

CNS and Anesthesia

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The Nervous System

- Central (CNS) and Peripheral (PNS)

Central nervous system (CNS)

- Nerves and associated structures within the brain and spinal cord

Brain

- Cerebrum
- Brain stem

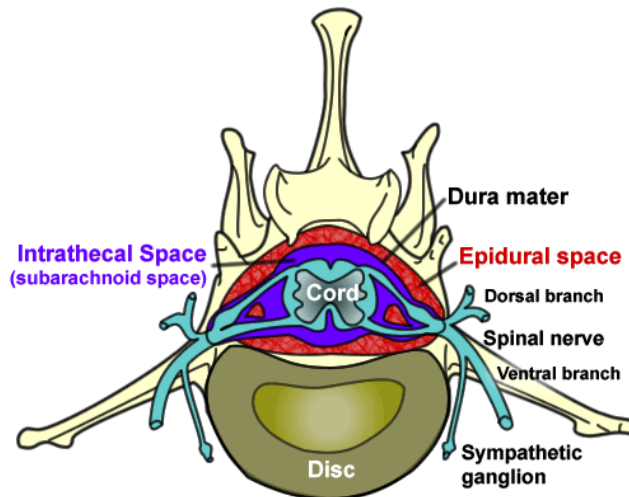
Spinal cord

- Gray matter

White matter

- Meninges; dura mater, arachnoidea, pia mater
- Epidural space
- Subarachnoid space(intrathecal space)

Figure 1. Anatomy of spinal cord



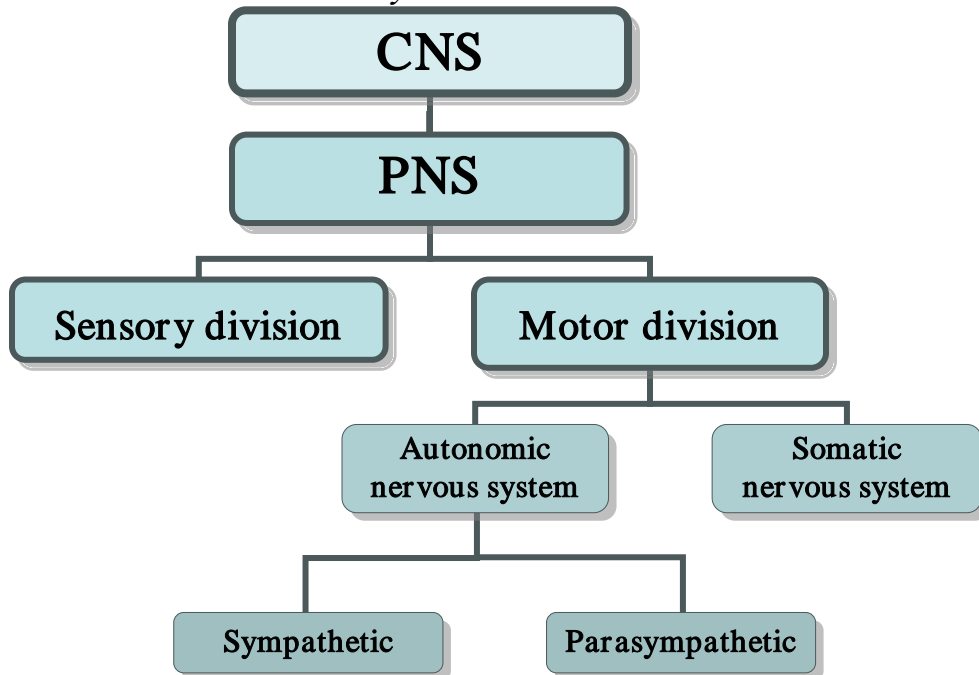
CSF

- Formed at choroid plexuses in the ventricles
- Cushioning effect
- Normal: 10 mmHg in pressure, 1.002 – 1.009 in SG, 7.32 in pH
- Increased production, decreased absorption, and/or obstruction of flow of CSF all contribute to hydrocephalus symptom

Peripheral nervous system (PNS)

- The nerves and ganglia which lie outside the brain and spinal cord.
- Cranial nerves and spinal nerves extend from the CNS to peripheral organs such as muscles, joints and glands.
- Nerves are bundles of nerve fibers, much like muscles are bundles of muscle fibers. Ganglia are collections, or small knots, of nerve cell bodies outside the CNS.
- The peripheral nervous system is further subdivided into an afferent (sensory) division and an efferent (motor) division (see figure 2)
- The efferent or motor division is again subdivided into the somatic nervous system and the autonomic nervous system.
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Figure 3. Division of the nervous system



Cranial nerves

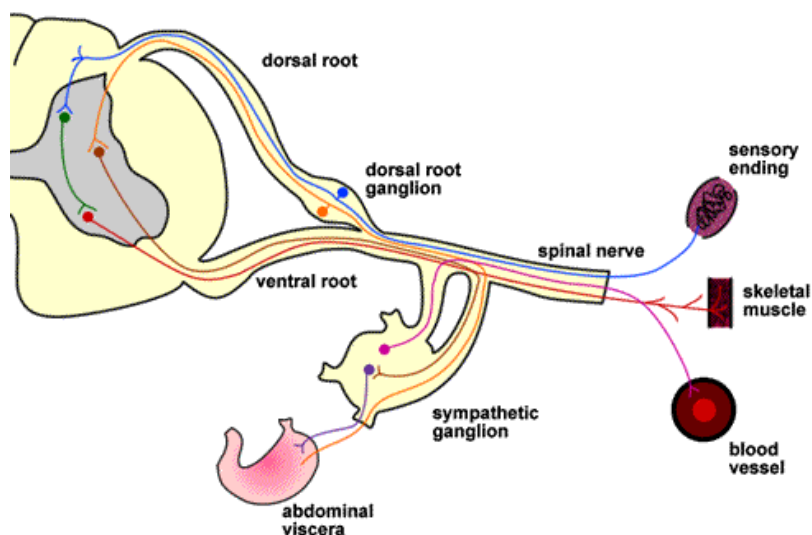
Table 1. Cranial nerves and their function

| Nerves in order | Modality | Function |
|--------------------------|-----------------|---|
| Olfactory (I) | Sensory | Smell |
| Optic (II) | Sensory | Vision |
| Oculomotor (III) | Motor | Levator palpebrae, superioris, superior, medial & inferior recti muscles |
| | Motor | Parasympathetic to ciliary and pupillary constrictor muscles |
| Trochlear (IV) | Motor | Dorsal oblique muscle |
| Trigeminal (V) | Motor | Muscles of mastication |
| | Sensory | Sensory for head/neck, sinuses, meninges, & external surface of tympanic membrane |
| Abducens (VI) | Motor | Lateral rectus muscle, retractor oculi muscle |
| Facial (VII) | Motor | Muscles of facial expression |
| | Motor | Parasympathetic to all glands of head except the parotid |
| | Sensory | The skin of external ear |
| | Sensory | Taste buds of tongue |
| Vestibulocochlear (VIII) | Special Sensory | Hearing and Balance |
| Glossopharyngeal (IX) | Motor | Stylopharyngeus muscle |
| | Motor | Parotid and zygomatic salivary glands |
| | Sensory | Carotid body and sinus |
| | Sensory | Sensation posterior one-third tongue & internal surface of tympanic membrane. |
| | Sensory | Taste posterior one-third tongue |
| Vagus (X) | Motor | Muscles of pharynx, larynx and esophagus |
| | Motor | Parasympathetic to neck, thorax, and abdomen |
| | Sensory | Sensory from pharynx, larynx and viscera |
| | Sensory | Sensory from external ear |
| Spinal Accessory (XI) | Motor | Muscles of the neck and head |
| Hypoglossal (XII) | Motor | Muscles of the pharynx, larynx and tongue |

Spinal nerves

- Begins at foramen magnum and terminates at L6/7 in dogs, at L7/S1 in cats and L6/S1 in horses.
 - Consists of ventral and dorsal roots. (see figure 3)
 - The dorsal root contains sensory neurons while the ventral root contains motor neurons.
 - Consists of white matter which forms ascending and descending pathways and grey matter that contains cell bodies

Figure 3. Components of a spinal nerve



Anatomy and function of the nerve fibers

- A neuron consists of a cell body or soma, dendrites, and a nerve fiber or axon. The axon of one neuron terminates (synapses) near the cell body or dendrites of another neuron. **Neurons** are cells that transfer stimuli to other cells.
- The larger nerve fibers are surrounded by a coat of fatty material-the myelin sheath, while the smaller nerve fibers may not be myelinated.
- The myelin lamellae are not continuous along the entire length of the fiber, being interrupted at more or less regular intervals (the nodes of Ranvier).
- Peripheral nerves are classified as A, B, and C on the basis of fiber diameter and velocity of conduction of nerve impulses (see table below).
- The largest diameter A fibers are subdivided into alpha, beta, gamma, and delta.
- A-alpha fibers innervate skeletal muscles.
- Tactile sensory receptors transmit signals in type A-beta fibers.
- A-gamma fibers are distributed to skeletal muscles.
- A-delta fibers transmit touch, temperature and fast pain.
- C fibers transmit slow pain, temperature and touch.
- A and B fibers are myelinated, whereas C fibers are unmyelinated.
- Nerve fibers are afferent if they transmit impulses from peripheral receptors to the spinal cord and efferent if they relay signals from the spinal cord and CNS to the periphery.

Table 3. Peripheral nerve classification on the basis of fiber diameter and velocity of conduction of nerve impulses

| <i>fiber</i> | <i>Anatomic location</i> | <i>Myelinated</i> | <i>Fiber diameter (μm)</i> | <i>Conduction speed (m/sec)</i> | <i>Function</i> | <i>Sensitivity to block by local anesthetics</i> |
|-----------------------------|---|-------------------|--|---------------------------------|--|--|
| C | Postganglionic sympathetic, sensory roots, and afferent peripheral nerves | No | 0.4-1.2 | 0.5 - 2 | Vasomotor, visceromotor, slow pain, temperature, touch | ++++ (highest) |
| B | Preganglionic sympathetic | Yes | < 3 | 3 -15 | Vasomotor, visceromotor | ++++ |
| A | | | | | | |
| Aδ | Sensory roots | Yes | 1-4 | 12 - 30 | Fast pain, temperature, touch, muscle tone, | +++ |
| Aγ | Efferent to muscle spindle | Yes | 3-6 | 15 - 30 | Fast pain, temperature, touch, muscle tone, | ++ |
| Aβ | Efferent and Afferent to muscles and joints | Yes | 6-22 | 30 - 70 | Motor and proprioception | ++ |
| Aα | Efferent and Afferent to muscles and joints | Yes | 6-22 | 70 - 120 | Motor and proprioception | + (lowest) |

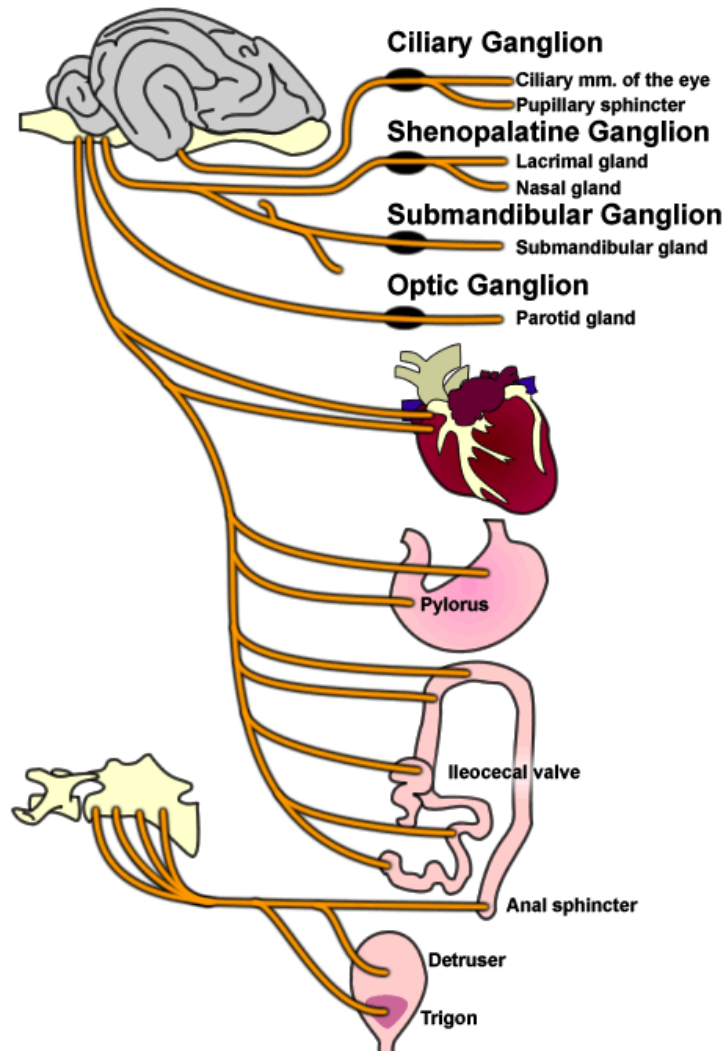
Autonomic nervous system

- It is further subdivided into sympathetic and parasympathetic divisions (see figure 3).
- Because the autonomic nervous system regulates involuntary or automatic functions, it is called the involuntary nervous system.

The Parasympathetic Nervous System (craniosacral)

- Acetylcholine is transmitter both at pre and postganglionic (muscarinic) neurons
- long preganglionic neurons, short postganglionic neurons; ganglia are diffusely spread; allows for discrete, localized innervation and control
- Vagus nerve innervates heart, lungs, esophagus, stomach, small intestine, proximal colon, liver, gallbladder, pancreas, kidneys, upper ureters
- Distribution of innervation to the heart is to the AV node, SA node, and atria (essentially none to the ventricles)
- Sacral outflow from 2nd, 3rd, and 4th sacral segments of the cord; form the pelvic nerves, and innervate the bladder, distal colon, rectum, and sexual organs

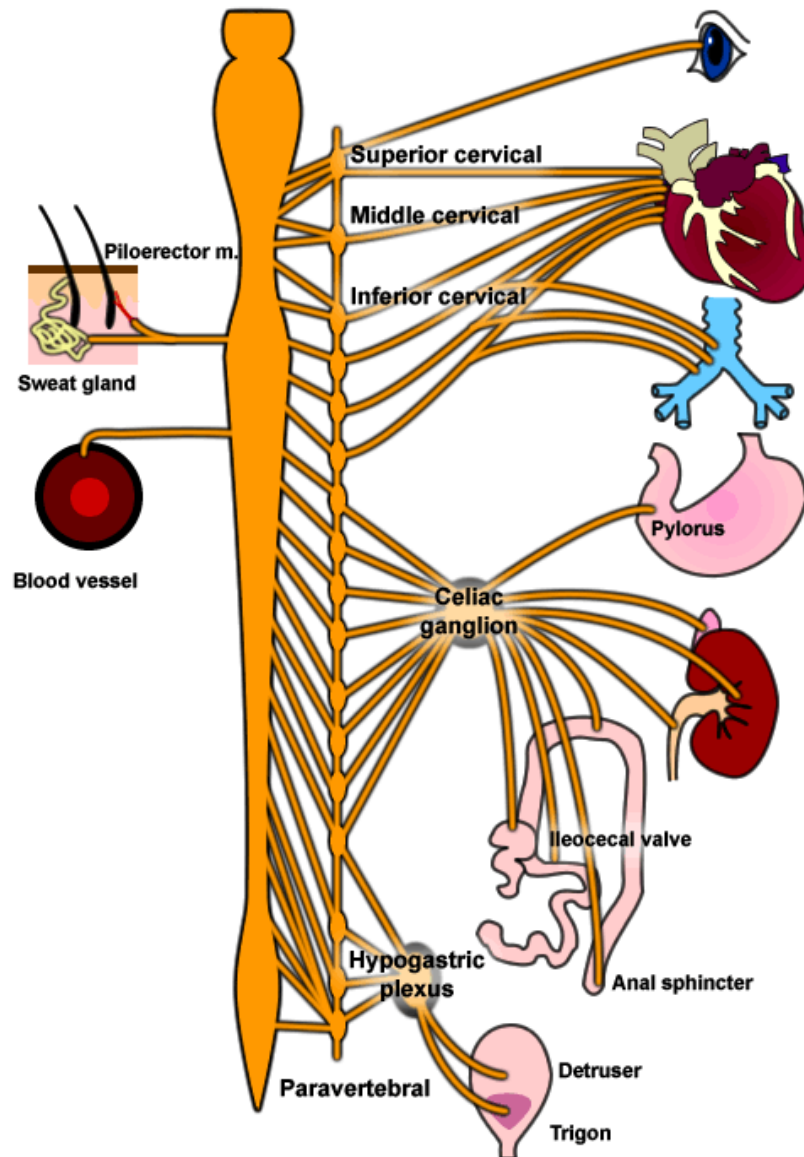
Figure 4. Parasympathetic nervous system



The Sympathetic Nervous System (thoracolumbar)

- acetylcholine is transmitter between pre and postganglionic neurons; norepinephrine is neurotransmitter between the neuron and effector cell
- sympathetic stimulation produces more generalized effects than parasympathetic stimulation
- adrenal medulla is essentially a specialized sympathetic ganglia, which functions by releasing epinephrine and norepinephrine into the systemic circulation; this results in sympathetic activation even in cells that do not have direct sympathetic innervation (but have sympathetic receptors)

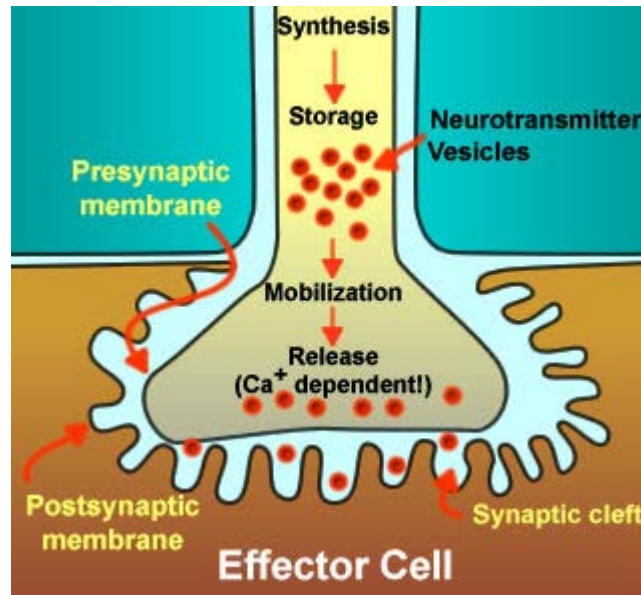
Figure 5. Sympathetic system



Neurotransmission

- A nerve impulse is an electric current that passes along an axon to the presynaptic membrane. Upon reaching the presynaptic membrane, it causes the release of neurotransmitters into the synaptic cleft.
- The neurotransmitter then interacts with receptors on effector cells to induce a response in the effector cell.

Figure 6. A nerve terminal



Neuroregulators

- Neurotransmitters are released into the synaptic cleft in response to action potentials - release is voltage dependent and requires calcium influx
- Neuropeptide modulators are released in smaller quantities than neurotransmitters in response to action potentials - they serve to amplify or dampen neural activity.

Cholinergic transmission

- Acetylcholine is the neurotransmitter
- Primary means of terminating action is break down of acetylcholine into acetate and choline by acetylcholine esterase (AChE), found principally in neurons and neuromuscular junctions
- Cholinergic receptors are present in the parasympathetic nervous system, brain, ganglia of the sympathetic nervous system, and skeletal muscle
- Two main types of receptors present
- Muscarinic (principally autonomic nervous system)
- Nicotinic (principally skeletal muscle)

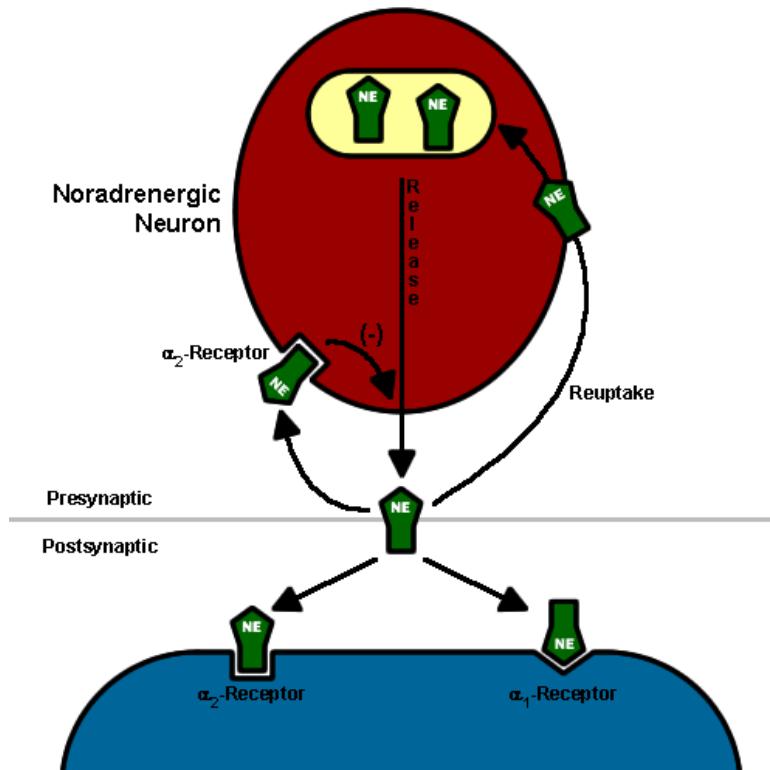
Adrenergic transmission:

- Catecholamines (dopamine, norepinephrine, epinephrine) are the neurotransmitters
- Primary means of terminating action is by neural membrane reuptake of the transmitter, although metabolism by catechol-O-methyltransferase (COMT) and monoamine oxidase (MAO) is important in some tissues.

Adrenergic receptors

- **Alpha receptors** are mainly subdivided into alpha-1 and alpha 2 receptors
- Alpha-1
 - principally found in peripheral vascular smooth muscle
- Alpha-2
 - occur both presynaptically and postsynaptically
 - those occurring presynaptically on sympathetic nerve terminals reduce the release of norepinephrine, thus producing a negative feedback loop
 - also may modulate cholinergic, serotonergic, GABA-ergic neurons
 - central alpha-2 adrenergic receptor stimulation results in sedation, analgesia, decreased sympathetic outflow, tranquilization
 - indirectly affects cardiac function by decreased sympathetic tone
 - act pre- and postjunctionally to decrease motility and secretions in the GI tract
 - produces diuresis by inhibiting ADH release, blocking ADH's effect in the renal tubule, increasing GFR, and inhibiting renin release
 - stimulate platelet aggregation
- **Beta receptors**, again, are mainly subdivided into beta-1 and beta 2 receptors
- Beta-1
 - located in the myocardium, SA node, ventricular conduction system, and adipose tissue
- Beta-2
 - vascular smooth muscle of the skin, muscles, mesentery and bronchial tree; stimulation results in vasodilation and bronchodilation
- **Dopaminergic receptors**
 - dopamine: splanchnic and renal vasodilation

Figure 7. Alpha adrenergic receptor



NANC(nonadrenergic & noncholinergic) – NO

- In the brain, spinal cord, and peripheral nervous system.
- L-Arginine and O_2 produce L- Citrulline and NO by NO synthases
- It activates guanyl cyclase to increase cGMP which leads to relaxation of smooth muscle.
- NMDA glutamate receptor activation releases NO and in turn results in excitatory neurotransmission in the CNS.
- NOS inhibitor causes dose-dependent MAC decrease

Neuromuscular junction and neuromuscular blocker (NMB)

- It consists of presynaptic nerve terminal and postsynaptic muscular membrane.
- Mainly cholinergic nicotinic receptors, two at postsynaptic and one presynaptic
- The neurotransmitter is the quaternary ammonium ester, acetylcholine
- Acetate and choline through choline acetylase form Acetylcholine at motor nerve ending
- Acetylcholinesterase at cholinergic receptors is responsible for hydrolysing Ach into Acetic acid and choline

- Choline can reenter nerve terminal to again participate in the synthesis of new acetylcholine
- Depolarizing neuromuscular blocker
 - Succinylcholine (suxamethonium in Europe), mimics the action of Ach by occupying postsynaptic nicotinic cholinergic receptor, thus depolarizing postsynaptic membrane. However, hydrolysis of Sch is slower, so postjunctional membrane does not respond to subsequently released Ach prolonging neuromuscular blockade (Phase I).
 - Side effects include hyperkalemia, hypertension, myalgia, cardiac arrhythmia, and increased intraocular pressure. Also known as a trigger for malignant hyperthermia in susceptible patients.
- Nondepolarising NMBs
 - Some examples of drugs falling into this category are pancuronium, atracurium, doxacurium, vecuronium and mivacurium.
 - These agents bind to the post synaptic nicotinic cholinergic receptors without causing any activation of ion channel permeability, and yet impeding normal postjunctional depolarization with less Ach availability at the receptor leading to the neuromuscular blockade.
 - Occupation as many as 70 % does not produce neuromuscular blockade, but 80 – 90 % occupation fails neuromuscular transmission, indicating wide safety margin of the drug.
- Clinically, a peripheral nerve stimulator is employed to assess the neuromuscular blocking effect induced with the drugs.
- Train of Four, Single Twitch, Tetanic or Double Burst Stimulation are applied to test the degree of neuromuscular transmission.

Theories of Anesthesia

- Wide range of compounds produce anesthesia, without any unifying chemical structure or activity
- We don't as yet understand how general anesthetics function
- A key concept in any theory regarding anesthetic mechanisms must be the ability of the anesthetic to disrupt cellular and intercellular communication, particularly in the CNS.
- Many hypotheses have been proposed over the years; it appears that there is expansion and fluidization of the cell membrane by anesthetic agents that result in depressed synaptic transmission, and some anesthetic agents also hyperpolarize neurons by increasing potassium permeability.
- Meyer-Overton hypothesis asserts that, anesthesia results from the presence of a certain concentration of the anesthetic at a hydrophobic site. Evidence for this has come from the fact that potency is strongly correlated with the lipid solubility of the drug.
- Critical volume theory asserts that anesthetic's direct action on proteins (ion channel proteins - nicotinic Ach, GABA, glycine, NMDA; signal transduction pathways) will induce conformation change on lipoprotein (expansion beyond the critical volume) and lead to interruption of neurotransmission by obstructing ion flux with changes of electrical conductivity in the neurons.

- The reticular activating system, a multi-synaptic structure, is believed to be the most important site within the central nervous system for anesthetic action.
- We do have an understanding of how certain classes of drugs work - those that interact with specific receptor sites.
 - opioids (eg, morphine, butorphanol)
 - alpha-2 receptor agonists (eg, xylazine, medetomidine)
 - benzodiazepines (eg, diazepam, midazolam)