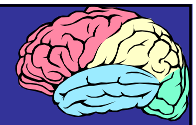
THE PERIPHERAL NERVOUS SYSTEM
BY
CHOUNNA NDONGMO W. P.

The Nervous System



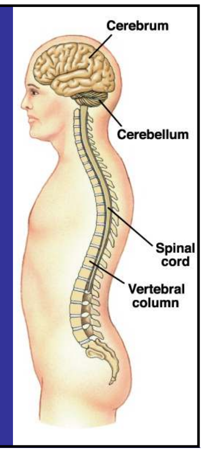
- A network of billions of nerve cells linked together in a highly organized fashion to form the rapid control center of the body.

Basic Functions of the Nervous System

1. Sensation
   - Monitors changes/events occurring in and outside the body. Such changes are known as *stimuli* and the cells that monitor them are *receptors*.
2. Integration
   - The parallel processing and interpretation of sensory information to determine the appropriate response
3. Reaction
   - Motor output.
     - The activation of muscles or glands (typically via the release of neurotransmitters (NTs))

Organization of the Nervous System

- 2 big initial divisions:
  1. Central Nervous System →
     - The brain + the spinal cord
       - The center of integration and control
  2. Peripheral Nervous System
     - The nervous system outside of the brain and spinal cord
     - Consists of:
       - 31 Spinal nerves
         - » Carry info to and from the spinal cord
       - 12 Cranial nerves
         - » Carry info to and from the brain



Peripheral Nervous System

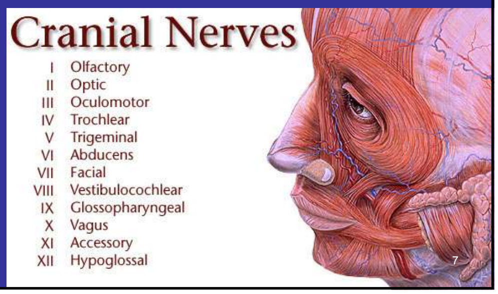
- Responsible for communication between the CNS and the rest of the body.
- Peripheral nerve fibres consist of endoneurium, perineurium and epineurium
- Divided into:
  - Sensory Division (Afferent division)
    - Conducts impulses from receptors to the CNS
    - Informs the CNS of the state of the body's interior and exterior
    - Sensory nerve fibers can be **somatic** (from skin, skeletal muscles or joints) or **visceral** (from organs in the ventral body cavity)
  - Motor Division (Efferent division)
    - Conducts impulses from CNS to effectors (muscles/glands)
    - Motor nerve fibers

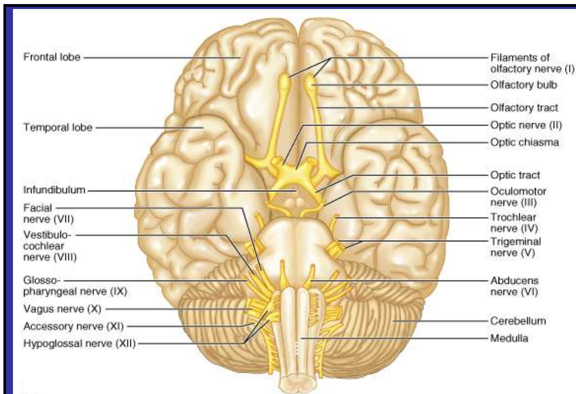
Motor Efferent Division

- Can be divided further:
  - Somatic nervous system
    - VOLUNTARY
    - Somatic nerve fibers that conduct impulses from the CNS to skeletal muscles
  - Autonomic nervous system
    - INVOLUNTARY
    - Conducts impulses from the CNS to smooth muscle, cardiac muscle, and glands.

Somatic nervous system

- Made of 12 cranial nerves

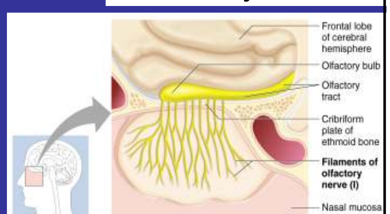


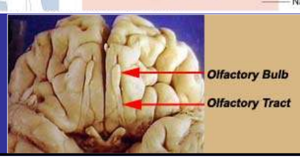


The 12 cranial nerves

CN1 Olfactory nerves

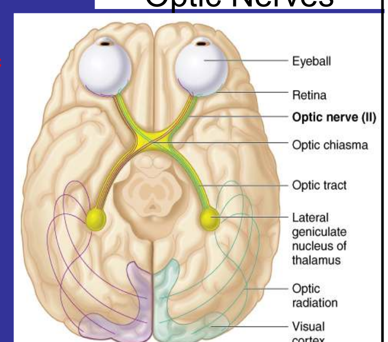
- Sensory nerve
- Run from the nasal mucosa to the olfactory bulb.
- Extend through the cribriform plate.
- Lesion to these nerves or cribriform plate fracture may yield anosmia – loss of smell.





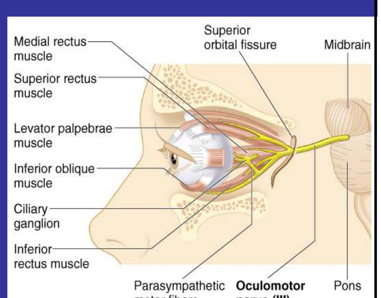
CN2 Optic Nerves

- Sensory nerve
- Begin at the retina, run to the optic chiasm, cross over, continue as the optic tract and synapse in the thalamus.
- Optic nerve damage yields blindness in the eye served by the nerve. Optic tract damage yields partial visual loss.
- Visual defects = anopia



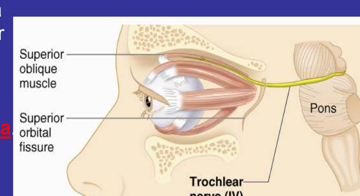
CN3 Oculomotor Nerves

- Motor nerve
- Originate at the ventral midbrain.
- Synapse on:
  - Extraocular muscles
    - Inferior oblique; Inferior, medial, and superior rectus
  - Iris constrictor muscle
  - Ciliary muscle
- Disorders can result in eye paralysis, diplopia or ptosis.



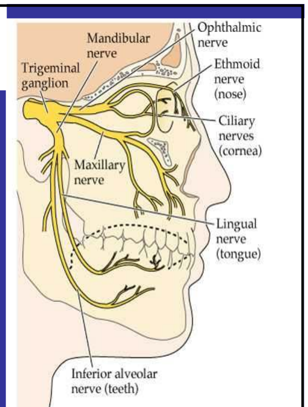
CN4 Trochlear Nerves

- Motor nerve
- Controls the superior oblique muscle which depresses the eye via pulling on the superior oblique tendon which loops over a ligamentous pulley known as **the trochlea**
- Originates on the dorsal midbrain and synapses on the superior oblique
- Trauma can result in double vision.



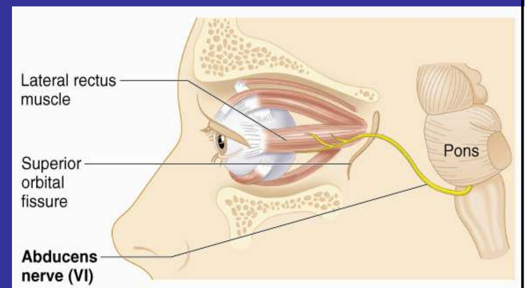
CN5
Trigeminal Nerve

- Mixed nerve
- Biggest cranial nerve
- Originates in the pons and eventually splits into 3 divisions:
  - Ophthalmic (V1), Maxillary (V2), & Mandibular (V3).
- Sensory info (touch, temp., and pain) from face.
- Motor info to muscles of mastication



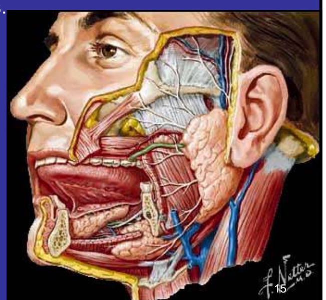
- Motor nerve
- Runs between inferior pons and lateral rectus.

CN6
Abducens Nerve



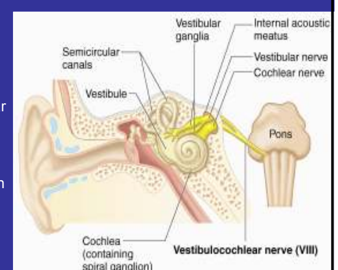
- Mixed nerve
- Originates at the pons
- Convey motor impulses to facial skeletal muscles – except for chewing muscles.
- Convey parasympathetic motor impulses to tear, nasal, and some salivary glands.
- Convey sensory info from taste buds on anterior 2/3 of the tongue.
- Facial nerve damage may yield Bell's pasy, total ipsilateral hemifacial paralysis

CN7
Facial Nerve



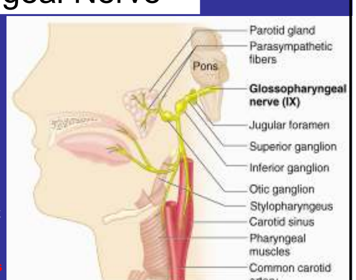
CN8
Auditory/Vestibulocochlear Nerve

- Sensory nerve
- Originates at the pons
- 2 divisions:
  - Cochlear
    - Afferent fibers from cochlea in the inner ear
    - HEARING
  - Vestibular
    - Afferent fibers from equilibrium receptors in inner ear
    - BALANCE



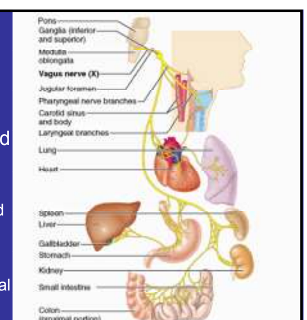
CN9
Glossopharyngeal Nerve

- Mixed nerve
- Fibers emerge from medulla and run to the throat.
- Motor Functions:
  - Motor fibers to some swallowing muscles
  - Parasympathetic fibers to some salivary glands
- Sensory Functions:
  - Taste, touch, heat from pharynx and posterior tongue.
  - Info from chemoreceptors on the level of O_2 and CO_2 in the blood. Info from baroreceptors on BP.
    - Chemoreceptors and baroreceptors are located in the carotid sinus – a dilation in the internal carotid artery.



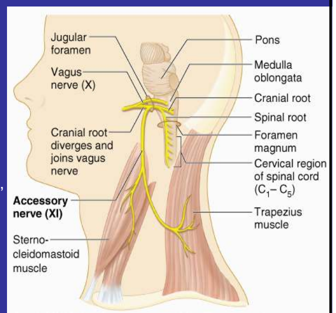
CN10
Vagus Nerve

- Mixed nerve
- Only cranial nerves to extend beyond head and neck.
  - Fibers emerge from medulla, leave the skull, and course downwards into the thorax and abdomen.
- Motor Functions:
  - Parasympathetic efferents to the heart, lungs, and abdominal organs.
- Sensory Functions:
  - Input from thoracic and abdominal viscera; from baro- and chemoreceptors in the carotid sinus; from taste buds in posterior tongue and pharynx



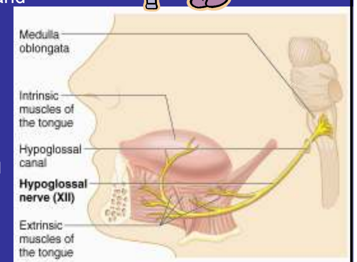
CN11 Accessory Nerve

- Motor nerve
- Formed by the union of a cranial root and a spinal root.
  - CR arises from medulla while SR arises from superior spinal cord. They then leave the skull via the jugular foramen.
  - Cranial division then joins vagus and innervates larynx, pharynx, and soft palate.
  - Spinal division innervates sternocleidomastoids and trapezius.



CN12 Hypoglossal Nerve

- Motor nerve
- Arise from the medulla and exit the skull via the hypoglossal canal and innervate the tongue.
- Innervate the intrinsic & extrinsic muscles of the tongue.
  - Swallowing, speech, food manipulation.



Spinal Nerves

- 31 pairs exist
- The pairs are named and grouped according to the vertebrae with which they are associated

  8 cervical

  12 thoracic

  5 lumbar

  5 sacral

  1 coccygeal

- Each nerve is formed by union of motor and sensory nerve root : Mixed nerves
- Spinal nerves emerging from the intervertebral foramen divide into branches or *Rami:* A ramus communicante, posterior ramus (supply skin, muscles) and anterior ramus(neck trunk)
- Plexuses: network of nerves proceeding to supply the skin, bones, muscles of a particular area: these are arranged such that injury to one spinal nerve does not cause loss of function of a region

- In the thoracic region, the anterior rami form no plexuses
- Five large plexuses of mixed nerves forming on each side of the vertebral column are:

1.Cervical plexuses

2.Bachial plexuses

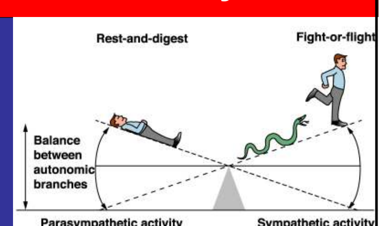
3.Lumbar plexuses

4.Sacral plexuses

5.Coccygeal plexuses

Autonomic Nervous System

- Can be divided into:
  - Sympathetic Nervous System
    - "Fight or Flight"
  - Parasympathetic Nervous System
    - "Rest and Digest"



These 2 systems are antagonistic.

Typically, we balance these 2 to keep ourselves in a state of dynamic balance.

Differences between Sympathetic and Para sympathetic nervous systems include:

Target Organ	Parasympathetic Effects	Sympathetic Effects
Eye (Iris)	Stimulates constrictor muscles. Pupil constriction. (M3 receptors)	Stimulates dilator muscles. Pupil dilates. (alpha receptors)
Eye (Ciliary muscle)	Stimulates. Lens accommodates – allows for close vision.(M3 receptors)	Relaxation (Beta-1 receptor)
Salivary Glands	Watery secretion.	Mucous secretion.
Sweat Glands	No innervation.	Stimulates sweating in large amounts. (Cholinergic receptors)
Gallbladder	Stimulates smooth muscle to contract and expel bile.	Inhibits gallbladder smooth muscle. (Beta receptors)
Errector Pili	No innervation	Stimulates contraction. Piloerection (Goosebumps)

Target Organ	Parasympathetic Effects	Sympathetic Effects
Cardiac Muscle	Decreases HR.	Increases HR and force of contraction.
Coronary Blood Vessels	Constricts.	Dilates
Urinary Bladder; Urethra	Contracts bladder smooth muscle; relaxes urethral sphincter.	Relaxes bladder smooth muscle; contracts urethral sphincter.
Lungs	Contracts bronchiole (small air passage) smooth muscle.	Dilates bronchioles.
Digestive Organs	Increases peristalsis and enzyme/mucus secretion.	Decreases glandular and muscular activity.
Liver	No innervation	No innervation (indirect effect).

Target Organ	Parasympathetic Effects	Sympathetic Effects
Kidney	No innervation.	Releases the enzyme renin which acts to increase BP.
Penis	Vasodilates penile arteries. Erection.	Smooth muscle contraction. Ejaculation.
Vagina; Clitoris	Vasodilation. Erection.	Vaginal reverse peristalsis.
Blood Coagulation	No effect.	Increases coagulation rate.
Cellular Metabolism	No effect.	Increases metabolic rate.
Adipose Tissue	No effect.	Stimulates fat breakdown.

Target Organ	Parasympathetic Effects	Sympathetic Effects
Mental Activity	No innervation.	Increases alertness.
Blood Vessels	Little effect.	Constricts most blood vessels and increases BP. Exception – dilates blood vessels serving skeletal muscle fibers (cholinergic).
Uterus	Depends on stage of the cycle.	Depends on stage of the cycle.
Endocrine Pancreas	Stimulates insulin secretion.	Inhibits insulin secretion.

Receptors

1. Cholinergic Receptors

•All cholinergic receptors work by opening ligand-gated ion channels and changing the postsynaptic potential of the target cell

•two classes

a. nicotinic receptors- occur on the postsynaptic cells, in all ganglia of the ANS, in the adrenal medulla, and in neuromuscular junctions

•All cells with nicotinic receptors are excited by ACh

b. muscarinic receptors- occur on all gland, smooth muscle, and cardiac muscles cells that receive cholinergic innervation

•some cells with muscarinic receptors are excited while others are inhibited by ACh

2. Adrenergic Receptors

•Two classes

•**alpha (α)** - usually exitatory

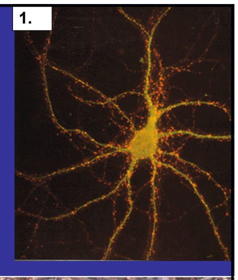
•**beta (β)** - usually inhibitory

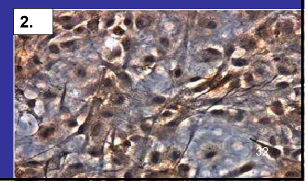
Enteric Nervous System

- Unlike the ANS, it does not arise form the brain stem or spinal cord
- Like the ANS, it innervates smooth muscles and glands
- Consist of millions of neurons embedded in the wall of the digestive tract.
- Forms two plexuses
  1. Myenteric plexus
- Lies between layers of longitudinal and circular muscles of alimentary canal
- Extends from pharynx to anus
  2. Submucosal plexus
- lies within submucosal layer of intestines, from the junction with the stomach to the anus
- Controls activity of gastrointestinal tract in three ways:
- 1) controlling intestinal peristalsis
- 2) modulating blood flow through gut
- 3) regulating the release of secretions from gastrointestinal glands

Nervous Tissue

- Highly cellular
  - Unique in that its functional unit is the neuron
- 2 cell types
  1. Neurons
     - Functional, signal conducting cells
  2. Neuroglia
     - Supporting cells

1.


2.


Neuroglia

- Outnumber neurons by about 10 to 1
- 6 types of supporting cells
  - 4 are found in the CNS and 2 in the PNS:

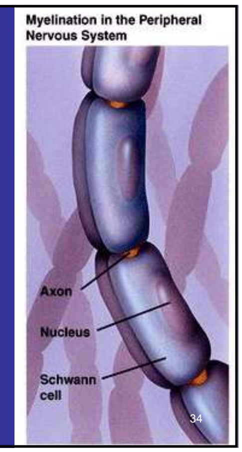
In the CNS are: Astrocytes, Microglia, Ependymal Cells, Oligodendrocytes

In the PNS are Satellite cells and Schwann cells

Neuroglia

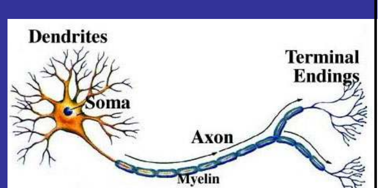
- 2 types of glia in the PNS

1. Satellite cells
   - Surround clusters of neuronal cell bodies in the PNS
   - Unknown function
2. Schwann cells
   - Form myelin sheaths around the larger nerve fibers in the PNS.
   - Vital to neuronal regeneration



Neurons

- The functional and structural unit of the nervous system
- Specialized to conduct information from one part of the body to another
- There are many, many different types of neurons but most have certain structural and functional characteristics in common:
  - Cell body (soma)
  - One or more specialized, slender processes (axons/dendrites)
  - An input region (dendrites/soma)
  - A conducting component (axon)
  - A secretory (output) region (axon terminal)



Communication

- Begins with the stimulation of a neuron.
  - One neuron may be stimulated by another, by a *receptor* cell, or even by some physical event such as pressure.
- Once stimulated, a neuron will communicate information about the causative event.
  - Such neurons are sensory neurons and they provide info about both the internal and external environments.
  - Sensory neurons (a.k.a. afferent neurons) will send info to neurons in the brain and spinal cord. There, association neurons (a.k.a. interneurons) will integrate the information and then perhaps send commands to motor neurons (efferent neurons) which synapse with muscles or glands.

Communication

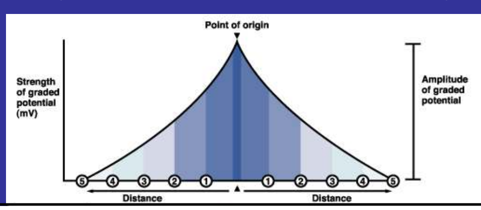
- Thus, neurons need to be able to conduct information in 2 ways:
  1. From one end of a neuron to the other end.
  2. Across the minute space separating one neuron from another. (synapse)
     - *The 1st is accomplished electrically via APs.*
     - *The 2nd is accomplished chemically via neurotransmitters.*

Graded Potentials

- Let's consider a stimulus at the dendrite of a neuron.
- The stimulus could cause Na^+ channels to open and this would lead to depolarization.
- However, dendrites and somata typically lack voltage-gated channels, which are found in abundance on the axon hillock and axolemma.

Graded Potentials

- The positive charge carried by the Na^+ spreads as a wave of depolarization through the cytoplasm (much like the ripples created by a stone tossed into a pond).
- As the Na^+ drifts, some of it will leak back out of the membrane.
  - What this means is that the degree of depolarization caused by the graded potential decreases with distance from the origin.

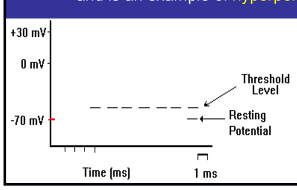


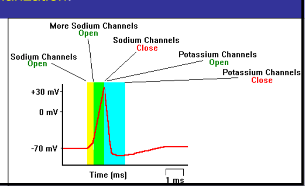
Graded Potentials

- Their initial amplitude may be of almost any size – it simply depends on how much Na+ originally entered the cell.
- If the initial amplitude of the GP is sufficient, it will spread all the way to the axon hillock where V-gated channels reside.
- If the arriving potential change is suprathreshold, an AP will be initiated in the axon hillock and it will travel down the axon to the synaptic knob where it will cause NT exocytosis. If the potential change is subthreshold, then no AP will ensue and nothing will happen.

Action Potentials

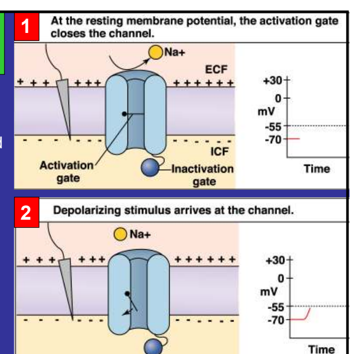
- If V_M reaches threshold, Na^+ channels open and Na^+ influx ensues, depolarizing the cell and causing the V_M to increase. This is the rising phase of an AP.
- Eventually, the Na^+ channel will have inactivated and the K^+ channels will be open. Now, K^+ effluxes and repolarization occurs. This is the falling phase.
  - K^+ channels are slow to open and slow to close. This causes the V_M to take a brief dip below resting V_M. This dip is the undershoot and is an example of hyperpolarization.

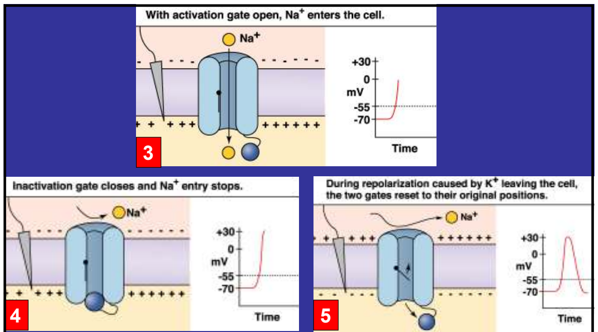




Na^+ Channels

- They have 2 gates.
  - At rest, one is closed (the activation gate) and the other is open (the inactivation gate).
  - Suprathreshold depolarization affects both of them.





Absolute Refractory Period

- During the time interval between the opening of the Na^+ channel activation gate and the opening of the inactivation gate, a Na^+ channel CANNOT be stimulated.
  - This is the ABSOLUTE REFRACTORY PERIOD.
  - A Na^+ channel cannot be involved in another AP until the inactivation gate has been reset.
  - This is why an AP is said to be unidirectional

Relative Refractory Period

- Could an AP be generated during the undershoot?
  - Yes! But it would take an initial stimulus that is much, much stronger than usual.
  - This situation is known as the relative refractory period.

Imagine, if you will, a toilet.

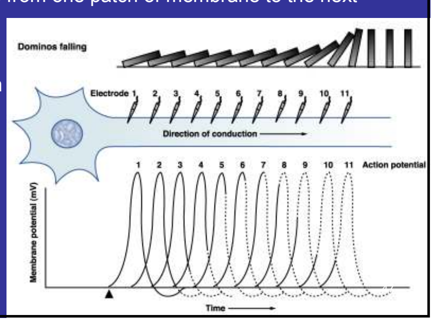
When you pull the handle, water floods the bowl. This event takes a couple of seconds and you cannot stop it in the middle. Once the bowl empties, the flush is complete. Now the upper tank is empty. If you try pulling the handle at this point, nothing happens (*absolute refractory*). Wait for the upper tank to begin refilling. You can now flush again, but the intensity of the flushes increases as the upper tank refills *(relative refractory)*

Action Potential Conduction

- If an AP is generated at the axon hillock, it will travel all the way down to the synaptic knob.
- The manner in which it travels depends on whether the neuron is myelinated or unmyelinated.
- Unmyelinated neurons undergo the *continuous conduction* of an AP whereas myelinated neurons undergo *saltatory conduction* of an AP.

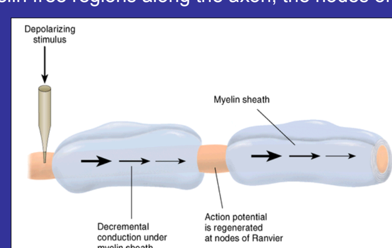
Continuous Conduction

- Occurs in unmyelinated axons.
- In this situation, the wave of de- and repolarization simply travels from one patch of membrane to the next adjacent patch.
- APs moved in this fashion along the sarcolemma of a muscle fiber as well.



Saltatory Conduction

- Occurs in myelinated axons.
- *Saltare* is a Latin word meaning "to leap."
- Recall that the myelin sheath is not completed. There exist myelin free regions along the axon, the nodes of Ranvier.



Rates of AP Conduction

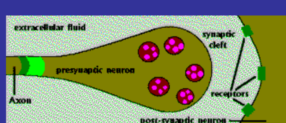
1. Myelinated axons have a faster rate of AP conduction than unmyelinated axons
2. An axon with a large diameter would conduct an AP faster than an axon with a small diameter

Types of Nerve Fibers

1. Group A
   - Axons of the somatic sensory neurons and motor neurons serving the skin, skeletal muscles, and joints.
   - Large diameters and thick myelin sheaths.
     - How does this influence their AP conduction?
2. Group B
   - Type B are lightly myelinated and of intermediate diameter.
3. Group C
   - Type C are unmyelinated and have the smallest diameter.
   - Autonomic nervous system fibers serving the visceral organs, visceral sensory fibers, and small somatic sensory fibers are Type B and Type C fibers.

Chemical Signals

- One neuron will transmit info to another neuron or to a muscle or gland cell by releasing chemicals called neurotransmitters.
- The site of this chemical interplay is known as the synapse.
  - An axon terminal (synaptic knob) will abut another cell, a neuron, muscle fiber, or gland cell.
  - This is the site of transduction – the conversion of an electrical signal into a chemical signal.

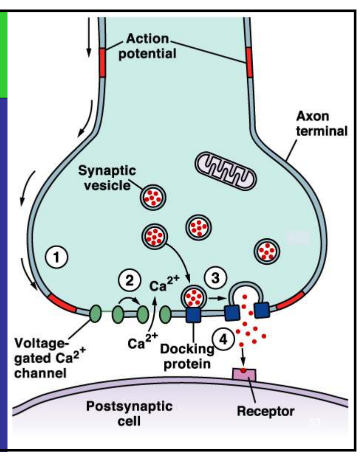


More ANS neurotransmitters

Transmitter	*Functions*
nitric oxide (NO)	parasympathetic - important in erection and in gastric emptying. Activates guanylate cyclase.
vasoactive intestinal polypeptide (VIP)	parasympathetic - co-release with ACh affects salivation; also in sympathetic cholinergic fibres. May be important throughout the gastrointestinal tract.
adenosine triphosphate (ATP)	sympathetic - blood vessels and vas deferens. Co-released with catecholamines.
neuropeptide Y (NPY)	sympathetic - facilitates effect of noradrenaline (co-released). Causes prolonged vasoconstriction.
serotonin (5HT)	important in enteric neurones (peristalsis)
gamma-amino butyric acid (GABA)	enteric.
dopamine	May mediate vasodilatation in the kidney
gonadotropin releasing hormone (GnRH)	co-transmitter with ACh in sympathetic ganglia.
Substance P	sympathetic ganglia, enteric neurones
calcitonin gene related peptide (CGRP)	contributes to neurogenic inflammation

Synaptic Transmission

- An AP reaches the axon terminal of the presynaptic cell and causes V-gated Ca^{2+} channels to open.
- Ca^{2+} rushes in, binds to regulatory proteins & initiates NT exocytosis.
- NTs diffuse across the synaptic cleft and then bind to receptors on the postsynaptic membrane and initiate some sort of response on the postsynaptic cell.



Effects of the Neurotransmitter

- Different neurons can contain different NTs.
- Different postsynaptic cells may contain different receptors.
  - Thus, the effects of an NT can vary.
- Some NTs cause cation channels to open, which results in a graded depolarization.
- Some NTs cause anion channels to open, which results in a graded hyperpolarization.


THANK YOU
55