**Nervous system** (chapter 7, 8, and 9)  **Page 1**

The two regions of the nervous system:

 • Central nervous system (CNS) = The brain and spinal cord

 • Peripheral nervous system (PNS) = All nervous tissue outside the

 CNS

Nervous system

Organs made of nervous tissue. The nervous system carries out these three functions:

1) Senses stimuli (such as sight, touch, taste, etc.)

2) Formulates a response to the stimuli

√ This function is our perceptions, thoughts, and reflexes

√ This function occurs in the CNS

 3) Transmits signals rapidly between body parts

 √ Ex: Signals from sense organs to the CNS

 √ Ex: Response signals from the CNS to the muscles

Table 7.1

### Nervous system Page 2

Nervous tissue consists of neuron cells and neuroglial cells

Neuron

The nervous tissue cell type that performs all the functions of the nervous system (senses stimuli, formulate responses, carries electrical signals between body parts)

 • Cell body = The round region of the neuron that contains the nucleus

 and most other major organelles

 • Processes = Extensions from the cell body

 √ Dendrites = Detect stimuli and start the electrical signal

√ Axon = Conducts the electrical signal toward the target cell

 (the cell that will receive the signal)

 √ Axon terminals = Bulbs at end of the axon where signals

 pass to the target cell

 – Colaterals = Branchings of the axon near an axon’s

 end

• Myelin sheath = A wrapping of myelin (white fatty material)

 around the axon that speeds the signal

Figs 7.1 and 7.2

### Nervous system Page 3

Neuroglia cells

Cells that support and assist neurons, but that do not carry out any sensing, responding, or signaling

There are several types of neuroglia cells, each with a specialized

structure and function

• Schwann cells = Neuroglia cells in the PNS that wrap themselves

 around axons to form the myelin sheath

• Oligodendrocytes = Star-shaped neuroglia cells in the CNS that

 wrap branches around several axons to form many myelin sheaths

• Astrocytes = Star-shaped neuroglia cells in the CNS that form a

 bridge between neurons and blood vessels to transfer nutrients from

 the blood to the neurons in the CNS

 √ Blood-brain barrier = Capillaries in the brain (unlike

capillaries in other parts of the body) do **not** allow most

nutrients and other molecules in the blood to exit by

uncontrolled leaking out of the capillary

Table 7.2

Figs 7.5, 7.6, 7.8, and 7.10

### Nervous system Page 4

Functionally, there are three neuron types:

1) Sensory neurons (afferent neurons)

PNS neurons that detect sense stimuli and carry sense signals into the

CNS

• They have a unipolar shape (axon and dendrites connect to the same

 side of the cell body)

 • They are stimulated by sense stimuli (light, sound, touch, etc.)

 • They pass their signal to neurons in the CNS

2) Interneurons (association neurons)

All neurons inside the CNS. Interneurons can receive sensory neuron signals, communicate with other interneurons, and generate response motor signals (signals to motor neurons to activate muscles)

• The communications between interneurons are our perceptions,

 feelings, emotions, and thoughts

3) Motor neurons (efferent neurons)

PNS neurons that conduct response motor signals out from the CNS

• They are stimulated by interneurons

• They pass their signal to muscles or glands

Figs 7.1 and 7.3, Table 7.1

### Nervous system Page 5

Nerves

Bundles of neurons (wrapped in connective tissue) in the PNS

 • Most nerves are mixed nerves (they contain sensory and

 motor neurons)

• Cranial nerves = Nerves that connect to the CNS in the head

• Spinal nerves = Nerves that connect to the CNS in the spine

(• Inside the CNS, bundles of neurons are called tracts)

Fig 8.27

Ganglion

 A cluster of neuron cell bodies in the PNS (within a nerve)

 • Ganglia are visible as a bulge in a nerve’s connective tissue

 • They can be clusters of sensory neuron cell bodies or motor neuron

 synapses within the nerve

 (• Inside the CNS, clusters of cell bodies are called nuclei)

Fig 9.1

### Nervous system Page 6

Synapse

 The location where a neuron passes its signal to its target cell (the cell

that will receive the signal)

• Pre-synaptic cell = The neuron that brings the signal to the synapse

• Post-synaptic cell/Target cell = The cell that receives the signal

- The target cell is usually a neuron or a muscle cell

- The post-synaptic cell generates its own electrical signal in

 response to receiving the signal from the pre-synaptic neuron

 • The synapse includes…

a) The axon terminals of the pre-synaptic cell

b) The dendrites of the post-synaptic cell

c) The synaptic cleft (the gap between pre-synaptic cell

 and the post-synaptic cell)

Figs 7.23 and 7.30

Nerve signals crossing the synaptic cleft:

 • Electrical nerve signals cannot cross the synaptic cleft

 • The pre-synaptic neuron uses neurotransmitters to send the signal

 across the synaptic cleft

Figs 7.23 and 7.30

**Nervous system Page 7**

Neurotransmitters

Molecules released by axon terminals to carry the signal across the

synapse to the target cell

 • Neurotransmitters are stored in vesicles in the pre-synaptic cell’s

 axon terminals

 • When the electrical signal reaches the axon terminals, the vesicles

 release the neurotransmitters into the synaptic cleft

 • The neurotransmitters diffuse across the cleft to the dendrites of the

 post-synaptic cell

 √ They bind receptor proteins on the dendrites

 √ The binding of neurotransmitter to receptor is what causes the

 post-synaptic cell to generate its own electrical nerve signal

 – Some neurotransmitters (called inhibitory

 neurotransmitters) do the opposite: They decrease the

 neuron’s ability to generate its own electrical signal

 • The neurotransmitters are rapidly removed from the synaptic cleft

 √ Enzymes in the pre-synaptic and postsynaptic cells destroy

 the neurotransmitters

√ The pre-synaptic neuron can also reuptake unused

 neurotransmitters from the synaptic cleft

Figs 7.23 and 7.30

**Nervous system Page 8**

There are many types of neurotransmitters, but each individual neuron releases only one of the types

Neurotransmitter: Usual location Actions:

Acetylcholine PNS & CNS Contracts voluntary muscles

 Can relax or stimulate

 involuntary muscles and organs

Norepinephrine PNS & CNS Can relax or stimulate

 involuntary muscles and organs

Dopamine CNS Generation of motor signals

 Reward/pleasure feelings

Serotonin CNS Boosts mood, reduces appetite

Glutamic acid CNS General excitatory brain

 neurotransmitter

GABA CNS General inhibitory brain

and Glycine neurotransmitters

Endorphin CNS Feelings of euphoria

 Pain reduction

Table 7.7

**Nervous system Page 9**

Action potential

The electrical nerve signal that travels through the axon

• Resting neurons (neurons that are not carrying a signal) have an

 electrical potential (voltage) of –70 millivolts (mV)

 √ This is due to removal of Na+ ions from inside the neuron

 √ There are more K+ ions inside the neuron than outside, and

 more Na+ ions outside the neuron than inside (due to the

 sodium-potassium pump)

√ The neuron is said to be “polarized” when it is at –70 mV

 • The action potential is a change in the axon voltage from –70 mV to

 +30 mV

 √ The change in voltage is caused by voltage-gated sodium

 channels along the axon, which let Na+ ions into the neuron

 √ The neuron is said to be “depolarized” when it reaches

 +30 mV

• After an action potential has passed through a region of the axon,

 that region returns to -70 mV

 √ The change in voltage is caused by opening of voltage-gated

 potassium channels along the axon

 √ The neuron is said to be “repolarized” when it returns to

 -70 mV

• When a region of the axon has started to depolarize, it must fully complete its entire depolarization and repolarization sequence before a new action potential can begin

 √ This is called the refractory period

Figs 6.19, 7.11, 7.12, 7.13, 7.17, 7.20; Table 7.4

**Nervous system Page 10**

Voltage-gated sodium channels

 Channel proteins in the axon membrane that, when open,

allow sodium ions to flow into the axon

• When a voltage-gated ion channel opens, it always allows enough sodium ions to enter so as to make its region of the axon +30 mV

 • The voltage around the channel determines whether it is open or

 closed

√ Channels open when the voltage around them is -55 mV or

 more positive, but close when the voltage is more negative

 than –55 mV

 - 55 mV is called the threshold voltage of the channel

 • Voltage-gated sodium channels are found all along the axon

√ They are spaced closely enough together so that when one

 Na+ channel opens it creates enough positive charge to open

 The next Na+ channel, which creates enough positive charge

 to open the next Na+ channel, etc.

 - In other words, each Na+ channel that opens causes the

 next Na+ channel to pass its threshold of -55 mV

√ Therefore, whenever the first Na+ channel opens it starts a

 chain reaction that opens all the Na+ channel down the axon,

 one after another

Figs 7.12, 7.13, 7.17

**Nervous system Page 11**

Voltage-gated potassium channels

 Channel proteins in the axon membrane that, when open,

allow potassium ions to flow out of the axon

 • Potassium channels are found near each voltage-gated sodium

 channel

 • The potassium channel opens just after the nearby sodium channel

 has made the region of the axon +30 mV

• The exiting of K+ ions from the axon return the voltage to –70 mV

Figs 7.19 and 7.20

**Nervous system Page 12**

Excitatory and inhibitory neurotransmitters

 • Excitatory neurotransmitters promote an action potential in the post-

 synaptic neuron

 • Inhibitory neurotransmitters inhibit an action potential in the post-

 synaptic neuron

Receptors for excitatory neurotransmitters are chemical-gated Na+ ion channels

• When they bind to their neurotransmitter, they open their Na+

 channel, which allows Na+ to enter the cell

 √ This causes the postsynaptic cell to have a region of positive

 charge inside

√ Excitatory Postsynaptic Potential (EPSP) = The region of

 positive charge inside the neuron from one binding of

 excitatory neurotransmitter

√ The more excitatory neurotransmitters in the synapse, the

 more EPSPs will occur in the postsynaptic neuron

 – The total amount of positive voltage in the neuron is

 the sum of all EPSPs together

 √ If the sum of all EPSPs is enough to make the first voltage-

 gated sodium channel in the axon -55 mV or more positive,

 then the in the post-synaptic neuron will have an action

 potential

**Nervous system Page 13**

Receptors for inhibitory neurotransmitters are chemical-gated Cl- ion channels

• When they bind to their neurotransmitter, they open their Cl-

 channel, which allows Cl- to enter the cell

 √ This causes the postsynaptic cell to have a region of negative

 charge inside

√ Inhibitory Postsynaptic Potential (IPSP) = The region of

 negative charge inside the neuron from one exposure to

 inhibitory neurotransmitter

√ The more inhibitory neurotransmitters in the synapse, the

 more IPSPs will occur in the postsynaptic neuron

 – The total amount of negative voltage in the neuron is

 the sum of all IPSPs together

 √ If the sum of all IPSPs is enough to keep the first voltage-

 gated sodium channel in the axon more negative than -55 mV

 then no action potential will occur

The sum total of all EPSPs and IPSPs is what determines whether the postsynaptic neuron will have an action potential

√ If the sum of all EPSPs and IPSPs together makes the first voltage-gated sodium channel in the axon -55 mV or more positive, then the action potential occurs

√ If the sum of all EPSPs and IPSPs together keeps the first voltage-gated sodium channel in the axon more negative than

-55 mV then no action potential occurs

Figs 7.24, 7.25, 7.32, 7.33, 7.34

**Nervous system Page 14**

Central nervous system (CNS)

 The brain and the spinal cord

 • The brain and spinal cord are surrounded by cerebral spinal fluid

 (CSF)

 √ Ventricles = Hollow areas in the brain filled with CSF

Figs 8.1 and 8.4

Regions of the CNS:

 • White matter = Areas containing mylenated axons

 √ Tract = A bundle of axons in the CNS

 • Gray matter = Areas of CNS containing cell bodies and dendrites

 √ Nuclei = A cluster of cell bodies in the CNS

• The brain has four major regions: The cerebrum, the diencephalon,

 the brain stem, and the cerebellum

Cerebrum

The largest and most superior brain region

• The cerebrum has many functions, including sense perception,

 muscle movements, emotion, memories and “higher functions” such

 as language, social behavior, logic, and mental images

Fig 8.6

**Nervous system Page 15**

Regions of the cerebrum:

• The cerebrum is gray matter on its cortex (surface) but is mostly

 white matter below the surface

 √ Basal nuclei = Small regions of gray matter deep within the

 white matter

 • Cerebral hemispheres = The left and right halves of the cerebrum

 √ The hemispheres are mirror images of each other; most

structures and functions in one hemisphere are found in the matching location in the other hemisphere

 - Cerebral lateralization: Structures and functions that are

 only in one hemisphere

√ Corpus calosum = A large tract that connects the two hemispheres, allowing them to communicate with each other

 • Cerebral lobes = Areas of the cerebrum named after the cranial

 bones that cover them.

 √ The frontal lobe, the parietal lobe, the temporal lobe, and the

 occipital lobe

Figs 8.5, 8.6, 8.11, 8.12, 8.13, and 8.14

Sense areas of the cerebrum

 Areas that receive nerve signals from sensory neurons and allow us to

experience the sense

• There are separate sense areas for vision, gustatory (taste), olfactory

(smell), hearing, and touch (the “primary sensory area”)

Figs 8.6 and 8.7

**Nervous system Page 16**

The primary motor area

The area of the cerebrum where voluntary motor signals (signals that control voluntary muscle movements) are generated

• The movements generated by the primary motor area are not smooth and coordinated. Its motor signals are refined by other brain areas (the substancia nigra and the cerebellum) for normal smooth movement to occur

Fig 8.7

The limbic system

A group of cerebral areas that cause feelings of emotion (such as

anger, fear, sadness, and happiness, and pleasure) as well as sex drive

and hunger

√ The thalamus (in the diencephalons brain region) works with

 the limbic system to generate many of these feelings

 • Two important regions of the limbic system are the hippocampus

 and the amygdala

 √ The amygdala specializes in fear

 √ The hippocampus specializes in several emotions, and also

 converts short term memories into long term memories

Fig 8.15

**Nervous system Page 17**

Other areas of the cerebrum

 • Areas of the frontal lobe allow us to control impulses, act socially,

 and provide motivation for actions

• The left hemisphere has areas that specialize in language, math, and

 using logic to solve problems

 √ Examples: Broca’s Area = Area that controls movement of

 vocal organs to speak words

 Wernicke’s area = Area that matches meaning to

each word

• The right hemisphere has areas that specialize in spatial visualization

 (“mental images”) and facial recognition

Figs 8.13 and 8.14

Diencephalon

The brain region located between the cerebral hemispheres and the brain stem. It is composed of the thalamus and the hypothalamus regions

 • The thalamus = A region that routes incoming sense signals to the

 proper sense areas in the cerebrum

• The hypothalamus = A region that controls thirst, temperature, and

 sleep/wake cycles

 √ Working in conjunction with the limbic system, the

hypothalamus also regulates emotions, hunger, and sex drive

√ The hypothalamus controls the pituitary gland, a major source

 of hormones

Fig 8.20

**Nervous system Page 18**

Brain stem

A tubular region between the diencephalon and the spinal cord that controls many basic body functions

• Its three regions (from top to bottom) are the midbrain, the pons, and the medulla oblongata

 • The midbrain contains the substancia nigra area, which (working

 with the cerebellum) adds smoothness and coordination to motor

 signals

• The pons and the medulla oblongata contain respiratory control

 centers that control breathing, and control centers for heart rate and

 blood pressure

 √ The inferior end of the medulla oblongata is continuous with

 the spinal cord

Figs 8.19, 8.21, and 8.22

Cerebellum

A round region of the brain located posterior to the brain stem

 • The cerebellum gives us the ability to stand with balance, and is also

 involved in motor learning (learning movements “by heart”)

 • Working with the substancia nigra, the cerebellum adds smoothness

 and coordination to motor signals

**Nervous system Page 19**

The spinal cord

 A downward extension of nervous tissue from the brain stem

 • The spinal cord conducts most of the signals between the brain and

 the rest of the body

 √ The spine conducts motor signals downward from the brain

 and touch sense signals upward to the brain

√ The signals enter and exit the spinal cord through spinal

 nerves, located in pairs at various distances from the

 brain

 • The center of the spinal cord is gray matter (in transverse section, it

 has a butterfly shape) and white (myelinated) matter along the edges

 √ The white matter is ascending tracts (for touch

 sense signals) and descending tracts (for motor signals)

√ The gray matter contains (a) cell bodies of motor neurons, (b)

 axon terminals of sensory neurons, and (c) interneurons that

 synapse with the motor and sensory neurons

Figs 8.24, 8.25, and 8.27

**Nervous system Page 20**

Spinal nerves

 Nerves that connect to the spinal cord

• There are 31 pairs of spinal nerves

 • Spinal nerves are bundles of sensory and motor neurons

• Where each nerve connects to the spine, it splits into a dorsal root

 (on the posterior side) and a ventral root (on the anterior side)

 √ The dorsal root contains the sensory neurons

 - Dorsal root ganglion = The cluster of sensory neuron

 cell bodies in the dorsal root

 √ The ventral root contains the motor neurons

Figs 8.27 and 8.29

Reflex

 A response to stimulation that is rapid, involuntary, and predictable

 • Reflex arc = The neural pathway of a reflex

 √ All reflex arcs have sensory and motor neurons

√ Some, but not all, reflex arcs have interneurons between the

 sensory and motor neurons

Fig 8.29

**Nervous system Page 21**

Peripheral nervous system (PNS)

 All the nervous tissue outside the CNS

 • The subdivisions of the PNS:



Fig 7.3

Somatic nervous system (SNS)

 Motor neurons that control voluntary muscles

 • Each SNS signal travels by a single motor neuron to its target cell

• All SNS neurons release acetylcholine as their neurotransmitter

Fig 7.3

Autonomic nervous system (ANS)

 Motor neurons that control involuntary muscles and glands

 • The ANS mostly controls hollow internal organs

√ Examples: The heart, digestive system organs, blood vessels,

 passages in the respiratory system

 • Each ANS signal travels through two consecutive motor neurons

 to its target cell

 √ Preganglionic neuron = The first of the two neurons

 √ Postganglionic neuron = The second of the two neurons

Fig 7.3

**Nervous system Page 22**

Divisions of ANS:

 The sympathetic and parasympathetic divisions

 • They have mutually antagonistic effects on most organs:

 Stimulation by Stimulation by

 Organ: Sympathetic Parasympathetic

Heart Stronger, faster beats Softer, slower beats

 Airway

 Passages Dilate/relax Contract

 (more airflow) (less airflow)

 Digestive

Organs Less activity/relax More activity/contract

Blood Vessels in skin and *Blood vessels have no*

Vessels digestive organs contract  *parasympathetic*

 (less blood flow) *innervation*

 Vessels in skeletal muscle

 heart, lungs dilate/relax

 (more blood flow)

Tables 9.4 and 9.7

**Nervous system Page 23**

Sympathetic division

 Puts organs in mode appropriate for threatening or harmful situations

 • Ganglion usually near spine, distant from target organ

• Postganglionic neurons secrete norepinephrine as their

 neurotransmitter

• The preganglionic neurons secrete acetylcholine as their

 neurotransmitter Figs 9.9 and 9.10

Parasympathetic division

 Puts organs in mode appropriate for relaxed peaceful situations

 • Ganglion in or near target organ

 • Postganglionic neurons release acetylcholine as their

 neurotransmitter

• The preganglionic neurons release acetylcholine as their

 neurotransmitter

Figs 9.9 and 9.10

Adrenergic receptors

 Receptor proteins that bind the neurotransmitter norepinephrine and

the hormone epinephrine

• There are several types of adrenergic receptors

 1 = Found only in cardiac muscle cells. It causes stronger and

 faster heart contractions

2 = Found in some smooth muscle cells. It causes the cells

 to relax (no contractions)

1 and 2 = Found in some smooth muscle cells. It causes the

cells to contact Figs 9.8 and 9.10, Table 9.5

**Nervous system Page 24**

Nervous system disorders:

Newborns

 • Mental retardation = Failure of cerebrum to develop to its full

 potential

 √ Usually caused by chromosomal abnormalities or through

 alcohol/drug abuse by mother during pregnancy

 • Cerebral palsy = A neuromuscular disability; poorly controlled

 voluntary muscles

Any age:

 • Spinal cord injury = Leads to paralysis of all limbs controlled by

 nerves below the point of damage

 • Injuries to brain = Symptoms vary with site of damage

 √ Deterioration of mental function often begins several minutes

 after the injury (due to swelling inside cranium)

 • Alcohol/drugs = Kill brain cells; decreases brain mass

Older adults:

 • Slow loss of neurons throughout life is normal; causes mild senility

 (forgetfulness or confusion) in some seniors

 • Stroke (cerebrovascular accident) = Lack of blood to a region of

 brain due to a clogged or broken blood vessel

 √ Effects vary with part of brain affected

• Alzheimers disease = Brain neurons become engulfed and damaged

 by protein fibers

√ Causes severe senility and dementia

 √ Cause not known