- Baroreceptors send information to the brain about blood pressure.
- Cerebrospinal fluid drains into the venous blood supply.
- The brain regulates heart rate and blood pressure.

Endocrine System

- Hormones provide feedback to the brain to affect neural processing.
- Reproductive hormones affect the development of the nervous system.
- The hypothalamus controls the pituitary gland and other endocrine glands.

Nervous System & Homeostasis



Nervous System & Homeostasis

Of all the body systems, the nervous system is the major control system of **homeostasis**. It provides monitoring, response, and regulation of all systems in the human body and other organisms. It functions from the tiny level of individual cells to affecting the whole body at once. **Receptors** inside and outside the body are constantly monitoring conditions and watching for changes. When a body system leaves a set point and falls outside its normal range, signals are sent through the nervous system which trigger responses to bring the system back into the normal range of functioning. This is the process of homeostasis. These complicated and intricate processes have evolved over millions of years. For example, **thermoreceptors** and **mechanoreceptors** in the skin sense changes in temperature and pressure, respectively. Then, signals sent from them to the brain make it possible to detect situations that could cause injury or death. In addition, nerves make muscles contract which moves the bones of the skeleton, making it possible to evade predators and/or fight. This ability to perceive the environment and reacting to it is critical to maintaining homeostasis in the body.

Vision

The nervous system is intricately involved in visual perception which also helps maintain homeostasis. In humans, there is a thin layer of nervous tissue called the **retina** covering the rear of the inside of the eye. This tissue is populated with millions of **photoreceptor cell**s, **ganglion cells**, and **bipolar cells**. The cells detect light and transmit electrical information to the brain via the optic nerve which results in a visual picture. Pupil dilation is also controlled by the nervous system, optimizing the amount of light entering the eye for best vision. Vision allows animals to see and escape danger and find food and mates.

Core Temperature

The nervous system is also responsible for **regulating the core temperature** of the body. When conditions are too warm and body temperature rises, the blood vessels dilate causing heat loss to the environment. Nerves trigger sweat glands to release fluid that evaporates and cools the skin. Conversely, a drop in core temperature makes blood vessels constrict to conserve heat. The nervous system also triggers muscles to shiver to generate heat and warm the body.

The Autonomic Nervous System

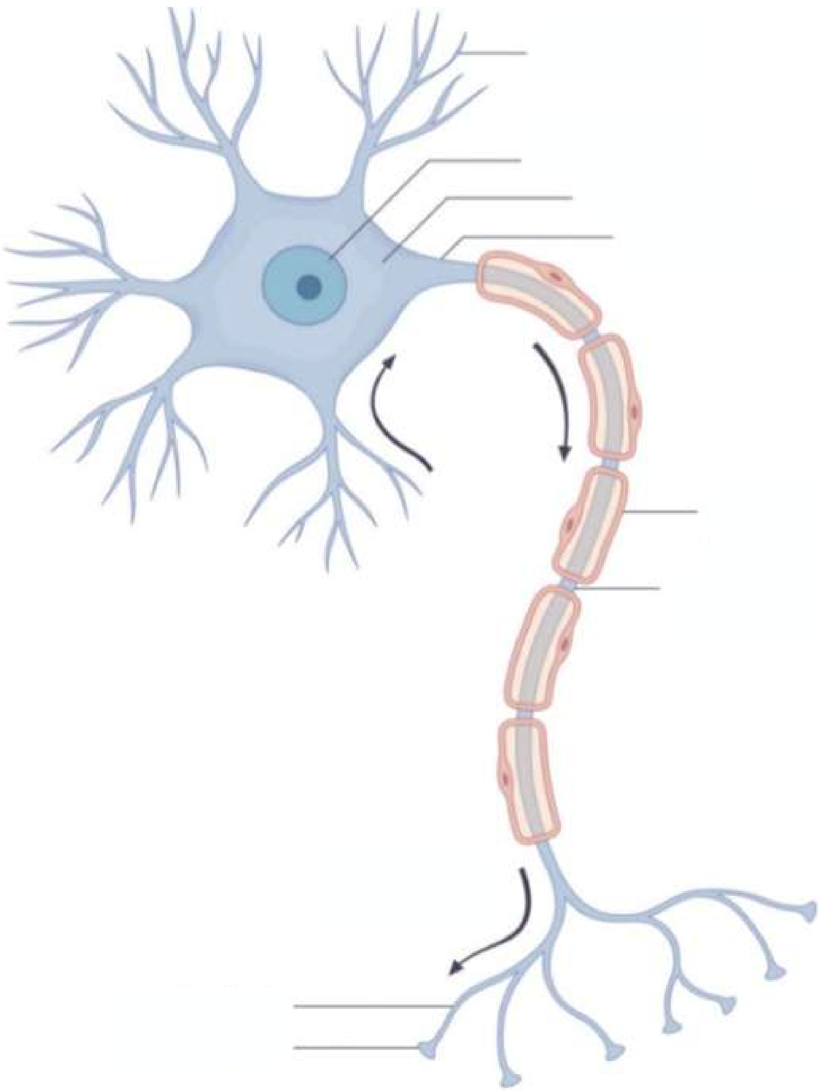
The autonomic nervous system is comprised on the **sympathetic** and **parasympathetic** nervous systems which both have critical homeostatic functions. The sympathetic system innervates the heart and increases heart rate and the force of its contractions. It also controls the constriction of blood vessels and dilation of bronchioles in the lungs. The parasympathetic system has the opposite effects on the heart and lungs but is has no effect on blood vessels.

Review Break

- What is one way the nervous system maintains homeostasis within the body?
- What is one way the nervous system interacts with other body systems?
- Name the major components of the nervous, and describe how neurons conduct electrical impulses (action potentials).

QUIZ!

Without looking back through the workbook label the diagram below and describe how neurons transmit action potentials



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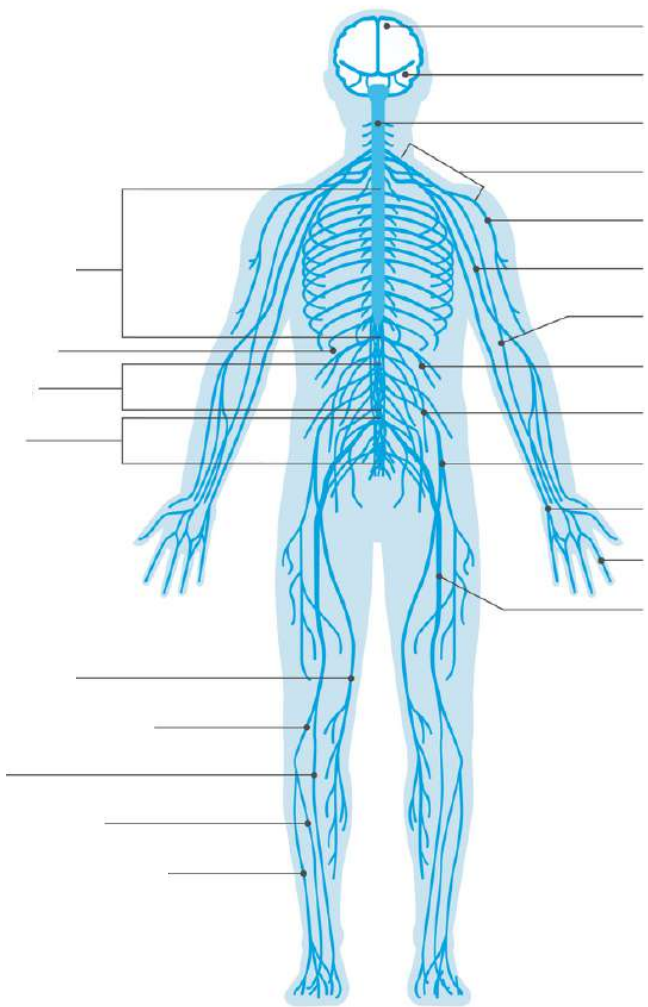

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