The Anatomy and Physiology of the Nervous System

CHAPTER 1

INTRODUCTION

The nervous system is one of the most intricate and essential systems in the human body. It plays a central role in regulating and coordinating bodily functions, processing sensory input and enabling communication between different regions of the body. A thorough understanding of its structure and function is fundamental for recognising normal physiological processes, identifying neurological dysfunction and delivering safe, person-centred care.

This chapter provides an overview of the nervous system, focusing on its two main divisions: the central nervous system and the peripheral nervous system. It explores how these components contribute to maintaining homeostasis and support crucial bodily functions such as movement, sensation, cognition and autonomic regulation. The chapter also examines the mechanisms of neural communication, the role of reflexes in protection and how the brain and spinal cord interpret and respond to both internal and external stimuli.

For those providing care to individuals with neurological conditions or injuries, a solid foundation in the anatomy and physiology of the nervous system is vital. This knowledge supports accurate assessment and informed clinical decision-making (McErlean and Migliozzi 2025).

Given the nervous system's complexity and its interaction with all other body systems, it is necessary to divide it into smaller anatomical and functional units for study. This chapter outlines these divisions, explores the structure and function of the nervous system and highlights its influence on other systems. In recognition of its critical role in maintaining homeostasis, the chapter also examines the protective mechanisms that safeguard the nervous system.

CENTRAL AND PERIPHERAL NERVOUS SYSTEMS

The nervous system is organised into two main components: the central nervous system and the peripheral nervous system. The central nervous system, which comprises the brain and spinal cord, serves as the primary control centre, responsible for processing information and coordinating many of the body's activities.

The peripheral nervous system connects the central nervous system to the rest of the body. It is responsible for transmitting sensory information from the body to the central nervous system and carrying motor commands from the central nervous system to muscles and glands. Understanding the direction in which information flows within the nervous system is essential, and this is illustrated in Figure 1.1.

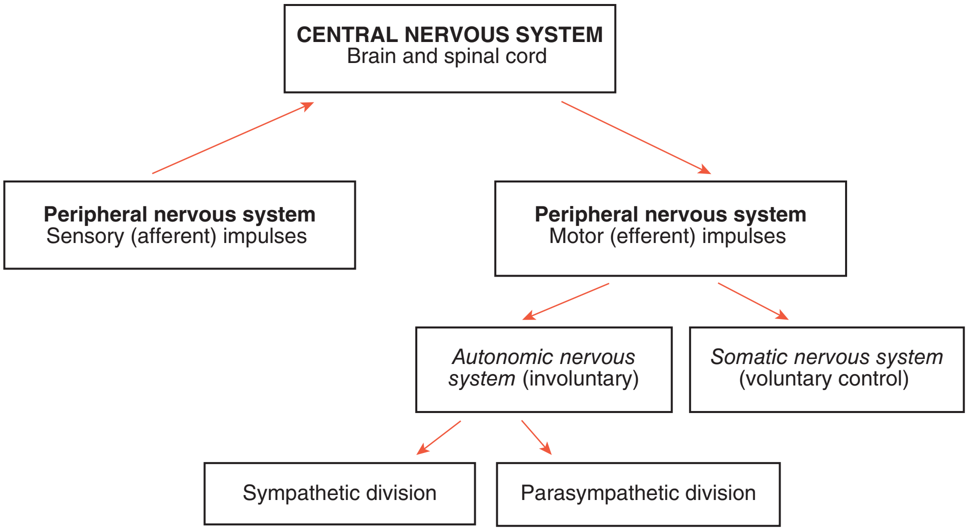

FIGURE 1.1 Organisation of the nervous system

THE BRAIN AND NERVES

THE BRAIN

The brain is one of the largest and most complex organs in the human body. It plays a central role in processing sensory information, initiating voluntary movements, regulating behaviour and serving as the centre for learning and memory.

Weighing approximately 1400 g, the brain is housed within the protective bony structure of the cranium (skull) and is surrounded by cerebrospinal fluid, which cushions and supports it. As the source of thought, emotion, memory and consciousness, the brain defines much of what makes us human (Figure 1.2).

The brain receives around 15% of the body's cardiac output and maintains a consistent blood supply through autoregulation, even when body position changes. The cerebral cortex, an outer layer of folded neural tissue, is particularly well developed, especially in the frontal lobes, which are responsible for executive functions such as decision-making, planning, reasoning and self-control.

THE MENINGES

Due to the fragile nature of nervous tissue, the brain and spinal cord are safeguarded by several protective structures. Externally, the hair, skin and bony cranium provide a first line of defence against physical trauma (see Figure 1.3). Beneath these external barriers lie the meninges, three specialised connective tissue layers that envelop the brain and spinal cord, offering both mechanical protection and structural support. The meninges consist of three distinct layers:

1. The dura mater is the outermost and toughest layer. It forms a durable protective sheath around the central nervous system and is closely attached to the inner surface of the skull.

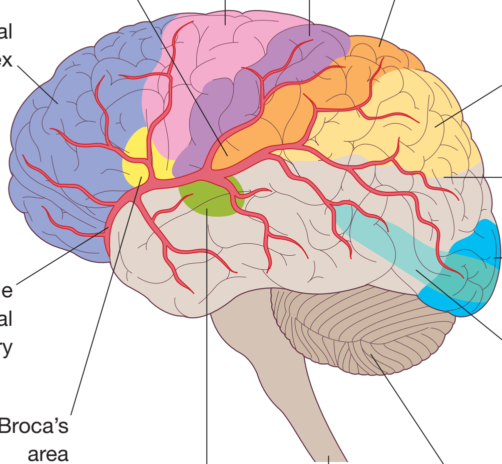

FIGURE 1.2 The brain

In the spinal canal, the dura mater creates a protective sac for the spinal cord and contributes to the epidural space, which is clinically important for procedures such as epidural anaesthesia.

2. The arachnoid mater lies beneath the dura mater. It is a thin, web-like membrane that bridges the space between the dura mater and pia mater. The area beneath the arachnoid, known as the subarachnoid space, contains cerebrospinal fluid, which cushions the brain and spinal cord and helps to absorb shock.
3. The pia mater is the innermost layer, which is thin and delicate. It adheres closely to the contours of the brain and spinal cord, following their folds (gyri) and grooves (sulci). The pia mater also supports an extensive network of blood vessels that penetrate the brain and spinal cord to supply oxygen and nutrients.

In addition to their protective role, the meninges play a key part in maintaining the homeostasis of the central nervous system. They help regulate the movement of cerebrospinal fluid, support venous drainage via dural venous sinuses and form part of the blood–brain barrier. Clinically, inflammation of the meninges, known as meningitis, can be life-threatening and requires prompt recognition and treatment.

Understanding the structure and function of the meninges is essential, particularly when interpreting neurological symptoms or undertaking procedures that involve the central nervous system, such as lumbar punctures or intrathecal drug delivery.

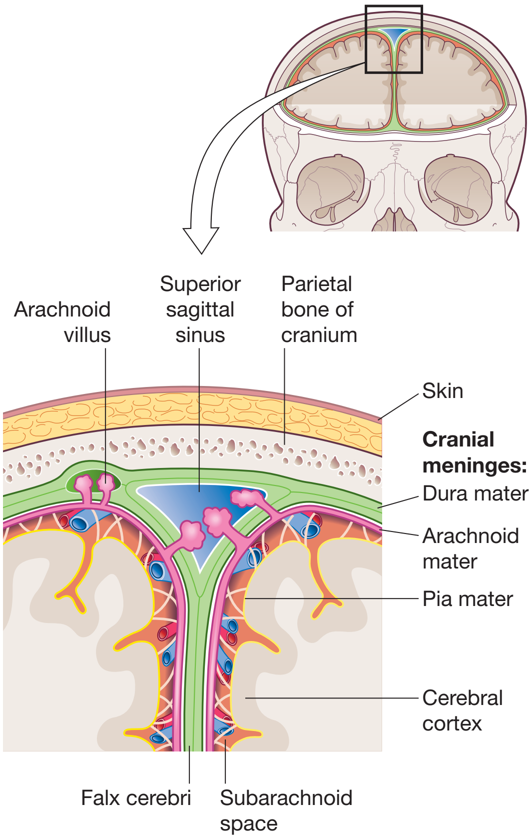

FIGURE 1.3 The brain and protective structures. *Source*: Peate and Nair (2014). With permission of John Wiley & Sons.

CEREBROSPINAL FLUID

Cerebrospinal fluid is a clear, colourless liquid that surrounds and bathes the brain and spinal cord, playing a critical role in protecting and supporting the central nervous system. It is primarily produced by specialised tissue called the choroid plexus, located within the ventricular system of the brain, specifically in the lateral, third and fourth ventricles.

Cerebrospinal fluid circulates through the ventricles, flows into the subarachnoid space surrounding the brain and spinal cord, and is eventually reabsorbed into the bloodstream via the arachnoid villi, located in the superior sagittal sinus. This process of production, circulation and reabsorption maintains intracranial pressure within a narrow range, which is essential for normal brain function. The functions of cerebrospinal fluid are both protective and regulatory:

- It acts as a cushion, absorbing mechanical shocks that might otherwise damage delicate nervous tissue in response to trauma or sudden movement.
- It helps to maintain a stable environment by regulating the distribution of pressure between different regions of the brain and spinal cord.
- Cerebrospinal fluid facilitates the transport of nutrients and the removal of waste products, contributing to overall central nervous system homeostasis.

- It also reduces the effective weight of the brain, allowing it to float within the skull and preventing it from compressing the cranial nerves or blood vessels beneath it.

Disruptions to the production, flow or absorption of cerebrospinal fluid can lead to serious clinical conditions. Hydrocephalus, for example, is a condition characterised by an abnormal accumulation of cerebrospinal fluid, leading to increased intracranial pressure, which may require surgical intervention such as the insertion of a ventriculoperitoneal shunt (Woodward 2024).

A clear understanding of cerebrospinal fluid dynamics is essential for healthcare students, especially when considering procedures such as lumbar puncture, which involves the sampling of cerebrospinal fluid for diagnostic purposes, including the identification of infections such as meningitis or conditions such as subarachnoid haemorrhage (McErlean and Migliozzi 2025).

THE NEURONE

The neurone is the fundamental building block of the nervous system. It is a highly specialised cell designed to transmit and process electrical and chemical signals throughout the body. While neurones share many features with other cells, such as the nucleus, cytoplasm and energy-producing mitochondria, they are uniquely adapted for communication and coordination within the nervous system. Each neurone has three main parts (see Figure 1.4):

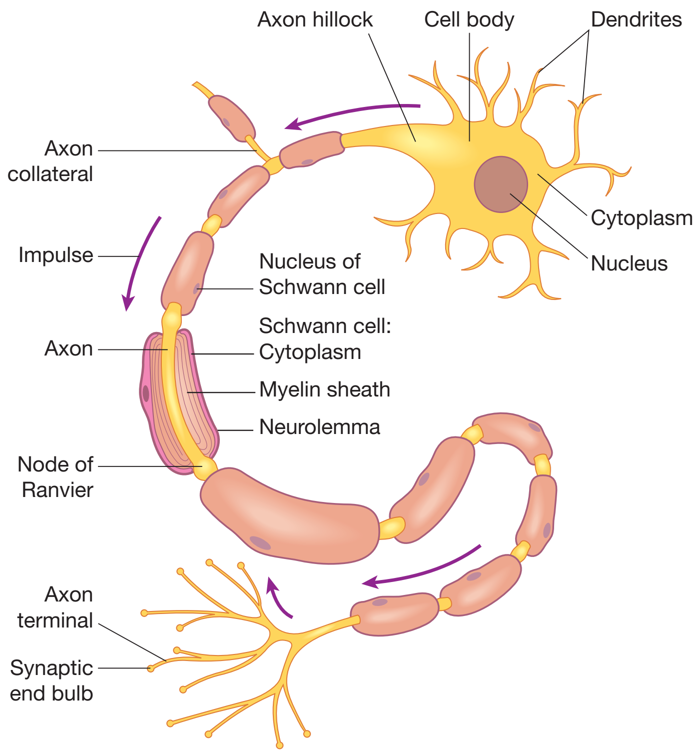

FIGURE 1.4 A neurone. *Source*: Peate and Nair (2014). With permission of John Wiley & Sons.

1. Dendrites: These are short, branch-like extensions that act as the neurone's receivers. They collect information from other nerve cells or from sensory receptors in the body (such as those in the skin, eyes or ears). Dendrites provide a large surface area to efficiently gather incoming signals.
2. Cell body (soma): This is the central part of the neurone that contains the nucleus and most of the cell's organelles. The cell body integrates the incoming information and decides whether to pass the message along.
3. Axon: This is a long, slender projection that carries electrical impulses away from the cell body. Each neurone has only one axon, but it can branch at its end to communicate with multiple other cells. Axons may be very short (less than a millimetre) or over a metre long in some cases, such as those that run from the spinal cord to the foot.

Neurones are structured to conduct electrical impulses in one direction only:

- Signals are received by the dendrites
- Processed in the cell body
- And then transmitted along the axon to the next cell, which may be another neurone, a muscle cell or a gland

At the end of the axon are axon terminals, which are specialised structures that release chemical messengers (neurotransmitters) across a gap known as the synapse. These messengers pass the signal to the next cell, continuing the chain of communication.

This one-way flow of information helps maintain orderly and efficient signalling, which is essential for everything from simple reflexes to complex thought processes.

Understanding how neurones work is vital, as many neurological conditions, including multiple sclerosis, motor neurone disease and stroke, are caused by damage to neurones or their supporting structures. Gaining insight into the anatomy and function of the neurone provides a strong foundation for recognising signs of nervous system dysfunction in clinical practice.

AXON

A neurone has one axon, though it may branch to form axon collaterals. Near the axon's end, it divides into multiple terminals that allow communication with other neurones or target tissues (see Figure 1.4). Axons vary in length, from a few millimetres to over a metre and are usually thicker and longer than dendrites. The axon hillock is the slightly widened region where the axon connects to the cell body, and it is the site where incoming signals are gathered and assessed to determine whether an electrical impulse should be generated. If the input is strong enough, an action potential is generated and travels along the axon.

DENDRITES

Dendrites are thin, branching extensions of the neurone that receive incoming signals. They become progressively narrower the farther they extend from the cell body. Dendritic spines, small outgrowths on dendrites, increase the surface area for synaptic input. In sensory neurones, dendrites may be part of sensory receptors, while in motor neurones, they contribute to synapses with other neurones (see Figure 1.4).

CELL BODY

The cell body (soma) houses the neurone's nucleus and is the site of most protein synthesis (see Figure 1.4). Cell bodies vary in size and are generally located within the central nervous system, forming part of the grey matter. In the central nervous system, clusters of cell bodies are referred to as nuclei, whereas in the peripheral nervous system, they are called ganglia.

MYELIN SHEATH

The myelin sheath is a protective, insulating layer that wraps around some axons, increasing the speed of electrical impulse transmission. In the central nervous system, oligodendrocytes produce myelin, while in the peripheral nervous system, Schwann cells perform this role. In the peripheral nervous system, Schwann cells wrap around the axon, forming a multi-layered sheath. The outermost layer is called the neurilemma. Gaps between adjacent Schwann cells are known as the nodes of Ranvier, which facilitate rapid conduction of nerve impulses (see Figure 1.4). Not all nerve fibres are myelinated; unmyelinated axons conduct impulses more slowly.

CRANIAL NERVES

There are 12 pairs of cranial nerves, which emerge directly from the brain and brainstem, rather than the spinal cord. These nerves pass through openings in the skull to reach their target structures and primarily serve the head and neck, although a few have functions that extend to areas such as the thorax and abdomen (see Figure 1.5).

Cranial nerves are classified based on their function into:

- Sensory nerves, which carry information such as smell, vision, taste and hearing to the brain.
- Motor nerves, which control the movement of muscles involved in facial expressions, eye movement, swallowing and speech.
- Mixed nerves, which carry both sensory and motor fibres, allowing them to both receive and send signals.

Each cranial nerve has a specific name and number (I–XII), based on its position from front (anterior) to back (posterior) of the brain. For example:

- Olfactory nerve (CN I) is responsible for the sense of smell.
- Optic nerve (CN II) carries visual information from the eyes to the brain.
- Vagus nerve (CN X) is a mixed nerve that controls functions such as heart rate, digestion and reflexes such as coughing and swallowing.

These nerves play a crucial role in sensory perception, voluntary movement and autonomic regulation. Because they are so closely involved with vital functions such as breathing, heart rate and digestion, any injury or dysfunction affecting the cranial nerves can have serious clinical consequences.

Table 1.1 outlines the 12 cranial nerves, their names, primary functions and whether they are sensory, motor or both.

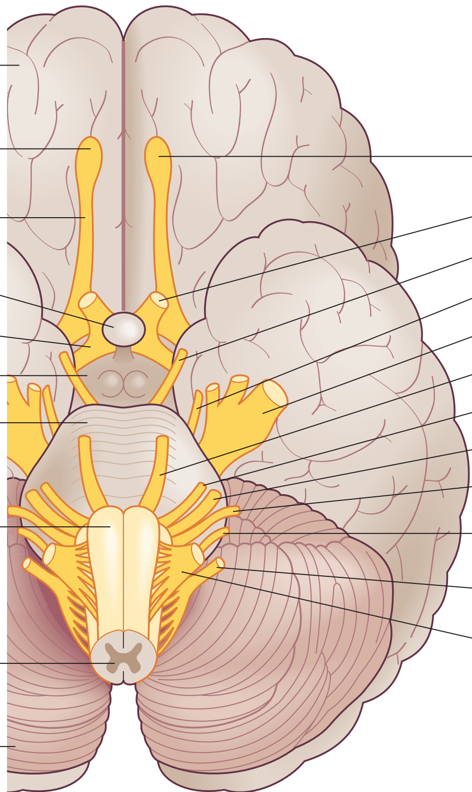

FIGURE 1.5 The cranial nerves. *Source*: Peate and Nair (2014). With permission of John Wiley & Sons.

Table 1.1 The cranial nerves

Number	Name	Primary function(s)	Type
I	Olfactory	Smell	Sensory
II	Optic	Vision	Sensory
III	Oculomotor	Eye movement, pupil constriction, eyelid elevation	Motor
IV	Trochlear	Eye movement (superior oblique muscle)	Motor
V	Trigeminal	Facial sensation, chewing muscles	Both
VI	Abducens	Eye movement (lateral rectus muscle)	Motor
VII	Facial	Facial expression, taste (anterior tongue), salivation, tears	Both
VIII	Vestibulocochlear	Hearing and balance	Sensory
IX	Glossopharyngeal	Taste (posterior tongue), swallowing, salivation	Both
X	Vagus	Autonomic control of heart, lungs, digestion, speech, taste	Both

Number	Name	Primary function(s)	Type
XI	Accessory (spinal)	Shoulder and neck movement (trapezius and sternocleidomastoid)	Motor
XII	Hypoglossal	Tongue movement	Motor

In clinical practice, cranial nerve assessment is a key part of a neurological examination, helping to identify issues such as nerve damage, brain injury or neurological disorders such as multiple sclerosis or stroke. Understanding the anatomy and function of the cranial nerves is therefore essential for recognising signs of neurological dysfunction and providing appropriate care.

STRUCTURES OF THE BRAIN

The brain is the control centre of the body. It allows us to think, feel, move and carry out essential functions such as breathing and maintaining a heartbeat. This section of the chapter considers the main parts of the brain and what they do. It also explains how the brain is supported by fluid-filled spaces and protective systems that help it work effectively and stay safe.

The brain is made up of four main regions:

1. The cerebrum
2. The diencephalon
3. The brainstem
4. The cerebellum

Each of these areas has a distinct structure and function, working together to control everything from thought and movement to vital bodily processes.

CEREBRUM

The cerebrum (also called the telencephalon) is the largest part of the brain, making up about two-thirds of its total mass. It sits above most other brain structures and rests on the brainstem, with the cerebellum located underneath its back portion (see Figure 1.6).

The cerebrum is split into two halves called the left and right hemispheres. The outer surface of these hemispheres is highly folded and is covered by a thin layer of grey matter that is known as the cerebral cortex. This part of the brain handles many complex functions, such as:

- Voluntary muscle control
- Memory storage and processing
- Speech production
- Interpretation of taste, sound and vision

DIENCEPHALON

The diencephalon lies deep within the brain and connects the cerebrum to the brainstem and spinal cord (see Figure 1.6). It contains three main structures:

- Thalamus
  Acts as a relay station, directing sensory information to the cerebral cortex and managing motor signals. It also has a role in memory processing.
- Hypothalamus
  This small but vital area regulates many automatic (autonomic) body functions, such as hunger, thirst and body temperature. It produces two important hormones: antidiuretic hormone (ADH) and oxytocin. The hypothalamus is also part of the limbic system, which is linked to emotions.
- Epithalamus
  Includes the pineal gland, which produces the hormone melatonin. This hormone helps control sleep and wake cycles.

BRAINSTEM

The brainstem connects the brain to the spinal cord and is responsible for many essential life functions, such as breathing, heart rate and blood pressure (see Figure 1.6). It also serves as a pathway for messages between the brain and body and is closely associated with the cranial nerves. The brainstem is made up of the following parts:

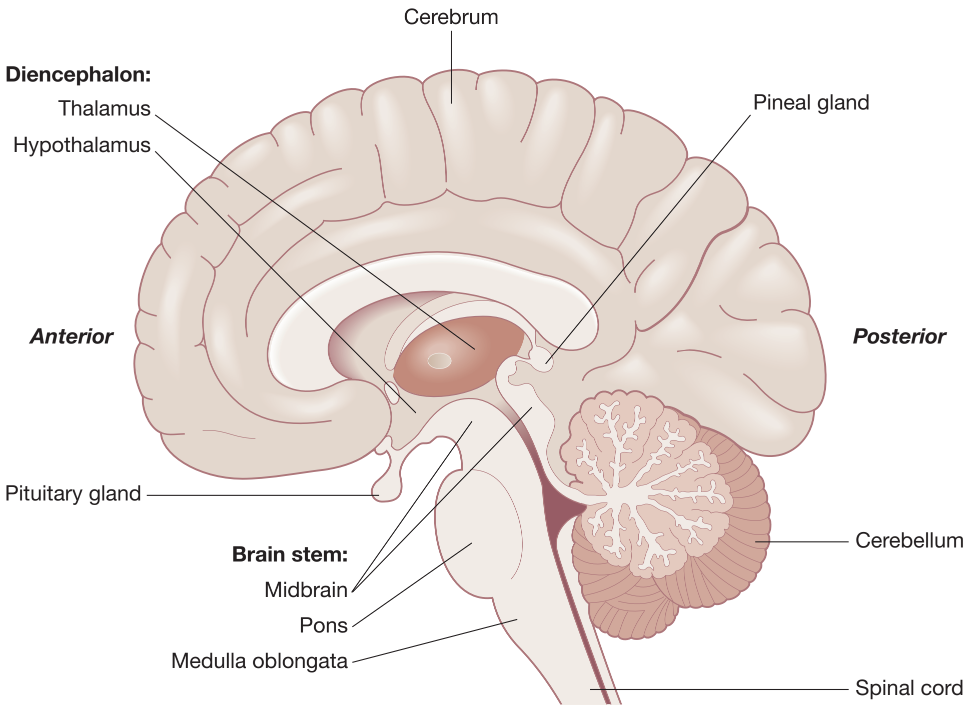

FIGURE 1.6 The cerebrum. *Source*: Peate and Nair (2014). With permission of John Wiley & Sons.

MIDBRAIN

Processes visual and auditory information and is involved in reflexes (see Figure 1.6). It also plays a role in maintaining alertness.

PONS

Connects the cerebellum with the rest of the brain and helps control breathing in partnership with the medulla (see Figure 1.6). It also supports both voluntary and involuntary motor control.

MEDULLA OBLONGATA

The medulla oblongata, part of the brainstem, is vital for controlling the body's automatic functions that are essential for survival. It regulates heart rate, breathing and blood pressure, and houses centres responsible for reflex actions such as coughing, sneezing, swallowing and vomiting. The medulla is also where most nerve fibres from the brain cross over to the opposite side of the body, a process called decussation. This means that the left side of the brain controls the right side of the body and the right side of the brain controls the left. The medulla oblongata acts as a critical relay point, connecting the brain with the spinal cord and ensuring smooth communication between them.

CEREBELLUM

Located underneath the back part of the cerebrum, the cerebellum is the second-largest part of the brain (see Figure 1.7). It helps coordinate voluntary movements such as walking and writing, and it also contributes to:

- Balance
- Posture

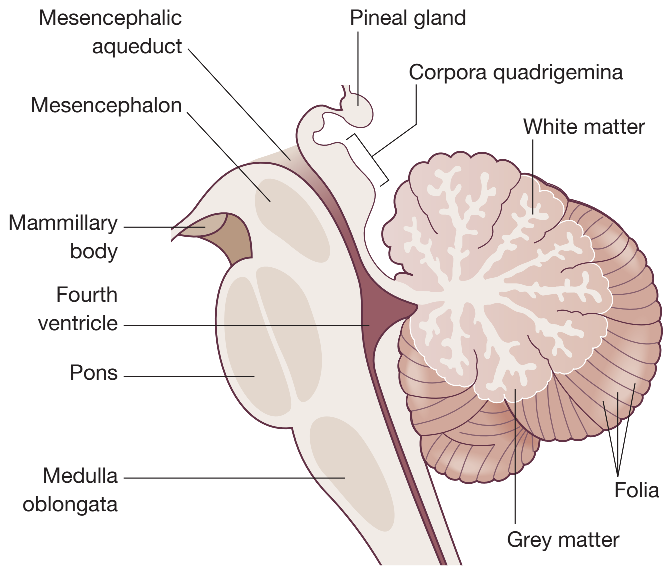

FIGURE 1.7 The cerebellum

- Motor learning
- Fine-tuning of movement

Although the cerebellum makes up only 10% of the brain's volume, it contains more than half of all neurones in the brain. It does not start movements, but it ensures they are smooth and precise.

LIMBIC SYSTEM

The limbic system is a group of interconnected structures beneath the cerebral cortex (see Figure 1.8). It includes the hippocampus, amygdala, thalamic nuclei, septum, fornix and other areas. This system plays a key role in the following:

- Emotions
- Behaviour
- Motivation
- Long-term memory
- Sense of smell

The limbic system also influences the autonomic nervous system and hormone release via the hypothalamus.

VENTRICLES OF THE BRAIN

The brain contains a series of hollow, fluid-filled spaces that are called ventricles, which form a connected network (see Figure 1.9). These include the following:

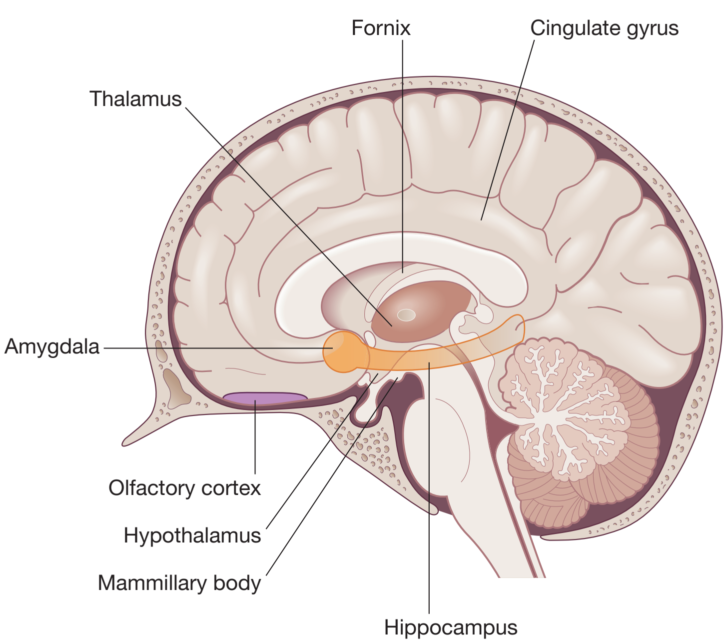

FIGURE 1.8 The limbic system

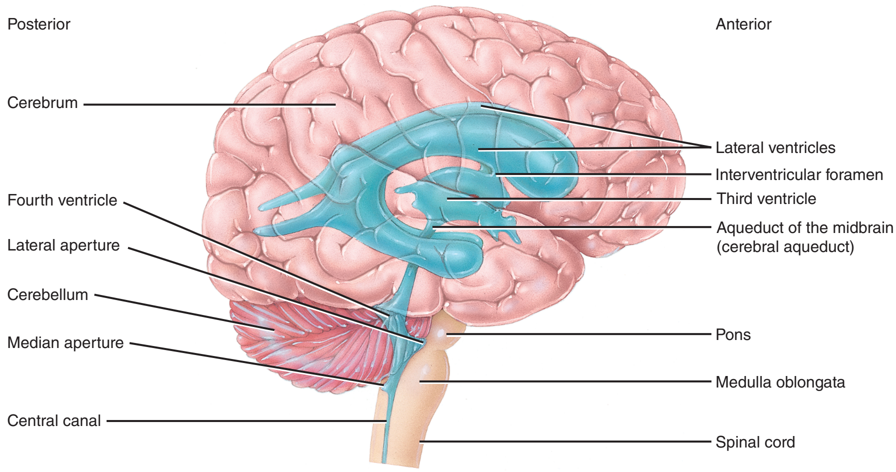

FIGURE 1.9 The ventricles. *Source*: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

- Two lateral ventricles
- The third ventricle
- The cerebral aqueduct
- The fourth ventricle

The ventricles are filled with cerebrospinal fluid, which is made by the choroid plexus found in most parts of the ventricular system.

CEREBROSPINAL FLUID: ROLES AND CIRCULATION

Cerebrospinal fluid is produced in the ventricles, circulates through the brain and spinal cord, and is reabsorbed into the bloodstream via the arachnoid villi. Approximately 150 mL of CSF is in circulation at any one time, and it is fully replaced every eight hours. CSF flows from the lateral ventricles to the third ventricle via the interventricular foramen (of Monro), through the cerebral aqueduct (of Sylvius) to the fourth ventricle and then into the subarachnoid space via the foramina of Luschka and Magendie. The arachnoid villi act as one-way valves, allowing CSF to enter the venous system only when CSF pressure exceeds venous pressure. This mechanism helps maintain stable intracranial pressure, prevents backflow and contamination from the bloodstream, and supports efficient removal of waste products, thereby protecting the central nervous system (Braine 2024).

THE SPINAL CORD

The spinal cord is a vital component of the central nervous system, serving as the main communication pathway between the brain and the body. In adults, it measures approximately 45 cm in length and 14 mm in width (Adigun et al. 2023; see Figure 1.10). It extends from the foramen magnum at the base of the skull, where it is continuous with the medulla oblongata, down to the level of the first lumbar vertebra. Enclosed within the vertebral canal, the spinal cord is protected by surrounding bone, meninges and cerebrospinal fluid.

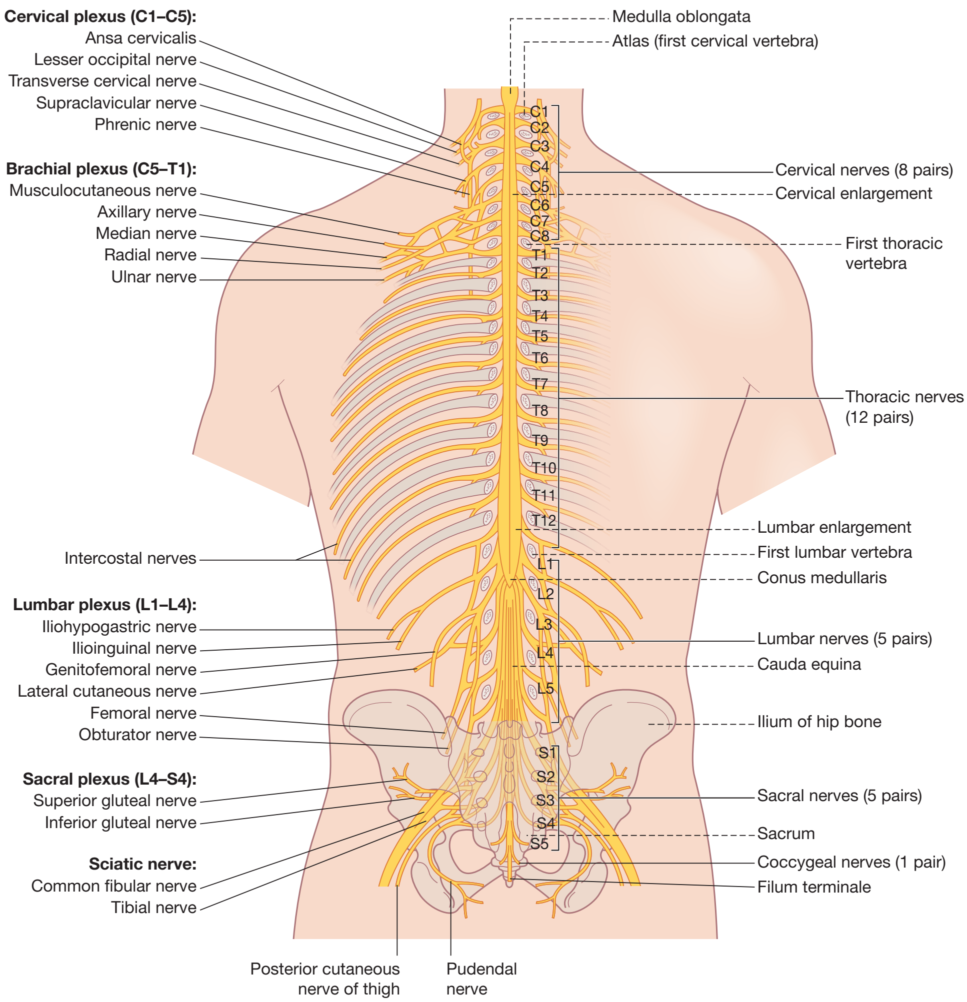

FIGURE 1.10 Spinal cord and spinal nerves. *Source*: Peate and Nair (2014). With permission of John Wiley & Sons.

Structurally, the spinal cord consists of two main types of tissue: an outer layer of white matter, which contains ascending and descending nerve tracts, and an inner core of grey matter that is shaped like a butterfly, which contains neuronal cell bodies. The grey matter surrounds the central canal, which carries cerebrospinal fluid and contributes to nutrient and waste exchange.

PROTECTIVE COVERINGS

Like the brain, the spinal cord is enveloped by three layers of protective membranes known as the spinal meninges (see Figure 1.11).

ORGANISATION AND BLOOD SUPPLY

The spinal cord is divided into 31 segments, each giving rise to a pair of right and left spinal nerves, which contain both motor and sensory fibres. At each level, nerve rootlets merge to

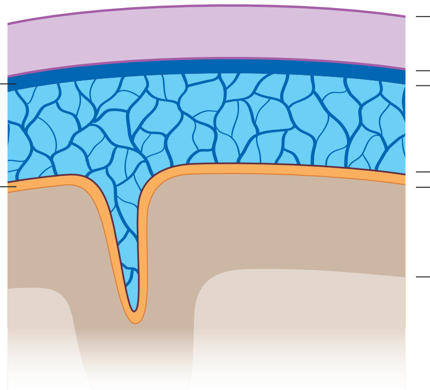

FIGURE 1.11 The meninges, the membranes surrounding the brain and spinal cord

form nerve roots, which then combine into spinal nerves. Associated with each segment are dorsal root ganglia, which house the cell bodies of sensory neurones whose axons enter the spinal cord via the dorsal roots.

The spinal cord receives its blood supply from three longitudinal arteries, one anterior spinal artery and two posterior spinal arteries, originating from the brain. These arteries travel through the subarachnoid space and give rise to smaller branches that penetrate the spinal cord to provide oxygen and nutrients.

FUNCTIONS OF THE SPINAL CORD

The spinal cord performs essential functions for communication and coordination within the body. It:

- Transmits sensory information from peripheral receptors to the brain and relays motor commands from the brain to the body through white matter tracts.
- Integrates reflex responses via grey matter, enabling the body to react quickly and automatically to specific stimuli without needing input from the brain.

REFLEX ACTIONS AND THE REFLEX ARC

A key function of the spinal cord is the mediation of reflexes, which are rapid, involuntary responses to stimuli that help protect the body from harm. For example, quickly withdrawing your hand from a hot surface is a spinal reflex. These actions occur via a reflex arc, a neural pathway that includes:

- A sensory receptor
- An afferent (sensory) neurone
- The spinal cord (including an interneurone)

- An efferent (motor) neurone
- An effector (usually a muscle or gland)

Reflex arcs allow for immediate responses, often bypassing conscious brain involvement.

SPINAL NERVES

There are 31 pairs of spinal nerves, each named according to the region of the vertebral column from which they emerge (e.g. cervical, thoracic, lumbar) (see Figure 1.10). These nerves are mixed nerves, containing both sensory (posterior root) and motor (anterior root) fibres. Each nerve innervates a specific myotome (group of muscles) and dermatome (region of skin), and many also supply internal organs.

Spinal nerves act as critical communication lines between the central nervous system and the body's peripheries, linking sensory receptors, muscles and glands. They play a vital role in movement, sensation and autonomic regulation.

THE BLOOD SUPPLY

The brain is a highly active organ that requires a constant and well-regulated supply of oxygen and nutrients to function effectively. Despite accounting for only about 2% of total body weight, the brain consumes approximately 20% of the body's oxygen and glucose at rest (Balasubramanian 2021). This intense metabolic demand makes it particularly sensitive to interruptions in blood flow. The brain's blood supply is delivered through a complex network of arteries, including the internal carotid and vertebral arteries, which converge at the base of the brain to form the Circle of Willis. This system provides vital redundancy, ensuring continued perfusion even if one route becomes compromised. Understanding the vascular anatomy of the brain is essential for recognising how conditions such as stroke, aneurysm or trauma can disrupt neurological function.

THE CIRCLE OF WILLIS AND THE BLOOD–BRAIN BARRIER

The Circle of Willis is a vital circulatory structure located at the base of the brain (see Figure 1.12). It is an arterial ring formed through the anastomosis or connection of several key arteries. This arterial circle acts as a junction between the brain's anterior (front) and posterior (back) circulations, helping to maintain consistent blood flow to the brain even if one part of the vascular supply becomes narrowed or blocked.

The Circle of Willis is one of the body's most important vascular safety mechanisms. The Circle of Willis encircles the stalk of the pituitary gland and connects the arterial supply of the forebrain and hindbrain. It is formed by the joining of several arteries:

- Anteriorly, the internal carotid arteries enter the cranial cavity and each divides into an anterior cerebral artery and a middle cerebral artery. The two anterior cerebral arteries are then joined by a short vessel known as the anterior communicating artery, completing the front portion of the circle.
- Posteriorly, the basilar artery, which is formed by the union of the left and right vertebral arteries, divides into the posterior cerebral arteries. These posterior cerebral arteries are linked to the anterior circulation by the posterior communicating arteries, thereby completing the ring.

This anatomical configuration allows for collateral circulation, meaning that if one artery is compromised, then blood can still reach the brain through alternative routes. The brain

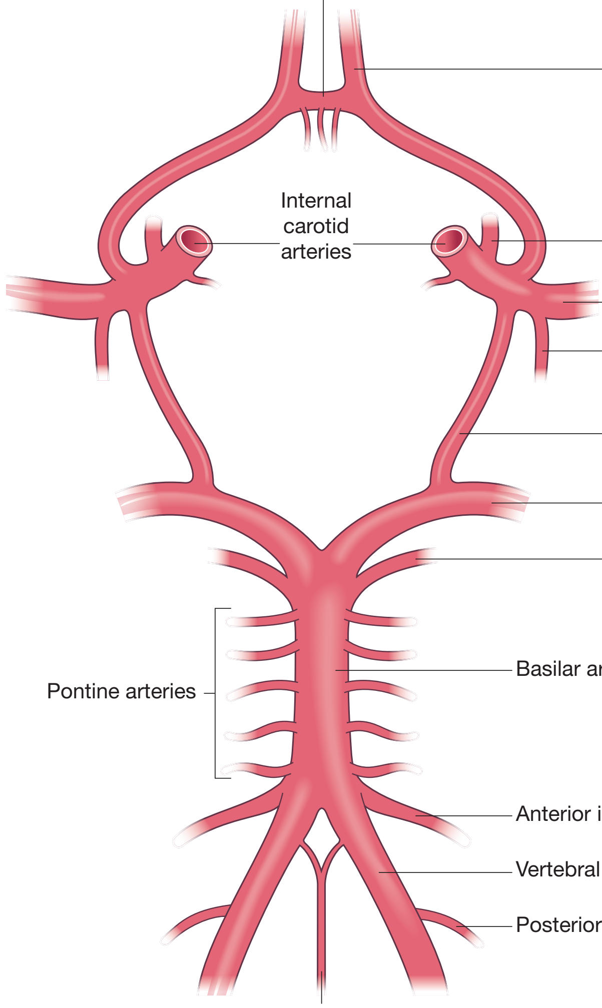

FIGURE 1.12 The Circle of Willis

has a degree of redundancy in its arterial blood supply. The cerebral arterial circle (Circle of Willis) provides collateral circulation, allowing blood to be redistributed if one vessel becomes narrowed or occluded. This backup system is especially important because the brain needs a constant supply of oxygen and glucose to work properly and cannot store them. Without this redundancy, even a brief interruption in blood flow could cause serious damage, as a sustained lack of oxygen for just four minutes may lead to irreversible brain damage.

FUNCTION OF THE CIRCLE OF WILLIS

The primary function of the Circle of Willis is to provide multiple pathways for oxygenated blood to reach brain tissue, helping to protect the brain from the consequences of reduced blood flow, such as those caused by vascular narrowing, disease or injury. Disruptions to this circulation, particularly in cases of atherosclerosis or embolism, can significantly increase the risk of stroke that may cause long-term neurological damage. Preventative strategies focus on reducing stroke risk through managing vascular health, particularly in individuals with high blood pressure, diabetes or other cardiovascular risk factors.

THE BLOOD–BRAIN BARRIER

The blood–brain barrier is a protective structural and physiological feature of the central nervous system. It is formed by a specialised lining of endothelial cells in the brain's capillaries that are tightly joined together, creating a selective barrier that regulates what substances can pass from the bloodstream into the brain tissue (see Figure 1.13).

Unlike capillaries in other parts of the body, where small gaps between endothelial cells allow for the exchange of materials, the endothelial cells in the brain are sealed by tight junctions. This prevents most substances in the blood, including potentially harmful chemicals, pathogens and fluctuations in hormones or neurotransmitters, from affecting the delicate environment of the brain. Surrounding the capillaries are astrocytes, a type of glial cell, which further reinforce the barrier and help regulate ion transport and other essential functions.

FUNCTION OF THE BLOOD–BRAIN BARRIER

Some substances cross the blood–brain barrier easily, including oxygen, carbon dioxide, alcohol and many anaesthetic agents. In contrast, water-soluble molecules such as glucose require dedicated transport proteins, while substances such as urea, most ions, proteins and many antibiotics are restricted.

The integrity of the blood–brain barrier can be compromised by a range of factors, including the following:

- Hypertension (high blood pressure)
- Trauma or inflammation

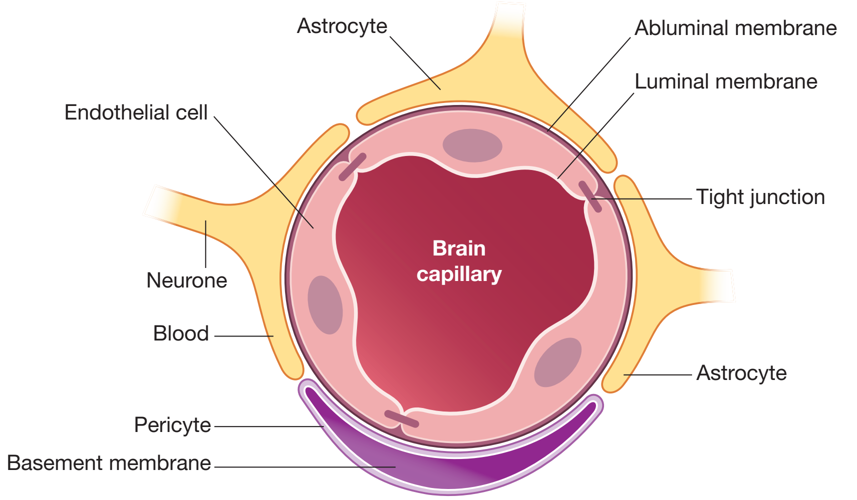

FIGURE 1.13 The blood–brain barrier

- Ischaemia (reduced blood flow)
- Exposure to radiation or infections

Although the blood–brain barrier blocks many harmful agents, it does not prevent the movement of all immune cells. For example, activated lymphocytes can enter the central nervous system even when the barrier is intact. This characteristic is important in understanding autoimmune and inflammatory conditions that affect the central nervous system, such as multiple sclerosis.

THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system plays a vital role in maintaining homeostasis by regulating the body's involuntary physiological functions. These include the control of heart rate, respiratory rate, digestion and glandular activity. Like the rest of the nervous system, the autonomic nervous system is composed of neurones, neuroglia and supportive connective tissue. However, its anatomical organisation is distinctive in that it is subdivided into two major branches: the sympathetic and parasympathetic divisions (see Figure 1.14). Most autonomic activities are not subject to voluntary control and cannot be consciously modified to any significant extent.

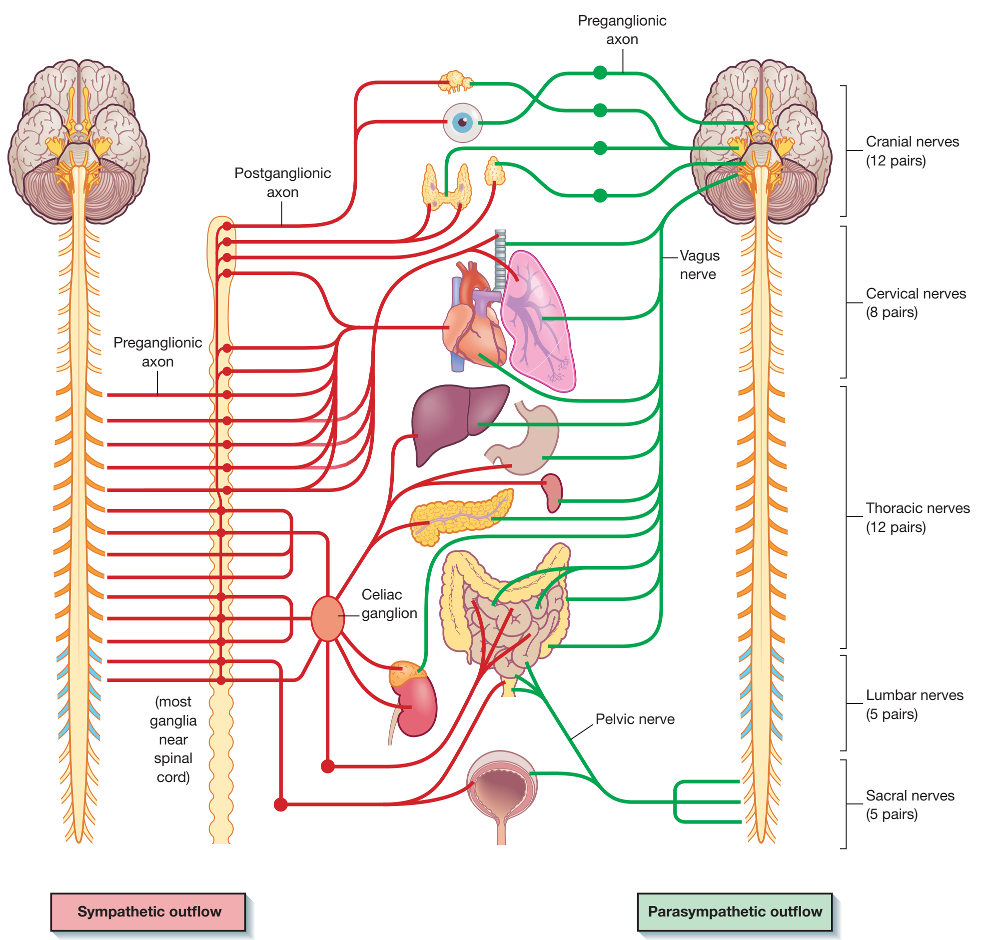

FIGURE 1.14 The sympathetic and parasympathetic divisions

THE SYMPATHETIC NERVOUS SYSTEM

The sympathetic division arises from the thoracic and upper lumbar regions of the spinal cord, specifically, the 12 thoracic and the first two lumbar segments. For this reason, it is often referred to as the thoracolumbar division. This system is activated during situations of physical or emotional stress and is responsible for initiating the fight or flight response. In such instances, the sympathetic nervous system promotes physiological changes that enable the body to respond to perceived threats. These changes are mediated largely by the release of norepinephrine (noradrenaline), which prepares the body for immediate action.

Neural organisation

The sympathetic nervous system functions via a network of interconnected neurones. While many sympathetic neurones reside in the peripheral nervous system, some originate in the central nervous system, particularly within the spinal cord. Communication between central nervous system-based and peripheral sympathetic neurones is facilitated through sympathetic ganglia, where synapses form between presynaptic (preganglionic) and postsynaptic (postganglionic) neurones.

Presynaptic neurones originate in the spinal cord and release acetylcholine at the ganglia. This neurotransmitter binds to nicotinic receptors on postsynaptic neurones, triggering a cascade of responses in target organs and tissues. These target neurones extend to effectors such as smooth muscle, cardiac muscle and glands.

Key functions

Activation of the sympathetic division produces a range of physiological effects, including the following:

- Increased heart rate and blood pressure
- Dilation of pupils (mydriasis)
- Bronchodilation to enhance respiration
- Redirection of blood flow to skeletal muscles and the heart
- Mobilisation of energy stores (e.g. glycogenolysis)
- Reduced gastrointestinal and urinary activity
- Increased sweat production
- Relaxation of the bladder

THE PARASYMPATHETIC NERVOUS SYSTEM

In contrast, the parasympathetic division supports restorative processes and predominates during periods of rest and recovery. It originates from the brainstem and sacral spinal cord; hence it is often termed the craniosacral division. This system uses acetylcholine as its primary neurotransmitter, facilitating a wide range of calming and energy-conserving physiological functions, collectively described as the rest and digest response.

Neural organisation

Parasympathetic output is transmitted via four cranial nerves, the most significant of which is the vagus nerve (cranial nerve X). This nerve plays a central role in conveying signals between the brainstem (particularly the posterior hypothalamus), the central nervous system and peripheral organs. The parasympathetic division counteracts the effects of sympathetic activation by reducing heart rate, lowering blood pressure, constricting pupils and enhancing digestive activity.

Unlike the sympathetic division, parasympathetic ganglia are located much closer to, or even within, the walls of their target organs, resulting in longer presynaptic and shorter post-synaptic fibres.

Key functions

Parasympathetic activity is associated with:

- Slowing of the heart rate and reduction of blood pressure
- Decreased respiratory rate
- Pupil constriction (miosis)
- Increased salivation and tear production
- Enhanced gastrointestinal motility and enzyme secretion
- Promotion of urination and defaecation
- Stimulation of sexual arousal responses
- Release of endorphins to promote a sense of well-being

CENTRAL AUTONOMIC REGULATION

The hypothalamus serves as the principal control centre for autonomic function. It integrates sensory input related to visceral organ status, temperature regulation, taste, smell and blood osmolality. The hypothalamus also processes emotional signals from the limbic system, thereby linking emotions to physiological responses.

Hypothalamic output influences autonomic control centres in the brainstem, including the cardiac, respiratory and salivatory centres and in the spinal cord, where reflexes such as urination and defaecation are coordinated. Through its anatomical and functional connections to both sympathetic and parasympathetic divisions, the hypothalamus ensures the appropriate balance of autonomic activity in response to internal and external stimuli. For example, sympathetic stimulation raises the heart rate, while parasympathetic activity slows it down.

AUTONOMIC REFLEXES

Autonomic reflexes are rapid, involuntary responses that help regulate vital bodily functions through a specific neural pathway known as the autonomic reflex arc. These reflexes maintain homeostatic balance by making real-time adjustments in systems such as cardiovascular regulation. The autonomic reflex arc includes the following components:

- Receptor: Detects a change or stimulus (e.g. baroreceptors sensing blood pressure).
- Sensory neurone: Transmits afferent signals from the receptor to the central nervous system.

- Integrating centre: Located in the spinal cord or hypothalamus and processes the information.
- Motor neurones: Transmit efferent signals from the central nervous system to the effector organs.
- Effector: Target tissue such as smooth muscle, cardiac muscle or glands that produce the response.

An example is the baroreceptor reflex, which helps regulate blood pressure by altering heart rate and vessel diameter in response to changes in arterial pressure.

This coordinated, bidirectional system of autonomic control ensures that the internal environment of the body remains stable, adapting rapidly to changing demands without the need for conscious thought.

THE PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system comprises all the neural structures that lie outside the central nervous system, which consists of the brain and spinal cord. The peripheral nervous system includes cranial nerves, spinal nerves and the components of the autonomic nervous system. Its main function is to serve as a communication network, transmitting information between the central nervous system and the rest of the body. The peripheral nervous system contains two major types of nerve cells:

- Sensory (afferent) neurones: These carry information from sensory receptors in the body towards the central nervous system. They respond to internal stimuli (such as blood pressure or organ stretch) and external stimuli (such as temperature or touch).
- Motor (efferent) neurones: These transmit signals from the central nervous system to muscles, glands and organs, enabling the body to respond appropriately.

The motor part of the peripheral nervous system is further subdivided into:

- The somatic nervous system, which governs voluntary control of skeletal muscles.
- The autonomic nervous system, which regulates involuntary activities of smooth muscle, cardiac muscle and glands.

PERIPHERAL NERVOUS SYSTEM, CONNECTIONS AND ORGANISATION

The peripheral nervous system connects the central nervous system to the rest of the body via 12 pairs of cranial nerves (arising from the brain) and 31 pairs of spinal nerves (arising from the spinal cord). Cranial nerves primarily serve the head and neck region, while spinal nerves extend into the limbs and torso. Most cranial nerves and all spinal nerves contain both sensory and motor fibres, allowing for two-way communication.

SENSORY (AFFERENT) DIVISION

The sensory division is responsible for conveying sensory information from receptors throughout the body to the central nervous system. It is further classified into two main subdivisions:

- Somatic sensory division: Transmits signals from receptors in the skin, skeletal muscles, bones and joints.
- Visceral sensory division: Carries information from internal organs (viscera), particularly those located in the thoracic and abdominal cavities.

These sensory signals allow the central nervous system to monitor both the internal environment (e.g. organ stretch or chemical changes) and the external environment (e.g. temperature or pain), enabling appropriate responses.

SOMATIC NERVOUS SYSTEM

The somatic nervous system is a voluntary system that manages conscious movements and processes sensory information from the external environment. It includes the following:

- Sensory (afferent) neurones, which carry impulses from receptors in the skin, eyes, ears, tongue and muscles to the central nervous system.
- Motor (efferent) neurones, which transmit signals from the central nervous system to skeletal muscles, facilitating voluntary movement (Figure 1.15).

Although most actions governed by the somatic system are voluntary, reflex actions, such as quickly withdrawing a hand from a hot surface, are involuntary and occur without conscious control.

VISCERAL (AUTONOMIC) NERVOUS SYSTEM

The visceral division is part of the autonomic nervous system, which oversees involuntary functions vital to life. It supplies motor fibres to smooth muscle, cardiac muscle and glands and regulates internal processes such as heart rate, digestion and glandular secretions. The autonomic nervous system is divided into two key subdivisions:

- Parasympathetic division: Often referred to as the 'rest and digest' system, it promotes restorative functions such as digestion, energy storage and tissue repair.
- Sympathetic division: Known as the 'fight or flight' system, it prepares the body for action in stressful situations by increasing heart rate, dilating airways and diverting blood flow to muscles.

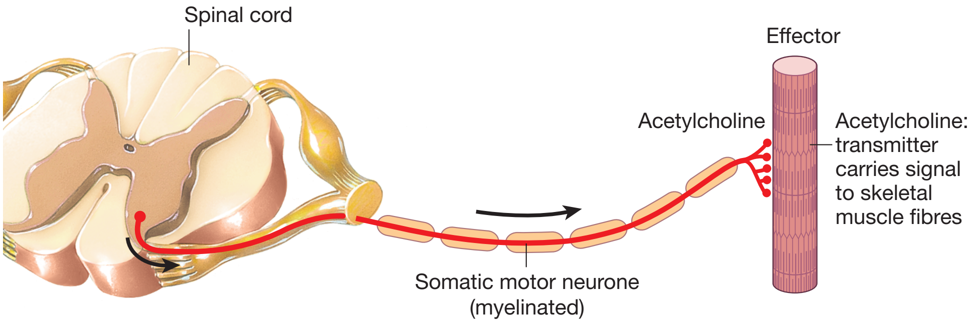

FIGURE 1.15 The somatic nervous system

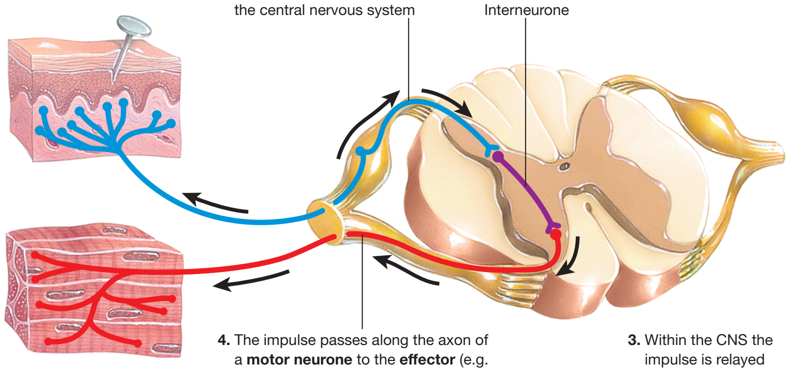

FIGURE 1.16 The motor pathway

These two divisions often have opposing effects and work in tandem to maintain internal balance or homeostasis.

MOTOR (EFFERENT) DIVISION

The motor division carries instructions from the central nervous system to the body's effectors, muscles and glands, via efferent nerve fibres (see Figure 1.16). Like the sensory division, it is also organised into two branches:

- Somatic motor division: Sends signals to skeletal muscles, allowing for voluntary movement.
- Visceral motor division (autonomic nervous system): Sends signals to smooth muscle, cardiac muscle and glands, regulating involuntary functions.

Each division plays a crucial role in coordinating the body's responses, whether they are voluntary movements or automatic adjustments to internal conditions.

This integrated system of nerves and cells allows the body to function smoothly, respond to internal and external changes and maintain a stable internal environment necessary for survival and health.

CONCLUSION

The nervous system is a complex and highly organised network that plays a vital role in regulating and coordinating bodily functions. Comprising the central nervous system and the peripheral nervous system, it enables communication between the brain, spinal cord and the rest of the body. The central nervous system processes information and governs vital functions such as movement, sensation, cognition and homeostasis, while the peripheral nervous system links the central nervous system to limbs and organs through sensory and motor pathways.

Understanding the structure and function of key components, such as the brain, spinal cord, meninges, cerebrospinal fluid and major nerve pathways, is essential for healthcare professionals in recognising signs of neurological impairment and delivering effective, person-centred care. The blood supply to the brain and the protective role of the blood–brain barrier further highlight the critical nature of maintaining neurological health.

A sound knowledge of the nervous system forms the foundation for clinical decision-making, assessment and intervention in practice, reinforcing the importance of this system in overall health and well-being.

GLOSSARY OF TERMS

Afferent neurone: A sensory neurone that carries nerve impulses from sensory receptors towards the central nervous system.

Arachnoid mater: The middle layer of the meninges; a web-like membrane between the dura mater and pia mater.

Astrocyte: A type of glial cell that supports neurones and contributes to the blood–brain barrier.

Autonomic nervous system: A subdivision of the peripheral nervous system that controls involuntary functions such as heart rate, digestion and respiratory rate.

Blood–brain barrier: A selective barrier that protects the brain from harmful substances in the bloodstream while allowing essential nutrients to pass.

Brainstem: The posterior part of the brain that connects the cerebrum with the spinal cord; includes the midbrain, pons and medulla oblongata.

Cerebellum: The part of the brain responsible for coordination of movement, balance and posture.

Cerebrospinal fluid: A clear fluid that surrounds the brain and spinal cord, providing cushioning and nutrient transport.

Cerebrum: The largest part of the brain, responsible for higher brain functions including thought, memory and voluntary movement.

Cranial nerves: Twelve pairs of nerves that emerge directly from the brain and brainstem, responsible for sensory and motor functions of the head and neck.

Dendrite: The branched extension of a neurone that receives signals from other neurones.

Diencephalon: A region of the brain that includes the thalamus and hypothalamus; involved in sensory relay and homeostasis.

Dorsal root ganglion: A cluster of sensory neurone cell bodies located in the dorsal root of a spinal nerve.

Dura mater: The tough, outermost layer of the meninges that protects the brain and spinal cord.

Efferent neurone: A motor neurone that carries impulses from the central nervous system to effectors such as muscles or glands.

Glial cells: Nonneuronal cells in the nervous system that provide support, insulation and protection for neurones.

Grey matter: Brain and spinal cord tissue primarily made up of neuronal cell bodies and dendrites.

Hypothalamus: A region of the diencephalon involved in homeostasis and hormone regulation via the pituitary gland.

Medulla oblongata: The lower portion of the brainstem that controls vital autonomic functions such as breathing, heart rate and blood pressure.

Meninges: The three protective membranes (dura mater, arachnoid mater, pia mater) that surround the brain and spinal cord.

Myelin sheath: A fatty covering around axons that speeds up nerve impulse transmission.

Neurone: A nerve cell that transmits electrical and chemical signals in the nervous system.

Neurotransmitter: A chemical messenger that transmits signals across a synapse from one neurone to another.

Parasympathetic nervous system: A branch of the autonomic nervous system that promotes 'rest and digest' responses.

Peripheral nervous system: All parts of the nervous system outside the brain and spinal cord, including cranial and spinal nerves.

Pia mater: The delicate, innermost layer of the meninges that closely adheres to the brain and spinal cord.

Reflex arc: A simple neural pathway involving a sensory receptor, sensory neurone, interneurone, motor neurone and effector, responsible for a reflex action.

Spinal cord: The cylindrical part of the central nervous system that runs through the vertebral column, transmitting signals between the brain and the body.

Spinal nerves: Thirty-one pairs of mixed nerves that emerge from the spinal cord, each innervating specific regions of the body.

Sympathetic nervous system: A branch of the autonomic nervous system that prepares the body for 'fight or flight' responses.

Synapse: The junction between two neurones where nerve signals are transmitted chemically or electrically.

Thalamus: A relay station in the brain for sensory and motor signals travelling to the cerebral cortex.

Ventricles: A series of interconnected cavities in the brain that produce and contain cerebrospinal fluid.

White matter: Brain and spinal cord tissue composed mainly of myelinated axons, responsible for communication between different brain regions.

MULTIPLE CHOICE QUESTIONS

1. What is the primary function of the myelin sheath?
   a) To store neurotransmitters
   b) To slow nerve impulse transmission
   c) To protect the neurone from pathogens
   d) To increase the speed of nerve impulse transmission

2. Which part of the brain controls vital functions such as breathing and heart rate?
   a) Cerebrum
   b) Cerebellum

c) Medulla oblongata
d) Hypothalamus

3. Which structure connects the left and right hemispheres of the brain?
   a) Corpus callosum
   b) Cerebellum
   c) Brainstem
   d) Thalamus

4. The peripheral nervous system includes:
   a) Brain and spinal cord
   b) Sympathetic and parasympathetic systems
   c) Only spinal nerves
   d) Only cranial nerves

5. Which lobe of the brain is primarily responsible for vision?
   a) Temporal
   b) Parietal
   c) Occipital
   d) Frontal

6. The blood–brain barrier is formed mainly by which cells?
   a) Schwann cells
   b) Ependymal cells
   c) Microglia
   d) Astrocytes

7. What is the role of the thalamus?
   a) Producing cerebrospinal fluid
   b) Regulating appetite
   c) Relaying sensory information to the cerebral cortex
   d) Controlling balance

8. Which of the following is not part of the brainstem?
   a) Midbrain
   b) Pons
   c) Medulla oblongata
   d) Hypothalamus

9. What fluid cushions and protects the brain and spinal cord?
   a) Cerebrospinal fluid
   b) Interstitial fluid
   c) Synovial fluid
   d) Blood plasma

10. The autonomic nervous system controls:
   a) Skeletal muscles
   b) Voluntary movements
   c) Involuntary functions
   d) Conscious thought

REFERENCES

Adigun, O.O., Reddy, V., and Varacallo, M.A. (2023). Anatomy, back, spinal cord. In: *StatPearls*. https://www.ncbi.nlm.nih.gov/books/NBK537004/.

Balasubramanian, V. (2021). Brain power. *Proceedings of the National Academy of Science* 118: e2107022118. https://doi.org/10.1073/pnas.2107022118.

Braine, M. (2024). The person with a neurological disorder (Chapter 32). In: *Nursing Practice*, 3e (ed. I. Peate and A. Mitchell). Oxford: Wiley.

McErlean, L. and Migliozzi, J. (2025). The nervous system (Chapter 15). In: *Fundamentals of Anatomy and Physiology*, 4e (ed. I. Peate and S. Evans). Oxford: Wiley.

Peate, I., Wild, K., and Nair, M. (eds.) (2014). *Nursing Practice: Knowledge and Care*. Wiley-Blackwell.

Tortora, G.J. and Derrickson, B.H. (2009). *Principles of Anatomy and Physiology*, 12e. Hoboken, NJ: John Wiley & Sons, Inc.

Woodward, S. (2024). Nursing patients with disorders of the nervous system (Chapter 11). In: *Alexander's Nursing Practice*, 6e (ed. I. Peate). London: Elsevier.