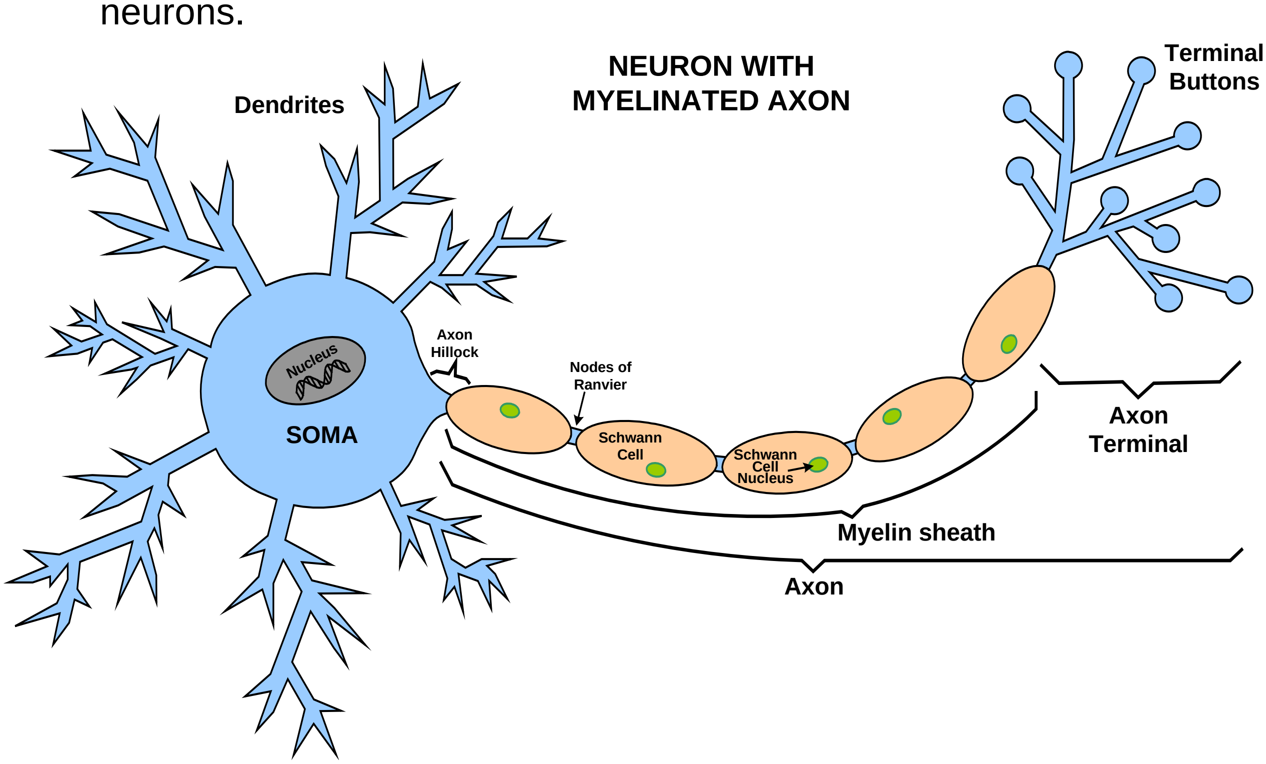
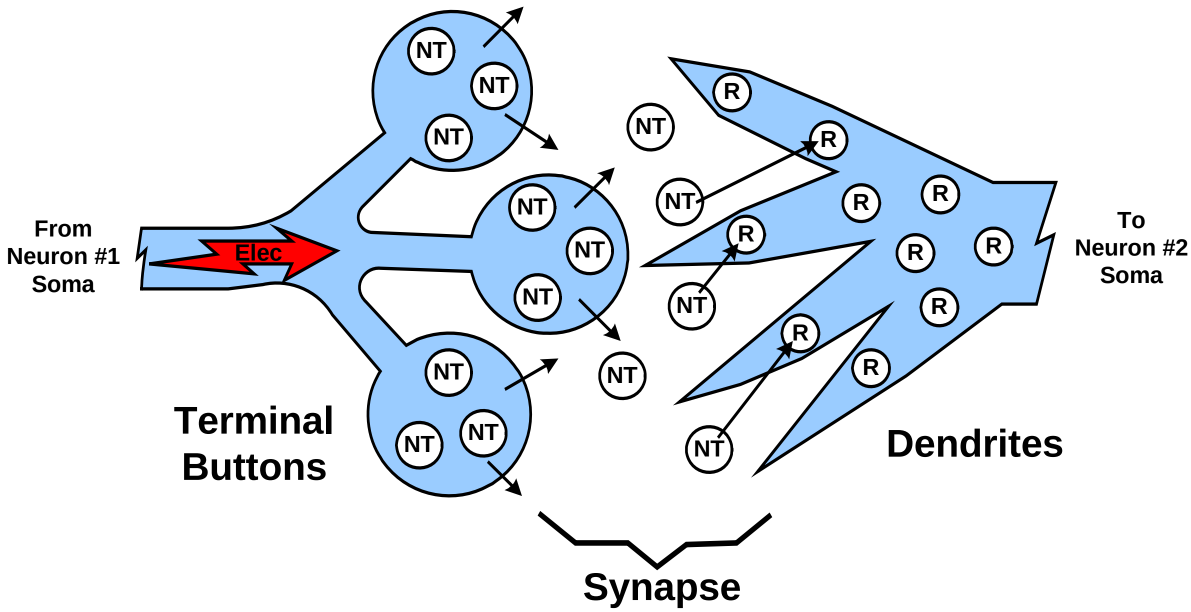
Neuron cell structure

- **Dendrites:** Contain neuroreceptors that respond when exposed to neurotransmitters.
- **Soma:** Body of neuron cell. DNA in the nucleus in the soma code for all the proteins of the neuron.
- **Axon hillock:** Contains a high concentration of voltage dependent sodium channels and considered the spike initiation zone for action potentials.
- **Axon:** Electrical pathway from the soma to the axon terminal. The axon hillock is the transition from soma to axon. The part of the axon beneath the myelin covering is the axon core.
- **Myelin sheath:** This is an insulating covering formed by multiple Schwann cells, each about 100uM long. Schwann cells are glial ("Glue") cells, cells that are needed to support nerve cells.
- **Nodes of Ranvier:** These are gaps of about 1um width between adjacent myelin sections that act as mini-axon-hillocks to regenerate action potentials periodically from the voltage impulses traveling under the myelin coating and serve to increase the propagation of axon signaling versus an unmyelinated axon.
- **Axon terminal / Terminal buttons:** When triggered by an action potential from the soma, the terminal buttons release stored neurotransmitters which are then received by nearby dendrites of other neurons.



- **<u>Synapse and neuron signaling</u>**
  - **<u>Action potential:</u>** This is an electrical signal from the soma that travels down the axon to the terminal buttons at the terminal end of the axon. This releases the neurotransmitter (NT) molecules stored in the terminal buttons into the synapse, the gap between the terminal buttons of one neuron and the dendrites of the next. Some of these neurotransmitters land on the nearby dendrites of a neuron at receptor (R) sites that cover both the soma and dendrites (dendrites are essentially fingerlike extensions of the soma). As neurons become more and more closely associated with other neurons through long term potentiation, the distance of the synaptic gap approaches zero and the number of dendrites of one neuron that are associated with the terminal buttons of another neuron may be increased.



Synapse and neuron signaling...

- **NT dependent ion channels:** When a neurotransmitter from a terminal button or other source hits a receptor on a dendrite, an ion channel specific to that receptor is opened.
    - **Excitatory postsynaptic channel:** A sodium channel is opened which pulls in positive ions thus increasing the internal cell potential.
    - **Inhibitory postsynaptic channel**: A potassium channel is opened which allows positive potassium ions to leave the cell thus lowering the cell potential.
- **Voltage dependent ion channels:** In the soma, in response to activation of receptors by released neurotransmitters on the dendrites and soma body that change the resting potential inside the cell, ion channels that open at one voltage and close at another cause the neuron to fire in an "All or nothing" manner therefore Increased neurotransmitter exposure does not change the level at which neurons fire but instead the number of times the neurons will fire per unit time.

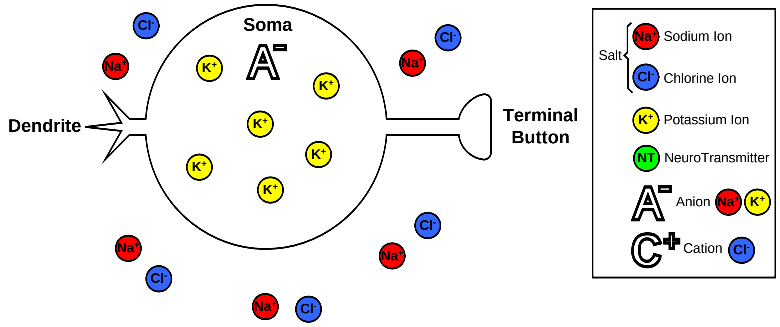
Neurotransmitters

- **Seratonin (5-Ht; Hydro-triptomine):** Controlled by pre-frontal lobe and is used for self-control, mood, sleep, appetite, sensory perception, arousal, temperature regulation and pain suppression.
- **Acetylcholine (Ach):** Used for muscle action, learning memory, REM sleep and emotion. Lactic acid in muscles breaks down Ach, so stretching after exercise releases the lactic acid so it can't eat all of your Ach reserves.
- **Dopamine (DA):** Used for muscle control for movement, attention, learning and emotion. Too little and you can't move, too little and you're schizophrenic!
- **Norepinephrine (NE) or Noradrenaline™:** Used in the central nervous system for mental energy and wakefulness.
- **Epinephrine or Adrenaline™:** Used by the peripheral nervous system for physical energy.
- **Gamma Aminobutyric Acid (GABA):** Inhibitory neurotransmitter that always is used to compete with Norepinephrine to put you to sleep.
- **Endorphins:** The brains naturally produced morphine that binds to opiate receptors to suppress pain, control appetite etc.

Neuron polarization

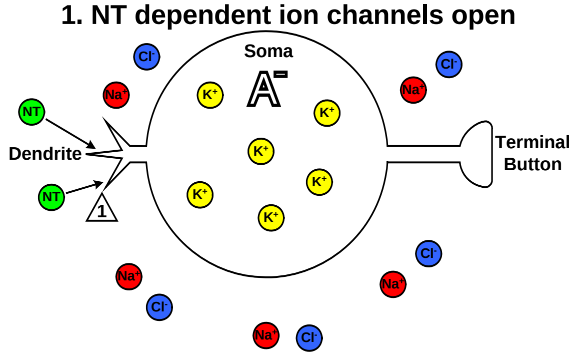
- **0. –70mV / Fully polarized:** When the neuron is at rest, the anion content of the neuron gives the inside of the neuron a net negative potential of –70mV with respect to the exterior of the cell that is surrounded by the saline solution of the brain fluid.

0. -70mV / Neuron at rest



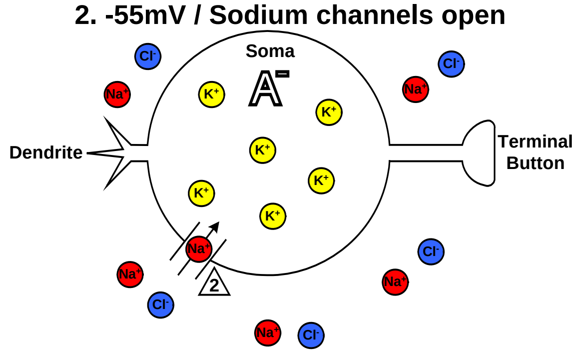
- **1. –70mV / Depolarization begins:** Neurotransmitters activate receptors on the dendrites. If the neuron does not reach the threshold of –55mV due to the insufficient stimulus of failed initiations, it will return to the fully polarized –70mV resting potential.

1. NT dependent ion channels open



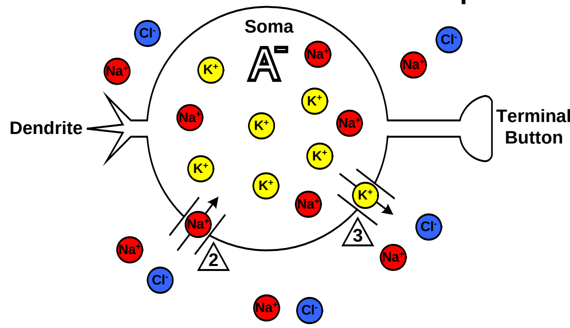
- **2. –55mV / Depolarization accelerates:** At about –55mV the voltage dependent sodium channels open which draw more sodium ions from the outside of the neuron, which further increases the depolarization of the neuron and drives it to full depolarization without and/or regardless of further external neurotransmitter stimulus.

2. -55mV / Sodium channels open



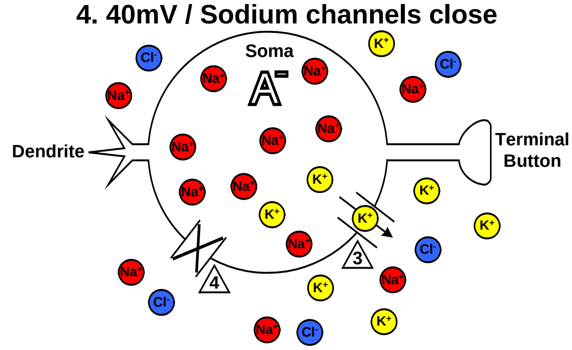
- **3. 0mV / Depolarization continues**: When the neuron potential reaches 0mV, the voltage dependent potassium channels open which allow positively charge potassium ions already in the neuron to be pushed out through electrostatic repulsion to the incoming sodium ions. The neuron potential will continue to climb as more sodium ions enter than potassium ions leave.

3. 0mV / Potassium channels open



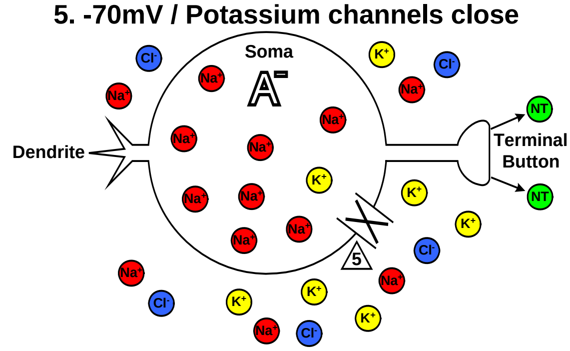
- **4. 40mV / Fully depolarized "Action potential":** When the neuron potential reaches about 40mV, the voltage dependent sodium channels close and prevent any more sodium ions from entering. Potassium ions continue to exit the neuron causing its potential to begin to fall back toward the rest state.

4. 40mV / Sodium channels close

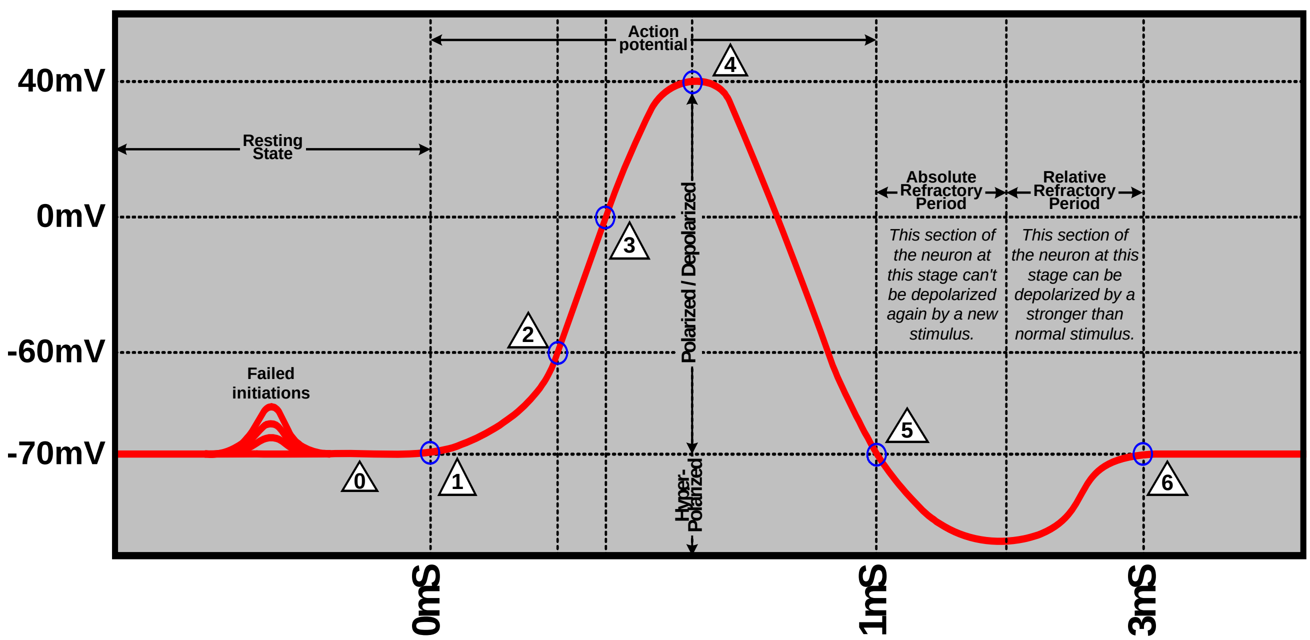


- **5. -70mV / Fully repolarized:** Between stage 3 and 4 as potassium ions continue to exit, the neuron potential falls until it reaches the -70mV rest state at which time the voltage dependent potassium channels close. At this point, sodium ions have replaced the potassium ions of the rest state so the neuron is not yet able to re-fire. (When the action potential propagates to the axon terminal, neurotransmitters are released.)

5. -70mV / Potassium channels close



- **5/6. < -70mV / Hyper polarization and rest state restoration:** Hyper polarization occurs as the neuron potential goes more negative than the rest state because so many potassium channels were opened between stages 3 and 5 and they don't all close at once. The period between stages 5 and 6 is also called ***undershoot***.
    - **Absolute refractory period:** After an action potential, the sodium channels can't be re-opened for this period due to entering into a temporary ***inactivated*** state, thus preventing re-firing regardless of the level of stimulus.
    - **Relative refractory period:** Sodium ions are pumped out and potassium ions are pumped into the neuron to return it to its original resting potential. During this time, some few potassium channels remain open so that although the neuron may re-fire at this time, it takes a higher than normal stimulus that during the resting state. The ion pumping requires expenditure of energy by the cell that consumes ATP.



- **Myelinated axons:** In a myelinated axon, action potentials travel between the Nodes of Ranvier electrically, and then are regenerated chemically at the nodes. The nodes are typically 1um wide and the distance between nodes is typically 100um which results in a majority of electrical impulse conduction that is faster than chemical conduction.
- **Unmyelinated axons:** In an unmyelinated axon, the action potential is propagated in a purely chemical fashion as sodium channels ahead of the action potential are activated while sodium channels behind are inactivated during their absolute refractory period leading to the unidirectional propagation from the soma to the terminal.