

THE NERVOUS SYSTEM
(SYSTEMA NERVOSUM)

THE FUNCTIONS OF THE NERVOUS SYSTEM

controlling function

- The neural control of the activity of the organs
- The basic property is the excitability and the generating of electric nerve impulses

The nerve cell (neuron)

- the basic component of the nervous system
- highly specialized (excitability, conductivity)

Glial cell (neuroglia)

- support, nutritive, defensive and other functions

Neuron

1. the body (perikaryon)

2. the projections

- **dendrites:** receiving of complaints
- **Axon (nerve fibre):** conducts electrical impulses away from the neuron's cell body

The types of the neurons

- **Multipolar**: the largest ones, several dendrites and one axon, star-shaped, 80%
- **Pseudounipolar** dendrite + axon - dendraxon, T-shaped, central and peripheral branch (spinal ganglions and ganglions of cranial nerves)
- **Unipolar** only one projection - axon (primary sensory cells, olfactory cells, rods and cones of the retina)
- **Bipolar** one axon and one dendrite, (the second neuron of the optic tract)

The synapse (a part of axon)

- Ended by enlargement– **terminal button** – is in contact with other neuron – the connection **synapse** (muscle – **neuromuscular junction**)
- presynaptic membrane, postsynaptic membrane
- Transfer of impulse– spread through axon centrifugally as electric signal – **action potential**
- **terminal button** – vesicles with **neurotransmitters**

The neuromuscular junction

Neuroglia

- **Astrocytes**: the largest ones
long unbranched cellular processes (with vascular feet), which cover all vessels of CNS – **blood-brain barrier**
- **Oligodendrocytes**: within the grey and white matter, they myelinate nerve fibres of CNS (nutrition, homeostasis)
- **Microglia**: the smallest ones (primarily within the bone marrow)
defense function – ability of phagocytosis)
- **Ependymal cells**: they cover the central canal of spinal cord and the brain ventricles –they are bathed by the cerebrospinal fluid and they help its flow

Neuroglia

Function: they accelerate the conduction of the excitement, nutrition, homeostasis, defence function

The myelin sheath

CNS: oligodendroglia

PNS: Schwann cells

- insulator, it is interrupted by the nodes of Ranvier, the neural impulses „jump“
- Myelinated nerve fibres
 - quicker transmission of the impulse

The bodies of the neurons: ganglions, grey matter of CNS

The projections of the neurons: white matter of CNS, nerves of PNS

THE DIVISION OF THE NERVOUS SYSTEM

1. central nervous system (*systema nervosum centrale*)

Spinal cord (*medulla spinalis*)

brain (*encephalon, cerebrum*)

- The hind-brain (*rhombencephalon*)
- The Medulla oblongata (*medulla oblongata*)
- The pons (*pons Varoli*)
- The cerebellum (*cerebellum*)
- The midbrain (*mesencephalon*)
- The fore-brain (*prosencephalon*)
- The diencephalon (*diencephalon*)
- The cerebrum (*telencephalon*)

2. peripheral nervous system (*systema nervosum periphericum*)

It connects CNS with the periphery of organism (centripetally, centrifugally)

- Spinal nerves (*nervi spinales*)
- Cranial nerves (*nervi craniales*) } **Cerebrospinal nerves**
- sympathicus (*pars sympathica*)
- parasympathicus (*pars parasympathica*) } **Autonomic nerves**

The terms:

- **funiculus** = cord
x
- **fasciculus** = bundle of axons -HETEROGENEOUS structure, it originates within the different nuclei of the grey matter and creates synapses also within the different structures x
- **tractus** = tract – bundle of axons - HOMOGENOUS structure, the fibres have a common origin and end
- **rostral**

The nervous system

- 1) It mediates relations between external environment and organism**
- 2) It provides body's response to stimuli from outside**
- 3) It mediates relations between all parts of organism**
- 4) It provides integrality of all actions within organism**

FUNCTIONAL TYPES OF AXONS WITHIN PNS

Afferent

somatosensory



Skin perception, proprioception, pain

viscerosensory



mechanoreception, pain

senzory



taste, hearing and vestibular informations,

Efferent

somatomotor



striated muscle

branchiomotor



striated muscle

visceromotor



Smooth muscle

sympathetic



myocardium

parasympathetic



glands

THE REFLEX ARC

- **The reflex is a fiziologic action, whose essence is the response of the organism to the change of the external or the internal environment- this is a response of the organism to the irritation.**

The nervous system constantly monitors the conditions of the external and internal environment of the organism using the receptors, it processes these informations within CNS and gives off the instructions for the executive organs – effectors = **REFLEX**

- The anatomical underlay of the reflex is the **reflex arc** – a system of the neural tracts, on which is the reflex carried out.

1. Receptors

2. Afferent neural tracts

3. CNS

4. Efferent neural tracts

5. Effectors

RECEPTORS

Receptor (sensor): responds to the changes of the internal or external environment of the organism and it converts them into action potential of the neural impulses, these impulses are emitted into directing centre within CNS

The division according to the location:

exteroreceptors – receptors, which respond to the stimuli (changes) from the external environment of the organism

interoreceptors – receptors, which respond to the stimuli (changes) from the internal environment of the organism

According to the specific location:

proprioceptors – receptors which are located within the locomotor system (within the muscles, tendons and articular capsules)

visceroreceptors – receptors which are located within the visceral organs and the walls of the vessels

The division according to the physical character of the acting stimulus

mechanoreceptors – receptors reponding to mechanical stimuli

chemoreceptors – receptors reponding to chemical stimuli

thermoreceptors – receptors reponding to thermal stimuli

photoreceptors – receptors reponding to light stimuli

The special case present so called **algoreceptors** – receptors which respond to pain.

The muscles

- Muscle and tendon spindles (intrafusar fibres) – **degree of contraction and tension of the muscle fibers**
- Free nerve ending around the muscle fibers - pain

The afferent nerve pathways

The afferent (centripetal, **sensory**) pathways conduct the neural impulses from the receptors into CNS.

They are formed by the projections of **sensory neurons**, whose bodies are located out of CNS within **sensory ganglions**.

The afferent pathways are divided into:

Somatosensory pathways – bring information from receptors within skin and locomotor system

Viscerosensory pathways – bring informations from visceroreceptors (from visceral organs)

Sensory pathways – bring informations from sensors – specialized sensory organs (visual, auditory, vestibular, olfactory and gustatory systems)

THE CENTRAL NERVOUS SYSTEM

- **The central nervous system (CNS) is the directing centre of the nervous system. It takes the informations from the receptors using the afferent nerve pathways. It processes and evaluates these informations and provides the responses of the organism using the efferent nerve pathways and effectors.**

The nervous tissue of CNS is formed by two types of the matter:

The grey matter (substantia grisea)

The white matter(substantia alba)

The grey matter (*substantia grisea*):

- is formed by the bodies and dendrites of the neurons + glial cells
- The bodies of the neurons take the informations from axons of sensory neurons of the sensory ganglions and give off the new informations for motor neurons within CNS
- On the connection between sensory and motor neurons may not be any other switching neuron (by the simplest reflexes), but usually there are one ore more switching neurons, so called interneurons, inserted

The white matter (*substantia alba*):

- Is formed by the bundles of myelinated axons of neurons, which are located within the grey matter and provide the communication between the neurons of the grey matter

Association pathways

Commissural pathways

Projection pathways – according to the direction, we divide them into two groups:

- Ascending tracts – tracts passing from the lower centre toward the higher one. They are the continuation of the afferent peripheral tracts.
- Descending tracts – tracts passing from the higher centre toward the lower one. They are the continuation of the efferent peripheral tracts

The efferent nerve pathways

The efferent, centrifugal, **motor** nerve pathways:

- They lead the nervous impulses from CNS into effectors (executive organs)
- They begin with the motor neuron within CNS, axon of this neuron leaves CNS and presents the proper efferent (motor) pathway

Somatomotor pathways

Visceromotor pathways

EFFECTORS

Effectors are the executive organs or tissues, which provide the proper response of the organism to the irritation. They can be:

Muscle cells– the result of the reflexu is the motion

Glandular cells– the result of the reflexu is the secretion

THE PERIPHERAL NERVOUS SYSTEM

(*systema nervosum periphericum*)

- The periphery nervous system is formed by a system of nerves and ganglions, which convey reversible transfer of the informations between CNS and the periphery (skin, locomotor system and visceral organs)
- Nerve is consist of nerve fibres and fibrous connective tissue
- Nerve fibres are myelinated (white) or unmyelinated (grey) projections of the neurons
- Nerve fibres create fascicles, a few fascicle create nerve,
- Particular nerve fibres are interconnected using the fibrous connective tissue – *endoneurium*, within the nerve
- the fascicles of the fibres are interconnecte using *perineurium*
- Teh surface of the nerve is covered by fibrous layer–
epineurium

Sensory nerves

- They consist the afferent fibres, which lead the information from the receptors toward CNS
- Within their course, there are sensory ganglions inserted with the bodies of **pseudounipolar neurons**
- **Peripheral branch** leads the impulses from receptors within the periphery into the ganglion, the bundles of these peripheral branches form the nerve
- **Central branch** leads the impulses from the ganglion toward the grey matter of CNS

somatosensory – lead the informations from the receptors within the skin and the locomotor system (muscles, tendons, periosteum, articular capsules)

viscerosensory –lead the information from receptors within the organs

sensory – lead the informations from sensors

motor nerves

- They consist the efferent fibres, which lead from CNS into effectors (muscles or glands) and provide their activity
- They originate within the nuclei of the grey matter of the spinal cord or the brainstem (body of the neuron)

somatomotor nerves – innervate **striated muscle**, the nerve fibers (axons) enter the muscles directly without switch-over

visceromotor nerves – innervate **smooth muscle** and **glandular cells**, into which the nerve fibers enter after at least one switch-over within autonomic ganglion

Mixed nerves

- They consist both motor and sensory fibers. **The most of the nerves are mixed**, only some are either clearly motor or clearly sensory

The peripheral system

1. According to from which part of CNS the nerves arise, we can divide them into:

The cranial nerves (pass through the base skull)

The spinal nerves (rise through foramina intervertebralia)

2. According to the innervated parts of the body:

somatic nervous system

- It is controlled by our consciousness
- It is consist of somatosensory (or sensory) and somatomotor nerve fibers (tracts)
- It does the sensory innervation of the skin and the locomotor system (muscles, tendons, bones, articular capsules) and the motor innervation of the striated muscle

autonomic nervous system

- It works independently on our consciousness
- sympathetic, parasympathicus

THE SPINAL NERVES (*nervi spinales*)

- The spinal nerves rise from the spinal cord in the number of 31 pairs

The cervical nerves (*nervi cervicales*) – 8 pairs

The thoracic nerves (*nervi thoracici*) – 12 pairs

The lumbar nerves (*nervi lumbales*) – 5 pairs

The sacral nerves (*nervi sacrales*) – 5 pairs

The coccygeal nerve (*nervus coccygeus*) – 1 pair

- Each spinal nerve rises from the spinal cord through two roots, the anterior one (*radix ventralis*) and the posterior one (*radix dorsalis*)
- The anterior roots consist only efferent fibres (motor), the posterior roots only afferent fibres (sensory)
- Within the course of the posterior root, there is the spinal ganglion (*ganglion spinale*) inserted

The posterior root (radix dorsalis) consists afferent fibres, which serve to superficial and deep perception, leading of pain, warmth and cold. On each posterior root, there is **ganglion spinale** located, which consists neurons of the afferent fibers.

The anterior root (radix ventralis) consists efferent somatomotor fibres (for striated muscle) and visceromotor fibres (for smooth muscle cells within the walls of organs and vessels, the skin etc.).

- The proper spinal nerve is formed by connection of the anterior and posterior root and it rises from the spinal canal through **foramen intervertebrale**
- After the leaving of the spinal canal, the spinal nerve divides into 2 branches – the posterior branch (**ramus dorsalis**) and the anterior branch (***ramus ventralis***), both branches consist the afferent and efferent tracts.

Ramus dorsalis: doesn't form plexuses

Ramus ventralis: forms plexuses

The nerve plexuses are allways formed only by the anterior branches of the appropriate spinal nerves!

The posterior branches (rami dorsales) –

don't form the plexuses

- They are short and thin branches of the spinal nerve
- **function:** motor and sensory innervation of the back part of the trunk (mixed nerves)
- They do the motor innervation of autochtoneí (deep) back muscles and sensory innervation of the skin in adjacent area
- During their course, they keep simple segmental arrangement
- Only the posterior branches of **C1 – C3**, **L1 – L3** a **S1 – S3** have more complicated arrangement

C1 – C3

n. suboccipitalis

n. occipitalis major

n. occipitalis tertius

- suboccipital muscles + skin

L1 – L3 a S1 – S3

nn. clunium superiores

nn. clunium medii

- skin of the gluteal region

Ramus dorsalis:

- **ramus medialis** (deep back muscles and the skin of medial part of the back)
- **ramus lateralis** (deep back muscles in the lateral part of the back)

The anterior branches (rami ventrales)

- They are longer and thicker branches of the spinal nerve
- **Function:** motor and sensory innervation of the anterior part of the trunk
- They do the motor innervation of the muscles of the anterior part of the trunk (neck except infrahyoid muscles, thorax, abdomen and pelvis) and the muscles of the limbs and the sensory innervation of the skin of the anterior part of the trunk and the limbs
- They have more complicated arrangement than the posterior branches of the spinal nerves, they lost the segmentation and created **nerve plexuses**):
- Plexus cervicalis C1-C4
- Plexus brachialis C4-Th1
- Nervi thoracici Th1-Th12 (they keep segmental arrangement)
- Plexus lumbalis Th12-L4
- Plexus sacralis L4-5,S1-5,Co

THE CERVICAL PLEXUS (*plexus cervicalis*)

- It is created by the anterior branches of first four cervical nerves (C1 – C4)
- It is located sides the cervical vertabral column and several sensory, motor and mixed nerve rise from it. The particular nerves of the cervical plexus innervate:

Sensory innervation: the skin in the neck area, a part of the head and a part of upper extremity girdle

Motor innervation: neck muscles (**infrahyoid muscles**, **musculi scaleni** and **deep neck muscles** and **diaphragm**, which originates in the neck area during embryonic development)

- *suprahyoid muscles + m. sternocleidomastoideus + m. platysma are of gill origin an they are innervated by some cranial nerves, not cervical nerves*

The cervical plexus

The sensory branches – they rise together by the posterior margin of m. sternocleidomastoideus – *punctum nervosum sensitivum*:

- n. occipitalis minor (C2–3)
- n. auricularis magnus (C2-C3) ramus anterior et posterior
- n. transversus colli (C3)- rr. superiores et inferiores- ansa cervicalis superficialis
- nn. supraclaviculares (C3-4)

mediales

intermedii

laterales

The motor branches – for pre- and intervertebral muscles, m. scalenus medius, m. sternocleidomastoideus, m. trapezius a m. levator scapulae

Ansa cervicalis (profunda) (C1–3) – (*ansa n. hypoglossi*) motor fibres for **infrahyoid muscles**, except *m. thyrohyoideus* (separate branch of n. thyrohyoideus)

- ***radix sup. (C1)*** – joins n. hypoglossus and passes between a. carotis comm. and v. jugularis int.

- ***radix inf. (C2–3)*** - along v. jugularis int., above tendon of m. omohyoideus both roots connect and ansa (loop) is created

The mixed branches

n. phrenicus (C3–5)

- It divides on the inferior surface of the diaphragm – **rr. phrenicoabdominales** – motor innervation of the diaphragm, sensory innervation of the peritoneum, gall bladder, pancreas; **r. pericardiacus** – sensory innervation of the pericardium and adjacent part of pleura

nn. phrenici acc. – accessory fibres

- a) directly from plx. brachialis (C5–6),
 - b) through n. subclavius
 - c) from radix inf. ansae cervicalis
- They can substitute typical n. phrenicus
 - Irritation of the nerve – singultus (hiccup)

THE THORACIC NERVES (*nervi intercostales*)

- They keep segmental arrangement, don't form plexuses, pass within intercostal spaces from behind forward together with the intercostal vessels (within sulcus costae on the inferior margin of the rib)
- 1. – 6. toward the sternum, 7. – 12. toward the anterior abdominal wall

they innervates:

- **Sensory i.:** skin of thorax and abdomen and parietal sheet of pleura and peritoneum
- **Motor i.:** proper thoracic (intercostal) muscles and anterior and lateral group of abdominal muscles

Nn. thoracici Th1-12

- **Don't form plexuses**

nn. intercostales

n. subcostalis

- **rr. musculares** (autochtone muscles of thorax)
- **rr. cutanei- laterales- nn. intercostobrachiales**
 - **anteriores** (by the sternal margin)

Skin of thorax and abdomen

- **rr. pleurales**

from Th1- strong connection into plexus brachialis
(nervus intercostobrachialis)

Nn. intercostobrachiales

(n. cutaneus brachii medialis)

- **Obrázky:**
- **Atlas der Anatomie des Menschen/Sobotta. Putz,R., und Pabst,R. 20. Auflage. München:Urban & Schwarzenberg, 1993**
- **Netter: Interactive Atlas of Human Anatomy.**
- **Naňka, Elišková: Přehled anatomie. Galén, Praha 2009.**
- **Čihák: Anatomie I, II, III.**
- **Drake et al: Gray's Anatomy for Students. 2010**