TERMS

Autonomic Ganglia - clusters of neuron cell bodies that relay sensory signals from the body's periphery to the central nervous system (CNS) integration centers

Diffusion - the process of movement of molecules under a concentration gradient

Neurons - pecialized nerve cells designed to transmit electrical signals over long distances

Membrane Potential - a separation of opposite charges across the plasma membrane

Leak Channels - permit ions to flow down concentration gradients

Concentration Gradient - Na+/K+ ATPase establishes the unequal distribution of Na+ and K+ ions inside and outside of the cell

Depolarization - change in membrane polarization to more positive values than resting membrane potential

Hyperpolarization - change in membrane polarization to more negative values than resting membrane potential

Action Potential - a rapid, all-or-nothing reversal in membrane potential (spike), lasting about 1 millisecond, hat is brought about by rapid changes in membrane permeability to Na+ and K+ ions

Repolarization - return to resting membrane potential after depolarization

Propagation occurs when an AP spreads as the locally generated depolarizing current moves to adjacent regions of the membrane causing it to depolarize

Myelin - multilayered sheath made of plasma membrane, produced by specialized glial cells, that wraps around axonal fibers. It serves as an insulator, facilitating the efficient flow of electrical signals

TERMS (cont)

Graded Potentials - ocal changes in membrane potential that decrease in strength as they travel over short distances. The magnitude of a graded potential typically correlates with the size of the stimulus.

Synapse - junction between two neurons, or between a neuron and a muscle or gland that enables one cell to electrically and/or biochemically influence another cell

Convergence - the synaptic input of many neurons onto one neuron

Divergence - the synaptic output of one neuron onto many neurons

Synaptic transmission - the primary means of rapid inter- neuronal communication in the brain

Thalamus - sensory relay station and is important in motor control

Hypothalamus - regulates many homeostatic functions (Circadian rhythms, thermoregulation)

Brain Stem - vital link between the spinal cord and higher brain regions

Sensory System - 6 major sensory systems in the mammalian brain, each is organized according to a common anatomical plan.

Receptors - stimuli are transduced by receptors grouped together to form a sensory surface

Transduction - the conversion of stimulus energy to a neuronal signal

Auditory Receptors - hair cells located in cochlea

Somatosensory Receptors - specific receptors for different modalities/sensations

Lateral Inhibition - inhibition of adjacent neurons in a map; facilitates localization of stimuli/sharpen contrast

Spinal Cord - each segment contains motor neurons that project to specific skeletal muscles on the same (ipsilateral) side of the body, via ventral roots

TERMS (cont)

Neuromuscular Junction - motor neurons and skeletal muscle fibers are chemically linked at

Spinal Reflexes - simple neuromuscular circuits that mediate reflex responses to sensory stimuli

Central Motor System - system of neural structures that carry out specific controls of the skeletal musculature

Limbic System - roup of cortical and subcortical structures that form an imprecise ring around the thalamus, playing a key role in emotion, motivation, learning, and memory.

Amygdala - cluster of nuclei at the front of the hippocampus; receives input and output to various subcortical and cortical structures. It plays a crucial role in regulating emotional responses, especially fear

Hippocampus - an elongated cortical structure located within the temporal lobe. It is anatomically linked to other parts of the limbic system and the cerebral cortex. It plays a key role in memory formation, spatial navigation, and can also be involved in epileptic activity

Organization of the Nervous System

Protection of CNS from injury: Cranium and vertebral column, Meninges, Cerebrospinal Fluid, Blood-Brain Barrier

Brain depends on constant delivery of oxygen + glucose by the blood

Central Nervous System (CNS) --> Subconsciously regulate homeostatic responses; Experience emotions; Voluntarily control movements; Be aware of body and surroundings; Engage in other higher cognitive processes

Components of the Brai = Forebrain (Cereburm (Cerebral Cortex + Basal Nuclei/Ganglia) ; Diencephalon (Hypothalamus + Thalamus)), Cerebellum, and Brain Stem

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Organization of the Nervous System (cont)

Cerebral Cortex: Organized into layer and functional columns

Frontal Lobe --> Primary Motor Cortex ; **Parietal Lobe** --> Somatosensory Cortex ; **Occipital Lobe** --> Primary Visual Cortex ; **Temporal Lobe** --> Primary Auditory Cortex

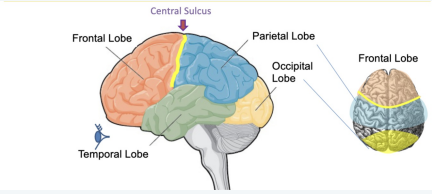
Thalamus = "Relay station" for preliminary processing of sensory input

Hypothalamus = collection of specific nuclei + associated fibers that lie beneath thalamus; integrating center importnat for homeostatic functions

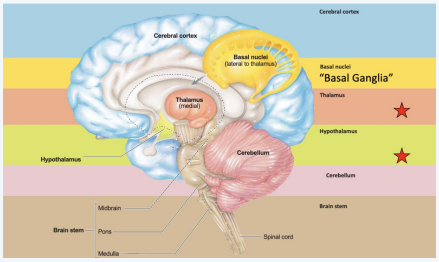
Circadian Clock (24hr Rhythms) --> Suprachiasmatic Nucleus (SCN); Body Temperature, Sleep-Wake, Blood Pressure, Hormone Levels

Brain Stem --> consist of midbrain, pons, and medulla.; MOST cranial nerves arise; regulate equilibrium and postural reflexes; cortical alertness; centers that govern sleep

Lobes of Cerebral Cortex



Thalamus + Hypothalamus



Diffusion + Membrane Potential

Diffusion Through Membrane --> Net movement due to random collisions between molecules ; Diffusion down a concentration Gradient

Diffusion + Membrane Potential (cont)

Rate of Diffusion Depends On: (1) Magnitude:↑ concentration gradient, ↑ rate of diffusion (2) Permeability: ↑permeability, ↑rate of diffusion (3) Surface Area: ↑surface area, ↑ rate of diffusion (4) Molecular Weight: ↑ molecular weight, ↓ rate of diffusion (5) Distance: ↑ distance , ↓ rate of diffusion

Nonpolor Molecules (O_2, CO_2, fatty acids) = Chemical Gradient **Small Ions** ($Na+$, $K+$, Ca^{2+}, Cl^-) = *Chemical Gradient + Electrical Gradient* = electrochemical Gradient

Plasma membranes of ALL living cells have a **membrane potential (Vm)**/polarized electrically

Across Membrane, most fluid is electrically neutral; separated charges forming a layer along plasma membrane

GREATER the separation of charges across membrane --> **LARGER** the potential

Equilibrium Potential for K^+ --> (1) K^+ tends to move out of the cell (2) Outside of the cell becomes more positive (3) Electrical gradient tends to move K^+ into the cell (4) Electrical gradient counterbalances concentration gradient (5) No further net movement of K^+ occurs (6) E_{K^+} = -90mV

Equilibrium Potential for Na^+ --> (1) Na^+ tends to move into the cell (2) Inside of the cell becomes more positive (3) Electrical gradient tends to move Na^+ out of the cell (4) Electrical gradient counterbalances concentration gradient (5) No further net movement of Na^+ occurs (6) E_{Na^+} = +60mV

Resting Membrane Potential (-70mV): Membrane more permeable to K^+ than Na^+; Large; Large net diffusion of K^+ and Small net diffusion of Na^+

Na/K ATPase --> Establishes and maintains concentration gradient ; Pumps *3 Na^+ OUT of the cell* for every *2 K^+ pumped INTO the cell* = **Na^+ is higher outside** the cell and **K^+ is higher inside** of the cell

Diffusion + Membrane Potential (cont)

Na^+ = **LOW** intracellular concentration K^+ = **HIGH** intracellular concentration

Resting Potential neither K^+ nor Na^+ is at equilibrium potentials and remain constant at resting state.

Vision

Sensory Motor Transformation (cycle): Brain --> Motor Outputs --> Body --> Sensory Inputs --> Brain

Organization: Receptor --> Relay Nuclei --> Thalamus --> Primary Cerebral Cortex --> Secondary Cerebral Cortex

Retina: photoreceptors, bipolar cells, ganglion cells, horizontal cells, amacrine cells; light passes theough retina before contract with photoreceptors in the back of the eye

Blind Spot = Optic Disc

Macula = Location of Fovea; bipolar and ganglion cell layers are pulled aside so light strikes photoreceptors directly

Phototransduction --> (1) Light activates rhodopsinRhodopsin activation causes the cGMP phosphodiesterase activation (3) Rhodopsin activation decreases cGMP, closes cGMP-gated Na+ channel (4) Membrane hyperpolarizes

Photoreceptors: **Rods**--> sensitive to very low light, LOW acuity + peripheral vision, and do not distinguish between different wavelengths of light; **Cones**--> sensitive to bright light; HIGH acuity in central field vision (fovea); distinguish between different wavelengths of light

Color Perception --> Blue, Green, and Red Cone

Optics of Eye - lens inverts and focuses the visual stimulus onto the surface of the retina

Thermosensation/Nociception --> Prevents us from being burned; influence decisions about environment and clothing

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Auditory

External Ear - pinna, external auditory meatus, tympanic membrane

Middle Ear - tympanic membrane, ossicles, oval window

Inner Ear - oval window, cochlea, vestibular apparatus, round window

Mechanograph is a stretch receptor that respond to mechanical pressure or distortion; Stretch/Open = Depolarize AND Loosen/Close = Hyperpolarize

Sound Transduction: Sound Waves --> Vibration of Tympanic Membrane --> Vibration of Middle Ear Bones --> Vibration of Oval Window --> Fluid Movement within the Cochlea --> Vibration of Basilar Membrane --> Bending of Hair Cells --> Graded Receptor Potential --> Action Potentials Generated in Auditory Nerve --> Propagation to Auditory Cortex

Auditory Discrimination: *Pitch* discrimination depends on the region of the basilar membrane that vibrates (where) ; *Loudness* discrimination depends on the amplitude of vibration of the basilar membrane (how much)

Somatosensory Receptors --> Touch (Mechanoreceptors), Pain (Nociceptors), Temperature (Thermoreceptors), and Proprioception (Mechanoreceptors)

Touch - **Tonic Receptor** = don't adapt/adapt slowly and sustain pressure and stretch of the skin ; **Phasic Receptor** = adapt rapidly, off response, and signal changes in pressure on the skin surface

Receptive Field - each sensory neurons respond to stimulus information only within a restrictive/specific area

Acuity (discriminative ability) INFLUENCED by (1) Density of receptors (2) Receptive Field Size (3) Lateral Inhibition

Higher Brain Functions

Language Areas areas of the cerebral cortex, predominantly located in the left hemisphere in about 97% of people, responsible for language processing and production

Wernicke's Area located ventrally and posteriorly to the auditory cortex, it integrates input from the auditory, visual, and somatosensory cortices; damage to this area leads to impaired language comprehension.

Broca's Area is located in the ventral and posterior part of the left frontal lobe, it sends signals to motor regions of the cortex; damage to this area causes difficulties with speech production

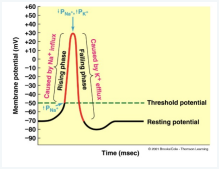
PERSONALITY --> **Prefrontal Association Areas** are in the frontal lobe, in front of the premotor regions, receiving input and sending output to various regions of the cerebral cortex; Damage to this area can lead to impairments in planning, personality, and social behavior

Phineas Gage had a tamping iron through his head and most of the front part of his left side of his brain was destroyed. **Deficits**: (1) socially unacceptable behavior (2) Unfocused (3) Lack of planning

Walter Freeman --> *"Ice-pick lobotomy"*; He used a transorbital approach to the prefontal cortex using an ice pick and a hammer. Performed under local anesthesia. The ice pick would perforate skin, subcutaneous tissue, bone and meninges in a single plunge; and then Freeman would swing it to severe the prefrontal lobe. (later seen as inhumane)

Patient HM - removal of hippocampus to treat intractable epilepsy --> RESULT: **Total Anterograde Amnesia**= couldn't form new long-term memories; slight display of retrograde amnesia= old memories until the age of the accident

Action Potentials



Action Potential (cont'd)

Rising Phase (Depolarization) = membrane polarization more POSITIVE

Voltage gated Na^+ Channel --> opens quickly (< .5 ms) in response to depolarization, allowing Na^+ to flow down its electrochemical gradient into the cell (rising phase of AP)

Falling Phase (Repolarization) = return to membrane potential after depolarization

Voltage gated K^+ Channel --> opens more slowly in response to depolarization, allowing K^+ ions to flow out of the cell down their electrochemical gradient. (falling phase of AP + after hyperpolarization))

AP Propagation--> Contiguous Conduction: propagation of action potentials in unmyelinated fibers by spread of locally generated depolarizing current to adjacent regions of membrane, causing it to depolarize; The original active area returns to resting potential, and the new activate area induces an action potential in the next adjacent inactive area. The cycle repeats itself down the length of the axon

Refactory Period -- *Absolute Refractory Period*: a brief period during a spike ; A second spike cannot be generated *Relative Refractory Period* : A brief period following a spike ; Capable of opening in response to depolarization

Refactory Period PREVENT "Backward" current flow: a region that has just experienced an action potential cannot immediately generate another one; this period ensures action potentials travel in only one direction and restricts how frequently they can occur

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Action Potential (cont'd) (cont)

Contiguous Conduction: unmyelinated fibers; touching, next to in sequence // **Saltatory Conduction**: myelinated fibers; jumping; propagation of AP in myelinated axons by jumping from node to node

Myelin = Axon --> Plasma Membrane --> Myelin Sheath

Nodes of Raniver - gaps in myelin insulation containing high densities of voltage-gated Na+ and K+ channels

Schwann Cells (PNS) - glial cells in the peripheral nervous system responsible for producing the myelin sheath around axons

Oligodendrocytes (CNS) - glial cells in the central nervous system that generate the myelin sheath around multiple axons

Graded Potentials: occur in varying grades/degrees of magnitude; die over short distances; spread by passive current flow

Synapses --> *Electrical Synapses*: neurons connected directly by gap junctions. *Chemical Synapses (most common)*: chemical messenger transmits information one way across a space separating the two neurons

Electrical Synapses formed by gap junctions (made up of multiple connexins) permits water-soluble particles to pass between cells but blocks passage of larger molecules

Chemical Synapses: Presynaptic Neurons (Convergence) --> Postsynaptic Neurons (Divergence)

Chemical Synapse --Sequence of Events --> (1) AP propagation in presynaptic neuron (2) Ca^{2+} entry into synaptic knob, terminal button (3) Release of neurotransmitter by exocytosis (4) Binding of neurotransmitter to postsynaptic receptor (5) Opening of specific ion channels in subsynaptic membrane

Action Potential (cont'd) (cont)

Synaptic Transmission = (1) Presynaptic axon initiates the signal (2) Neurotransmitter carries the signal across a synapse; binds to postsynaptic receptors (3) Postsynaptic (target cell) receives the signal (4) Postsynaptic targets can be a muscle, gland or another neuron

Excitatory Postsynaptic Potential (EPSP): Depolarizing change in membrane potential that moves the neuron closer to the threshold for firing an action potential, commonly triggered by excitatory neurotransmitters such as glutamate (Glu) and acetylcholine (ACh)

Inhibitory Postsynaptic Potential (IPSP): Hyperpolarizing change in membrane potential that moves the neuron further from the threshold for triggering an AP, typically caused by inhibitory neurotransmitters such as gamma-aminobutyric acid (GABA) and glycine (Gly)

Transmitter Removal: Degradation (enzymatic breakdown), Transport (active transport back into the presynaptic cell "reuptake), Diffusion (the transmitter simply diffuses away from the synaptic terminal)

Transmitter Release --> Tetanus Toxin (BLOCK); **Transmitter Uptake** --> Cocaine, SSRIs (PROLONG); **Transmitter Removal** --> insecticides (PROLONG); **Transmitter Binding** --> Curare (BLOCK)

Synaptic Transmission (cont'd)

Temporal Summation - the additive effect of postsynaptic potentials (PSPs) that occur in rapid succession at the same sy allowing napse, their effects to add together over time

Spatial Summation - the additive effect of multiple postsynaptic potentials (PSPs) that occur simultaneously at different locations on the same neuron

Cancellation Summation - EPSP and IPSP cancel each other

Synaptic Transmission (cont'd) (cont)

Presynaptic inhibition - the inhibition of neurotransmitter release caused by inhibitory input to the presynaptic terminal.

Motor System

Neuromuscular Junction: An action potential travels down a motor neuron to its terminal --> This electrical signal causes voltage-gated calcium (Ca^{2+}) channels in the terminal button to open, allowing Ca^{2+} to enter --> The influx of Ca^{2+} triggers the exocytosis of acetylcholine (ACh) from some of the synaptic vesicles --> ACh diffuses across the synaptic cleft and binds to specific receptor channels on the motor end plate of the muscle fiber membrane --> This binding opens nonspecific cation channels, resulting in a greater influx of sodium ions (Na^+) into the muscle cell than potassium ions (K^+) exiting --> ion movement generates an end-plate potential. Local currents then spread from the depolarized end plate to adjacent areas of the muscle membrane -> These local currents trigger the opening of voltage-gated Na^+ channels in nearby membrane regions --> Resulting Na^+ influx brings the membrane potential to threshold, initiating an action potential that spreads along the muscle fiber --> Acetylcholine is then broken down by the enzyme acetylcholinesterase, located on the motor end plate, thereby ending the muscle's response

Acetylcholine (ACh) – neurotransmitter used by motorneurons; ACh increases the membrane permeability to Na^+ leading to an EPSP called the end-plate-potential (EPP) ; Acetylcholinesterase (AChE) – enzyme that degrades ACh

Each muscle cell has only one neuromuscular junction

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