KINESIOL 1Y03

17: Neurotransmission

Neurotransmission

neurotransmission: can be sending signals within neurons, sending signals between neurons, and sending signals between neurons and target tissues
AP propagation: a series of APs occurs as each voltage-gated channel is triggered along the axon, starting at the trigger zone
travelling AP: AP synapses with the target neuron > GP is created > AP is created > communicates with target via chemical signal

Propagation Types

continuous conduction: occurs with unmyelinated axons; propagates by stimulating adjacent regions, spreading from trigger zone to presynaptic terminal
saltatory conduction: occurs with myelinated axons; AP "leaps" from one node of Ranvier to the next, skipping over internodes; Na+ gates are highly concentrated, creating large and fast local currents (which also use less ATP)
absolute refractory period: prevents additional APs from being triggered in the region they came from
local current: movement of positive ions; Na+ creates local current towards inside of cell and is attracted to negative areas, triggering neighboring voltage-gated channels

Propagation Speed

axon diameter: larger diameter = more surface area = more voltage gated Na+ channels = faster local current
myelination: heavier myelination = faster local current
temperature: higher temperature = probably helps proteins in gated channels function faster = faster local current

Nerve Fiber Types

type A: large diameter, myelinated, conducts at 15-120 m/s; skeletal motor neurons and most sensory neurons
type B: medium diameter, lightly myelinated, conducts at 3-15 m/s; part of the ANS
type C: small diameter, unmyelinated, conducts at 2 m/s or less; part of the ANS, especially processes (e.g. digestion) which don't need to happen rapidly

Synapses

synapse: junction between cells that allows a presynaptic neuron to communicate with a postsynaptic neuron or target tissue
electrical synapse: found in cardiac and smooth muscle (not really in nervous system); physical channel between cytosols; AP can go in different directions, but not back on itself; important for coordinated contractions

- ***connexons***: *tubular proteins forming a physical connection between cells*
- ***gap junction***: *space between cells; ~2 nm*

chemical synapse: postsynaptic membrane forms a pocket around presynaptic terminal

- ***synaptic cleft***: *space between the postsynaptic membrane and axon*
- ***neurotransmitters***: *chemical signals which relay information*
- ***synaptic vesicles***: *produce, store, and release neurotransmitters*
- ***mechanism***: *AP arrives at presynaptic terminal > voltage-gated Ca2+ channels open > Ca2+ diffuses into cell > exocytosis of synaptic vesicles > neurotransmitter diffuses across synaptic cleft > binds to receptor site > opens ligand-gated Na+ channels > Na+ diffuses into cell > depolarization*

neurotransmitter removal: need to be able to turn the signal off

- ***diffusion***: *neurotransmitter moves down the concentration gradient, moving away from the synaptic cleft*
- ***enzymatic degradation***: *enzyme (e.g. acetylcholinesterase) is mixed into ligand-gated receptor sites, so once neurotransmitter (e.g. acetylcholine) binds, it gets broken down (e.g. into choline and acetic acid); choline is taken up into presynaptic terminal and combines with acetyl CoA to reform acetylcholine; this process is very fast*
- ***uptake by neurons or glia***: *neurotransmitter transporters bring neurotransmitter (e.g. norepinephrine) is taken back to the presynaptic terminal in its original form; can be either repackaged or broken down for other metabolic intermediates*
- ***prozac***: *serotonin reuptake inhibitor (anti-depressant)*

Postsynaptic Potentials

EPSP: excitatory postsynaptic potential; depolarization occurs, creating a stimulatory response that might generate an AP
IPSP: inhibitory postsynaptic potential; hyperpolarization occurs, creating an inhibitory effect (e.g. opening K+ or Cl- channels); can be useful in cases such as when information in the thalamus doesn't need to go onto the cerebrum
summation: several signals can be added together at the postsynaptic membrane

- ***spatial***: *several different axons (can be both EPSP and IPSP) go to the same body and release neurotransmitter independently of each other*
- ***temporal***: *several signals coming from the same axon close together in time*

summary sheet by Jasmine Ah Yong for KINESIOL 1Y03 (2022)

KINESIOL 1Y03

18: Spinal Cord/Nerves

Spinal Cord Structure

spinal cord: long structure composed of nervous tissue (neurons and glia); part of the CNS which connects brain to PNS (continuous with medulla oblongata); integrates information and produces responses; extends from foramen magnum to L2

foramen magnum: *large hole in the base of the occipital bone*

L2: *around the level of the most inferior rib of the ribcage*

regions: *divided into cervical, thoracic, lumbar, sacral, and coccygeal regions*

vertebrae: bony structures which surround the spinal cord

vertebral column: stack of vertebrae

body of vertebra: *anterior side; smooth*

spiny processes: *posterior side; pointy*

vertebral foramen: *hole in the region of the spiny processes*

vertebral canal: created by the stacked foramina; surrounds spinal cord; longer than the spinal cord proper (continues growing to ages 18-22, whereas spinal cord stops at 4-5)

meninges: connective tissue layers which surround the spinal cord and keep it in place within the vertebral canal

intervertebral foramina: openings between vertebrae; where spinal nerves exit the canal

cauda equina: "horse's tail"; nerves coming out of the bottom of the spinal cord

conus medullaris: inferior end of the spinal cord; some nerves from here travel down the vertebral canal and exit intervertebral or sacral foramina

enlargements: spinal cord diameter is not uniform; enlargements exist to create extra nervous tissue for limbs

cervical: *C4-T1; for upper limbs*

lumbosacral: *T9-T12; for lower limbs; some continue down vertebral canal and exit later*

filum terminale: extension of the pia mater; anchors spinal cord to inferior part of vertebral column (coccyx), preventing movement in the superior direction

Meninges

meninges: layers of connective tissue to provide protection; continuous with meninges of the brain

periosteum: not part of the meninges, actually; connective tissue layer on bone

epidural space: between periosteum and dura mater; filled with fat, blood vessels, and areolar connective tissue, which helps hold things in place

epidural anesthesia: *injected into this space to block pain receptors exiting certain levels of the spinal cord; targets a specific area so only part of the body is impacted*

dura mater: dense irregular connective tissue; thickest and strongest; made of the meningeal layer of the cranial dura mater

subdural space: small area between dura and subarachnoid mater; contains serous fluid

arachnoid mater: thin avascular layer of simple squamous epithelial tissue; delicate network of collagen and elastin fibers

subarachnoid space: between arachnoid and pia mater; continuous with cranial subarachnoid space; contains CSF to cushion, deliver nutrients, and remove waste products

pia mater: adheres tightly to spinal cord and contains blood vessels

denticulate ligaments: *small extensions that connect to dura mater, between each of the roots exiting the spinal cord; anchors to prevent lateral movement*

filum terminale: *anchors spinal cord to inferior part of vertebral column (coccyx); anchors to prevent vertical movement*

Outer White Matter

white matter: made of myelinated axons

posterior median sulcus: narrow groove on posterior side

anterior median fissure: deeper groove on anterior side

white commissures: connect right and left sides, which are symmetrical; one posterior and one anterior

columns: myelinated axons group into nerve tracts, which group into columns (fasciculi), which contain both ascending and descending tracts; grouped by function or target region; there is a posterior, lateral, and anterior column on each side

Inner Grey Matter

grey matter: contains neuron cell bodies, dendrites, supporting cells, axon terminals, and interneurons (shorter neurons which connect sensory and motor neurons)

shape: in central location, forms a butterfly or H shape

posterior horn: axons of the sensory neurons; can either synapse with interneurons or combine with a nerve tract and ascend/descend the spinal cord

sensory nerve bodies: *found only in the dorsal root ganglion, not here*

interneuron cell bodies: *comprise all the cell bodies here*

reflexes: *interneurons allow direct connection between somatic and sensory neurons*

lateral: neurons of the ANS; found only in thoracic and lumbar regions (very small)

anterior: motor horn; much larger; contains cell bodies for somatic motor neurons

grey commissures: axons connecting the two sides

central canal: found in the middle of the grey matter; continuous with the ventricles of the brain

Spinal Nerves

naming convention: named and numbered for the level of the vertebral canal they exit at, not based on the spinal cord itself

31 pairs: of spinal nerves; 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal

rootlets: 6-8 rootlets merge to form a spinal root

roots: passes through subarachnoid space, pierces arachnoid mater, and join together

dorsal/posterior root: *sensory neurons exiting the spinal cord; contains a dorsal root ganglion (lots of unipolar, so the cell bodies are an extension of the axon and get bundled here)*

ventral/anterior root: *motor neurons entering the spinal cord*

spinal nerve: formed from merged roots

Nerve Pathways

sensory (afferent): sensory receptor > sensory neuron > dorsal root ganglion > dorsal root > spinal nerve > posterior grey horn

somatic (efferent): descending tract > anterior grey horn > somatic motor neuron > target tissue

autonomic: anterior root > autonomic ganglion > target tissue

Spinal Damage

regional damage: damage to any particular area results in a characteristic loss of sensation or motor function
polio: polio virus attacks the cell bodies in the anterior horn and cranial nerves, causing motor loss (paralysis)
amyotrophic lateral sclerosis: ALS, Lou Gehrig; damage to motor neuron cell bodies in the brain and spinal cord, causing loss of speaking swallowing, and breathing (expected 5 year prognosis)
complete spinal cord injury: the cord is transected (cut) entirely
- ***cervical***: *causes quadriplegia (both upper and lower limbs), may require ventilator*
- ***upper thoracic***: *paraplegia (lower limbs)*

partial spinal cord injury: part of the cord has been damaged

Naming Spinal Nerves

C1: between skull and first vertebra
C1-C7: named for vertebra beneath them
C8-Co: named for vertebra above them (because there is no C8 vertebra)
sacral foramina: 4 pairs exit here; sacrum starts as individual bones but eventually fuses together
intervertebral foramina: the rest of the pairs exit here

Axon Bundling

axons: surrounded by Schwann cells
endoneurium: separates axons from each other
fasciculus: bundle of axons
perineurium: binds together fasciculi; surrounded by arteries, veins, adipose, and loose connective tissue
spinal nerve: bundle of fasciculi
epineurium: binds together spinal nerve; dense connective tissue layer; continuous with dura mater

Rami

ramus: branch of spinal nerve; redistributes axons so the nerves tat reach target tissues carry impulses from several different levels of the spinal cord
dorsal ramus: innervates dorsal trunk muscles; responsible for movements of the vertebral column, and some connective tissue on the back
ventral ramus: innervates lateral and ventral skin of trunk, skin of the limbs, and muscles of skin and limbs
- ***intercostal nerve***: *in the thoracic region; controls intercostal muscles (T2-12); involved in breathing and skin of thoracic region*
- ***plexuses***: *formed by the other rami*

Spinal Nerve Functions

C1-C4: head and diaphragm movement
C4-C7: neck and shoulder movement
C6-T1: upper limb movement
T1-T12: rib movement in breathing, vertebral column movement, tone in postural back muscles
T11-L2: hip movement
L2-S3: lower limb movement

Cervical Plexus

nerves: C1-C4
description: most superior, relatively small; some run parallel to cranial nerves (including XII)
function: innervate superficial neck structures, skin of neck, and posterior portion of head
phrenic nerve: C3-C5; innervates the diaphragm

Brachial Plexus

nerves: C5-T1
structure: 3 trunks > 6 divisions > 3 cords > 5 branches
3 trunks: upper (C5-6), middle (C7), and lower (C8-T1)
6 divisions: 3 posterior divisions, 3 anterior divisions
3 cords: posterior cord, lateral cord, and medial cord
5 branches: named for the structure they innervate; listed from superior to inferior
- ***axillary***: *from posterior; deltoid and teres minor (shoulder)*
- ***radial***: *from posterior; posterior aspect of arm and forearm*
- ***musculocutaneous***: *from lateral; flexors of forearm (e.g., biceps brachii)*
- ***median***: *from lateral and medial; most of the anterior forearm, some hand muscles (thumb)*
- ***ulnar***: *from medial; forearm and most of the hand muscles*

Lumbar Plexus

nerves: L1-L4
structure: not very much mixing
major nerve: obturator (most inferior) and femoral (just superior to obturator)
function: supplies lateral abdominal walls, external genitals, and parts of the lower limbs
lumbosacral plexus: lumbar plexus and sacral plexus are often grouped together; L4 is found in both plexuses

Sacral Plexus

nerves: L4-S4
major nerves: common fibular (peroneal; superior) and tibial (inferior)
sciatic nerve: peroneal and tibial nerves are bound together by a sheath; largest peripheral nerve in the body
function: supplies much of the muscle and skin of the lower limbs

Coccygeal Plexus

nerves: S5-Co
function: innervates muscles of the pelvic floor; provides sensory information from skin over the coccyx

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19: Autonomic NS

Autonomic Nervous

autonomic nervous system: diverse range of connections to organs; often important for maintaining homeostasis
dual innervation: many organs are innervated by both sympathetic and parasympathetic nerves, which allows tight regulation
target tissues: smooth muscle, cardiac muscle, glands
importance: used in reflex loops; sense organ function and then coordinates neural responses
afferent PNS: has somatic/autonomic divisions for consciously vs. unconsciously perceived (visceral) sensations
reflexes: created by direct link between visceral sensory input and ANS motor responses

baroreceptors: *detect stretch in walls of larger arteries (e.g., carotid) to determine blood pressure*
high BP: *glossopharyngeal nerve > integration at MO > vagus nerve > wall of heart > short postganglionic neuron > release acetylcholine > decrease heart rate > decrease BP*
low BP: *MO > sympathetic chain > sympathetic nerve > wall of heart > releases norepinephrine > increases heart rate and force of contraction > increase BP*

Somatic Motor

structure: myelinated, one-neuron system
function: creates excitatory responses; there is no 'relax' signal
pathway: cell bodies (anterior horn of spinal cord) > ventral root > spinal nerve > effector > release acetylcholine > muscle contraction

Autonomic Motor

structure: two-neuron system
preganglionic neuron: cell bodies inside CNS, with nuclei of brainstem or lateral horn of spinal cord; always myelinated
postganglionic neuron: extends from synapse to the target tissue; always unmyelinated
function: can be either excitatory or inhibitory
pathway: preganglionic neuron > release acetylcholine > ventral root > spinal nerve > autonomic ganglion > release acetylcholine or norepinephrine
divisions: sympathetic, parasympathetic, and kinda sorta maybe enteric

Sympathetic Division

thoracolumbar division: another name for sympathetic, due to locations of neurons in the CNS
function: fight or flight; 4 E's (emergency, embarrassment, excitement, excercise)
mechanisms: increased heartrate, blood pressure, force of heart contraction, pupil dilation, blood flow to skeletal muscle and heart, airway diameter, and blood glucose concentration; decrease blood flow to nonessential regions (e.g., gut)
impacts: lasts longer and is more widespread; motor pathways diverge to many effectors, norepinephrine takes longer to deactivate, and adrenal medulla secretes norepinephrine when stressed
pathway: lateral horn of spinal cord (T1-L2) > ventral root > spinal nerve
sympathetic chain/trunk ganglia: vertical chains on either side of the vertebral column

structure: *collection of postganglionic cell bodies close to spinal cord, which connect to each other to form two chains on each side*

prevertebral/collateral ganglion: postganglionic cell bodies closer to the effectors

Main Sympathetic Routes

exit via spinal nerve: sympathetic chain > vertically along chain > postganglionic body > postganglionic axon > anterior ramus

effectors: *skin (neck, trunk, limbs), sweat glands, smooth muscle (blood vessels, erector pili of skin - makes hair stand up and creates goosebumps)*

exit via sympathetic nerve: sympathetic chain > sympathetic nerve

effectors: *organs of the thoracic cavity (heart, lungs)*

exit via splanchnic nerve: sympathetic chain > down chain > splanchnic nerve > collateral ganglia > postganglionic neuron

effectors: *abdominopelvic cavity (e.g., GI tract)*

synapse with adrenal medulla: adrenal medulla > specialized cells

adrenal medulla: *center of adrenal gland*
"second neuron": *modified cluster of postganglionic cell bodies*
structure: *no dendrites or axons, but cells are stimulated to release epinephrine and norepinephrine, which travel through the body as hormones*

Parasympathetic Division

craniosacral division: another name for parasympathetic, due to locations of cell bodies associated with nuclei of cranial nerves III, VII, IX, and X; and the lateral grey horn of the sacral region (S2-S4)
function: rest and digest; SLUDD (salivation, lacrimation, urination, digestion, defecation)
mechanisms: decreases heartrate, diameter or airway, and pupil diameter
impacts: more localized effects
pathway: preganglionic axons > terminal ganglia > postganglionic axons
CN III: ciliary muscles of eye, sphincter pupillae
CN VII: stimulates lacrimal, salivary, and nasal secretion glands
CN IX: stimulates parotid salivary gland
CN X: stimulated heart, pulmonary system, GI tract (up to midpoint of colon)
pelvic splanchnic nerves: S2-S4; smooth muscle and glands of colon (from midpoint on), bladder, and reproductive organs

Cholinergic Receptors

acetylcholine: neurotransmitter secreted by sympathetic preganglia, sweat glands, and all parasympathetic; inactivated by acetylcholinesterase
nicotinic: excitatory; opens Na+ channels

locations: *cell bodies of all postganglionic neurons, and on the plasma membrane of skeletal muscles (neuromuscular junction)*

muscarinic: excitatory or inhibitory; stimulates G-protein signaling pathway

locations: *plasma membrane of all parasympathetic effectors, some sympathetic*

Adrenergic Receptors

norepinephrine: neurotransmitter secreted by sympathetic postganglia (other than sweat glands); inactivated by monoamine oxidase
adrenergic receptor: can bind norepinephrine or epinephrine
classes: alpha and beta
function: A1/B1 receptors are excitatory; A2/B2 receptors are inhibitory (most of the time; depends on receptor and tissue)

NT Pathways

nicotinic: nicotinic receptors > excitatory response
muscarinic: nicotinic receptors > either excitatory or inhibitory
adrenergic: nicotinic receptors > either excitatory or inhibitory

General Comparison

number of motor neurons: single in somatic, 2 in autonomic
ganglia: close to effectors in parasympathetic, close to spinal cord or abdominal arteries in sympathetic
cooperative effects: several organs can be stimulated to work together (e.g., pancreas secretes digestive enzymes and smooth muscle of small intestine contracts)
paradoxical fear: when you feel there's no way to win; creates mass action effect in parasympathetic system, leading to accidental urination and defecation
hypothalamus: control center of ANS; coordinates activity of parasympathetic and sympathetic systems to ensure efficient and balanced responses

Enteric System

function: provides innervation to digestive tract
structure: composed of nerve plexuses in the walls of digestive tracts, containing both cell bodies and axons
points of input: 3 points of nervous input
- ***sensory neurons****: connect digestive system to CNS (sends information about homeostasis; stretch, chemical composition, etc.)*
- ***autonomic motor neurons****: connect CNS to digestive system (controls smooth muscles and gland secretions)*
- ***enteric neurons****: control autonomic reflexes without input from CNS (uses local reflex loops); found only in plexus proper*

interneurons: connect sensory and motor neurons for fast responses to sensory information

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iii: Spinal Injury

Spinal Cord Anatomy

vertebrae: protects the spinal cord; has holes for peripheral nerves to come out
meninges: surround the spinal cord
shape: spinal cord has variations in thickness and curvature
myelination: contains both white and grey matter
roots: spinal nerves are connected to the spinal cord via a dorsal root and ventral root

Dermatome Mapping

dermatome: region of skin that contains sensory nerves originating from a single spinal nerve root
Dexter's injury: between C5-C6; his sensation cuts off at the clavicle (~C5), he can't feel his extremities (C6-8), he can feel parts of his arm (C5)

Protective Plexuses

plexus: helps organize nerves and protect them from harm
protection: fluids and vertebrae help protect the plexuses
blood plexuses: arteries and veins split into smaller capillaries to produce plexus-like blood channels; allows continued blood flow even if one becomes damaged or clogged
cervical plexus: nerve connections to head, neck, and shoulder
brachial plexus: nerve connections to chest, shoulders, upper arms, forearms, hands

- ***dorsal scapular nerve***: *from ventral C5; goes to levator scapulae and rhomboid muscles*
- ***long thoracic nerve***: *motor nerve to serratus anterior muscle (pulls scapula forward around the thorax)*

lumbar plexus: back, abdomen, groin, thighs, knees, calves
sacral plexus: pelvis, buttocks, genitals, thighs, calves, feet (anterior L4-5, S1-4)
coccygeal plexus: anterior S4-5, Co

Spastic Paralysis

reflexes: do not go back to the brain, so not impacted in the same way
paralysis: muscle contraction requires a strong signal; spinal injury impedes the ability for the CNS to send the signal
localized damage: some nerves may be able to function since they are not damaged, and may be able to stretch or contract a bit, but not much
spasticity: caused by damage or disruption to the area of the CNS responsible for controlling muscle and stretch reflexes; imbalance in inhibitory and excitatory signals may lock muscles in place
upper motor neuron syndrome: motor control changes following an upper motor neuron lesion (damage to motor neurons above nuclei of cranial nerves or anterior horn cells of the spinal cord

- ***symptoms***: *weakness, spasticity, clonus, hyperreflexia*

Respiration

thoracic nerves: T1-12; rib movement
phrenic nerve: C3-5; diaphragm movement
high cervical: C3 and above; injuries here may require long-term ventilation
C3-C5: may or may not require ventilatory support
below C5: may be able to breathe independently

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