Introduction to the Nervous System

Nervous System

- Detects changes in the external environment using specialised sensors, interprets it and responds appropriately

Central Nervous System

- The body's control/ "integration" centre, information is processed, and commands are issued
- Made up by the brain and spinal cord
- Brain
    - Cerebrum
        - Telencephalon – the highest level of processing
        - Cortex – perception, decisions, memory, voluntary motor movement
        - Basal ganglia – motivation, movement
        - Amygdala – fear, emotion
        - Disorders here may cause dementia
    - Diencephalon
        - Thalamus – the "gateway" of sensory information coming from the afferent pathway of the peripheral nervous system
        - Hypothalamus – needs, autonomic
    - Midbrain
        - Mesencephalon
        - Colliculi – visual and auditory reflexes
        - *Substantia Nigra*
        - Disorders here may cause Parkinson's disease
    - Brainstem
        - Metencephalon and myelencephalon
        - Pons - motor and sensory to head
        - Cerebellum - coordination of movement
        - Medulla - breathing, heart rate
        - Disorders here may cause mood disorders
- Spinal Cord
    - Generally, handles reflex actions, i.e. not conscious
    - Monosynaptic Reflex Arc
        - A muscle is stretched and muscle spindles detect this, a sensory neuron transmits this information to the spinal cord where it synapses with an alpha motor neuron, this alpha motor neuron sends a signal to the muscle to contract and resist the stretch
        - This reflex only involves one synapse

Peripheral Nervous System

- Sensory organs, skin, muscles, glands etc.
- Delivers sensory input to the central nervous system via the afferent pathway and affects commands from the central nervous system via the efferent pathway
- Afferent Pathway
    - Inputs
    - Via special sensory organs, skin, muscle etc.
    - Sensation
        - Is unconscious, reflexive and aims to maintain homeostasis
        - E.g. the knee jerk reflex, detecting changes in oxygen etc.
    - Perception
        - Is conscious, interpretive and integrative
        - E.g. recognising a friend etc.
- Efferent Pathway
    - Outputs
    - Via muscles, glands etc.
    - Somatic Motor
        - Voluntary control of our body
        - Intentional action based on information we have received
        - Output is to skeletal muscles
        - E.g. throwing a ball etc.
    - Autonomic
        - Involuntary maintenance of homeostasis
        - Modifies the functions of our organs, has a modulatory effect where our body is more efficient in different situations
        - Output is to cardiac muscles, smooth muscles, exocrine and endocrine glands etc.
        - Includes sympathetic, parasympathetic and adrenal sympathetic pathways
        - E.g. fight or flight etc.

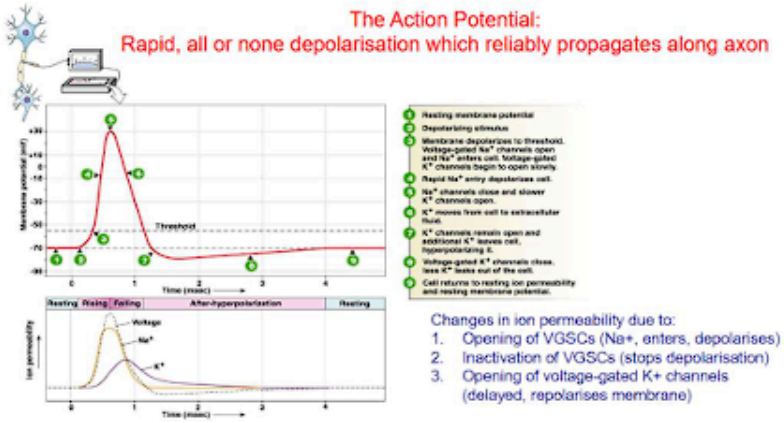
Cells of the Nervous System

- Glia
    - Physiological and structural support for neurons
    - Immune function
    - Developmental regulation
- Neurons
    - Basic functional unit of the nervous system
    - Transmits information via impulses/ action potentials and by synaptic transmission
    - Feature a cell body/ soma, dendrites (input), axon (output) and a synapse

Action Potentials and Signal Propagation

Action Potential

- In an action potential, the permeability to sodium suddenly increases and the membrane potential tends toward the equilibrium potential of sodium (+55mV)
- A stimulus begins to open voltage gated sodium channels, as the membrane rapidly depolarises, the sodium channels begin to inactivate and potassium channels begin to open, as the inward sodium current is shut off and outward potassium current increases, the cell is repolarised
- Once a stimulus reaches the "threshold" potential, the neuron will always generate the full action potential regardless of the stimulus' intensity (all or none), action potentials are always the same size and velocity for a given neuron and only the rate can change (frequency code) … action potentials cannot summate



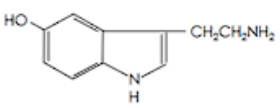
Voltage Gated Sodium Channels

- The opening of these channels briefly increases permeability to sodium, these channels are opened by a depolarising stimulus
- They exist in 3 states
    - Closed (resting membrane potential) (activation gate closed, inactivation gate open)
    - Open (when membrane depolarises to threshold) (activation gate opens)
    - Inactivated (unable to be opened (despite depolarisation)) (inactivation gate closes)

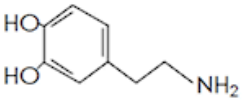
Refractory Periods

- Absolute Refractory Period
    - Voltage gated sodium channels are open/opening or inactivated
    - In this time, further action potentials can not be initiated or reverberated
- Relative Refractory Period
    - Some voltage gated potassium channels are still open
        - Slight delay from sodium channels resetting
    - In this time, the membrane is hyperpolarised, and a further action potential may be driven but requires a larger depolarising stimulus

Serotonin



indoleamine



catecholamine

Serotonin (5- HT)

- A monoamine, specifically an indoleamine featuring an indole ring (1 HO)
    - Noradrenaline, adrenaline and dopamine are also monoamines, specifically catecholamines, featuring a catechol ring (2 HO)
- It is a neurotransmitter, originally isolated from enterochromaffin cells in gastrointestinal mucosa, then from blood serum, then found in the central nervous system
- 90% of serotonin is in enterochromaffin cells of the GI tract mucosa, 0.1% is in myenteric plexus of the GI tract (excitatory), 9% is in blood platelets/plasma (released in tissue damage) and just 1% is in the central nervous system
- Synthesis
    - L- tryptophan is catalysed by *tryptophan hydroxylase* to form 5- hydroxytryptophan which is catalysed by *L- aromatic acid decarboxylase* to form serotonin/ 5-hydroxytryptamine
    - Synthesised by enterochromaffin cells in the gut and Raphe nuclei in the brain
- Storage
    - It is stored in vesicles in the presynaptic terminal, serotonin is actively transported into these vesicles by non-specific vesicular monoamine transporters (VMAT)
        - Driven by H+ electrochemical gradient generated by ATP dependent pump
    - Serotonin concentration within the vesicle is around 1.1M
    - It is stored in a way that prevents leakage out into the cytoplasm/synapse
- Release
    - Serotonin is released when the presynaptic terminal depolarises, exciting the membrane enough to open voltage gated calcium channels, allowing calcium entry, calcium promotes the fusion of serotonin filled vesicles with the membrane, then the serotonin is released via exocytosis
    - Serotonin (and noradrenaline) is also diffused via varicosities ("buds" that come off the axon) into the extracellular space, creating concentration gradients
    - Serotonin is also released when cells spontaneously "fire" and release serotonin, creating a baseline tone of release and activity in target neurons
        - Slower tonic firing allows for integration of information over a longer period
        - Rapid and discrete firing is superimposed on the baseline tone and is akin to traditional synaptic release
    - Released to the cortex, septum, hypothalamus, hippocampus, amygdala, thalamus, cerebellum, spinal cord etc.