Neuroanatomy 1: Introduction

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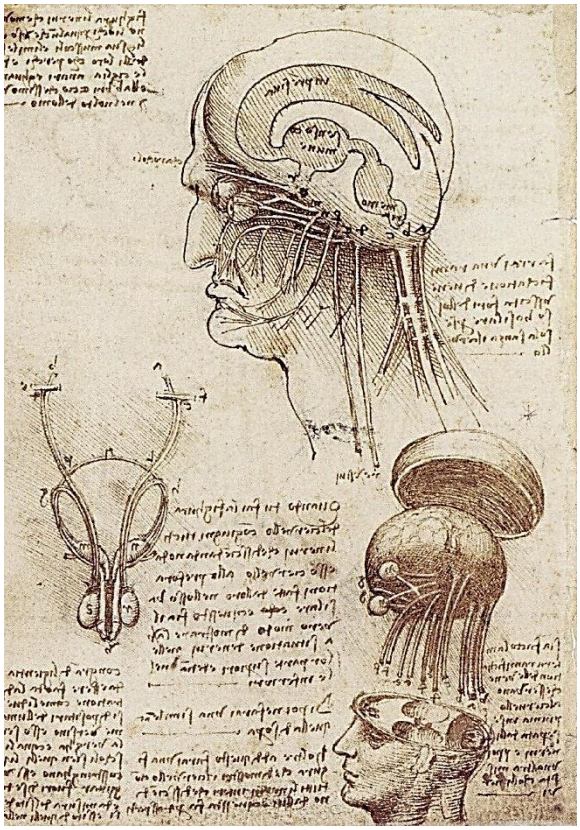
The Nervous System

The nervous system is one of the human body systems, which is principally concerned with awareness of- and the interaction with- the external (the world) & internal (the body) environments. The human nervous system is the most complex product of biological evolution. The nervous system is made of nervous tissue.



Leonardo Da Vinci: a study of the human brain, 1508.

The Nervous Tissue: one of the basic 4 tissue types in the human body. It consists majorly of cells (neurons & supportive cells) & low quantity of extracellular matrix, & very small amount of fibers. The number of neurons in the nervous system is thought to be around 10^{10}, while the supportive cells estimated to be 10-times this number. The nervous tissue that makes the brain & spinal cord is very soft, so it needs to be protected inside harder structures (the cranium & vertebral canal, respectively).

General Arrangement of the Nervous System:

The nervous system is divided anatomically into a central nervous system (CNS), consisting of the brain & spinal cord; & a peripheral nervous system (PNS), consisting of the cranial & spinal nerves. Cranial nerves are connected directly to the brain, while spinal nerves are connected to the spinal cord, which connects them to the brain. Our consciousness & awareness about the environment is the function of the brain. The brain receives information about the environment via the (afferent) nerve fibers in the cranial & spinal nerves, process & analyze those information, & makes the suitable reaction to them via the (efferent) nerve fibers in the cranial & spinal nerves. CNS reactions are motor stimuli to muscles (skeletal, smooth, or cardiac) or glands. So, in brief, the nervous system interaction with the environment can be summarized as in the following:

Sequence	Process	Nervous system component responsible	Neurons involved
1	Information transmission from environment to the CNS	Afferent (sensory) nerve fibers	Sensory (Bipolar or pseudounipolar) neurons
2	Information analysis, processing, & deciding the suitable response	Brain	Interneurons
3	Information (commands) transmission from the CNS to the effector cells	Efferent (motor) nerve fibers	Motor (multipolar) neurons

Higher brain functions like thinking, information storage (memory), emotions, behavior, etc are mediated by nerve impulses networking between different areas in the brain (cerebral) cortex via interneurons, & may not generate immediate motor reactions. Mental features like logical analysis, planning, creativity, etc are the features defining humans from lower vertebrates, & make us who we are.

Development of the Nervous System:

For a better understanding of the complex anatomy of the central nervous system, it is very important to review its development. The nervous system originates entirely from the ectoderm. After its formation, the neural tube extends in a cephalic-caudal direction & curves ventrally to assume a C-shape. The cephalic end of the tube enlarges & grows more rapidly to form the future brain, while the remaining caudal part forms the future spinal cord. The 2 parts are joined at an angulation (the cervical flexure). In the 4th week of development, the cephalic end of the tube shows 3 dilatations (the primary cerebral vesicles): the prosencephalon (forebrain), mesencephalon (midbrain), & rhombencephalon (hindbrain). A week later, secondary cerebral vesicles appear, as follows:

- The forebrain shows 2 lateral enlargements (telencephalon: the future cerebral hemispheres) & a central region (diencephalon: the future thalamic areas). From the diencephalon, 2 outgrowths appear laterally (the optic vesicles: the future retinae & optic nerves).
- The midbrain does not subdivide.
- The hindbrain differentiates into an upper enlargement (metencephalon: the future pons & cerebellum) & lower enlargement (the myelencephalon: the future medulla oblongata

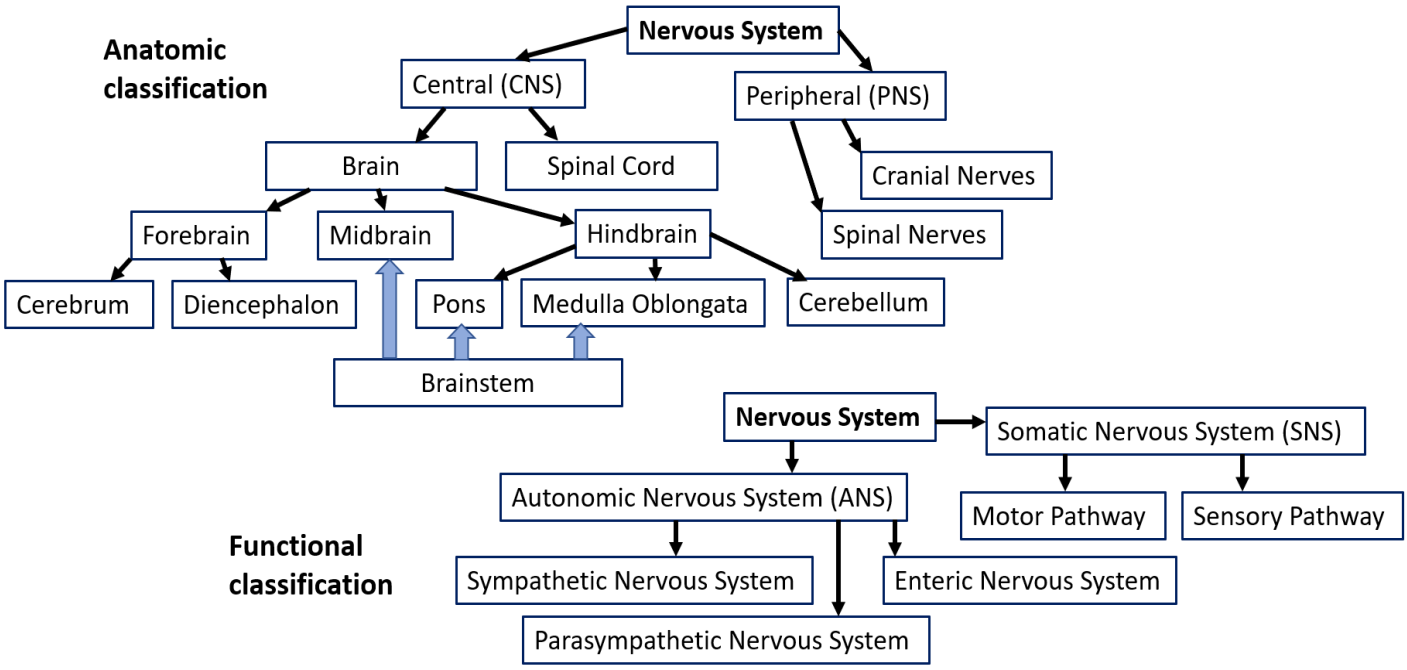
Among those structures, the cerebral & cerebellar hemispheres grow much more than the others, to form the largest parts of the full-term brain.

As the CNS develops from the neural tube, the cavity of the tube remains & assumes different shape & size in each one of the above-mentioned parts of the CNS. Those interconnected cavities make the ventricular system of the CNS, filled with CSF & communicating with the subarachnoid space.

In the spinal cord, motor & sensory neurons develop around the cord cavity (the central canal) with the motor neurons anterolateral to the canal, sensory neurons posterolateral to the canal, while autonomic neurons lateral to the canal. This arrangement results in the formation of ventral (motor), dorsal (sensory), & lateral (autonomic) horns of spinal cord grey matter.

In the brainstem, neurons arrange ventral to the cavity, with the motor neurons medially, followed by autonomic neurons, then the sensory neurons laterally. Those neurons are arranged as nuclei, which are further subdivided into 7 groups according to the function of each group.

Classifications of the Nervous System:



Important definitions:

Neuron: the nerve cell: a highly specialized cell that makes the nervous tissue & does its functions. Neurons have different sizes, shapes & functions. However, they all have a cell body (soma, perikaryon), from which cytoplasmic processes (the dendrites) emerge, one of them (the axon) is long & usually has branches (axon terminals) at its end. Neurons receive nerve signals (electrical signals = action potentials) from other cells via the dendrites, & send those signals to other cells via the axon (one direction: dendrites → cell body → axon). Neurons encode information, conduct it, sometimes over considerable distances, and then transmit it to other neurons or to non-neural tissues (muscles or glandular cells).

Morphological types of neurons:

Multipolar neuron: a neuron that has many dendrites & a single longer axon, that has terminal branches.

Bipolar neuron: a neuron that has 2 cytoplasmic processes, each one with few terminal branches. The process carrying information to the cell body is considered the dendrite, while the one carrying information away from the cell body is the axon.

Pseudounipolar neuron: a neuron with a spherical cell body & a single cytoplasmic process that divides into 2 branches: the peripheral process (dendrite) carrying information towards the cell body, & the central process (axon) carrying information away from the cell body.

Functional types of neurons:

Afferent (sensory) neuron: a neuron that sends information (sensations) from the peripheral body to the CNS. Its axon terminals end on other neurons in the CNS. Sensory neurons are pseudounipolar or bipolar neurons.

Efferent (motor) neuron: a neuron that sends information (commands) from the CNS to the peripheral body. Its axon terminals end on the effector cells, which are usually muscle or gland cells. Motor neurons are multipolar neurons.

Interneuron: a neuron that connects 2 other neurons within the CNS. Interneurons are multipolar neurons. Interneurons greatly outnumber sensory & motor neurons, they are responsible for the complex brain functions like information analysis & integration, memory, behavior, intellectual functions, emotions, etc in addition to contribution in many reflexes in the brain stem & spinal cord.

Glial (supportive) cells: those are non-neuronal cells that fill the space between the neurons. The have cytoplasmic processes connected to each other & to neurons, they cover the CNS surface, line its cavities, & act to create the suitable environment for proper function of neurons. Glial cells do not transmit nerve impulses. Specific types of glial cells form the myelin sheath around myelinated axons (Schwann cells in PNS & oligodendrocytes in CNS).

Neurotransmitter: a chemical material (protein) secreted from the axon terminals of a neuron upon the arrival of nerve signal. They reach the other cell (another neuron, muscle cell, or gland cell) causing certain effect.

Nerve fiber: an axon or a collection of axons

Myelinated nerve fibers: axons surrounded by a myelin sheath (an insulating lipid layer).

Non-myelinated nerve fibers: axons not surrounded by a myelin sheath.

Note: most of the nerve fibers in the body are myelinated.

Nerve: a collection of large number of axons bundled together in the PNS.

Sensory nerve: a nerve that transmits signals from the body tissues to the CNS

Motor nerve: a nerve that transmits signals from the CNS to the body tissues

Note: some nerves contain both sensory & motor fibers.

Plexus: a network of nerve fibers made by spinal nerves in specific regions, from which peripheral nerves arise.

Note: the autonomic nervous system also form plexuses around viscera & blood vessels.

Tract (fasciculus): a bundle of ascending or descending nerve fibers within the central nervous system, sharing the same origin & termination.

Column (funiculus): a large bundle of ascending or descending nerve fibers, composed of several different tracts.

Decussation: The level in the central nervous system where paired fiber tracts cross from one side of the body to the other.

Peduncle: a massive collection of nerve fiber bundles that connect the cerebrum and the cerebellum to the brainstem. The cerebrum has 2 peduncles, the cerebellum has 6.

Grey matter: a collection of nerve cell bodies, dendrites & glial cells in the CNS. Grey matter exists in 2 forms:

1. **Cortex**: a collection of nerve cell bodies to form the outer zone of CNS structure (cerebrum & cerebellum). So, there are cerebral cortex & cerebellar cortex.
2. **Nucleus**: a collection of nerve cell bodies in the CNS (deep inside the white matter). CNS nuclei may take different shapes: spherical, oval, longitudinal, irregular, etc. A nucleus receives afferent nerve fibers from different areas in the CNS & sends efferent fibers to different CNS areas. Efferent fibers of a nucleus are the axons of its neurons. Note: DO NOT confuse CNS nuclei with the nucleus of the cell.

White matter: a collection of myelinated nerve fibers in the CNS. The white matter occupies the inner zone of the cerebrum & cerebellum, & the outer zone of the rest of CNS. In the brain, white matter fibers are divided into 3 types:

1. **Association fibers**: fibers originating in an area of the brain cortex & terminate in a nearby area of the same side of the cortex.
2. **Commissural fibers**: fibers originating in an area of the brain cortex, cross the midline to terminate in an area on the other side of the brain cortex.
3. **Projection fibers**: fibers originating in the brain cortex & descend to lower CNS regions in the brainstem or the spinal cord.

Reticular formation: a group of various distinct populations of neurons scattered among the ascending & descending tracts occupying the central core of the brainstem on each side of the midline. Reticular formation has an extensive connections & may reach to the upper cervical spinal cord.

Ganglion: a collection of nerve cell bodies in the peripheral nervous system. PNS ganglia are of 2 types:

- Sensory ganglia: made of bipolar or pseudounipolar sensory neurons.
- Autonomic (sympathetic or parasympathetic) ganglia: made of multipolar neurons that receive preganglionic fibers, & send their axons as the postganglionic fibers.

Rostral (cephalic): Toward the nose (proceeding toward a higher position; the opposite of caudal)

Caudal: Toward the tail (proceeding to a lower position; the opposite of rostral)

Fissure: a deep cleft in the surface of a structure, usually transmitting blood vessels, eg: the anterior longitudinal fissure of the spinal cord.

Sulcus: a shallow depression on the surface of a structure.

Gyrus: a bulge on the surface of the brain (specifically the cerebrum & cerebellum).

Lobe: a big part of a hemisphere (cerebral or cerebellar).

Lobule: a small part of a hemisphere (cerebral or cerebellar).

END