The Sympathetic Systems

- The sympathetic nervous system activates what is often termed the fight or flight response, as it is most active under sudden stressful circumstances (such as being attacked).

- This response is also known as sympathetico-adrenal response of the body, as the pre-ganglionic sympathetic fibers that end in the adrenal medulla (but also all other sympathetic fibers) secrete acetylcholine, which activates the secretion of adrenaline (epinephrine) and to a lesser extent noradrenaline (norepinephrine) from it.

The parasympathetic nervous system

- The parasympathetic nervous system is part of the autonomic nervous system. Sometimes called the rest and digest system or feed and breed.

- The parasympathetic system conserves energy as it slows the heart rate, increases intestinal and gland activity, and relaxes sphincter muscles in the gastrointestinal tract.

- After high stress situations (ie: fighting for your life) the parasympathetic nervous system has a backlash reaction that balances out the reaction of the sympathetic nervous system.

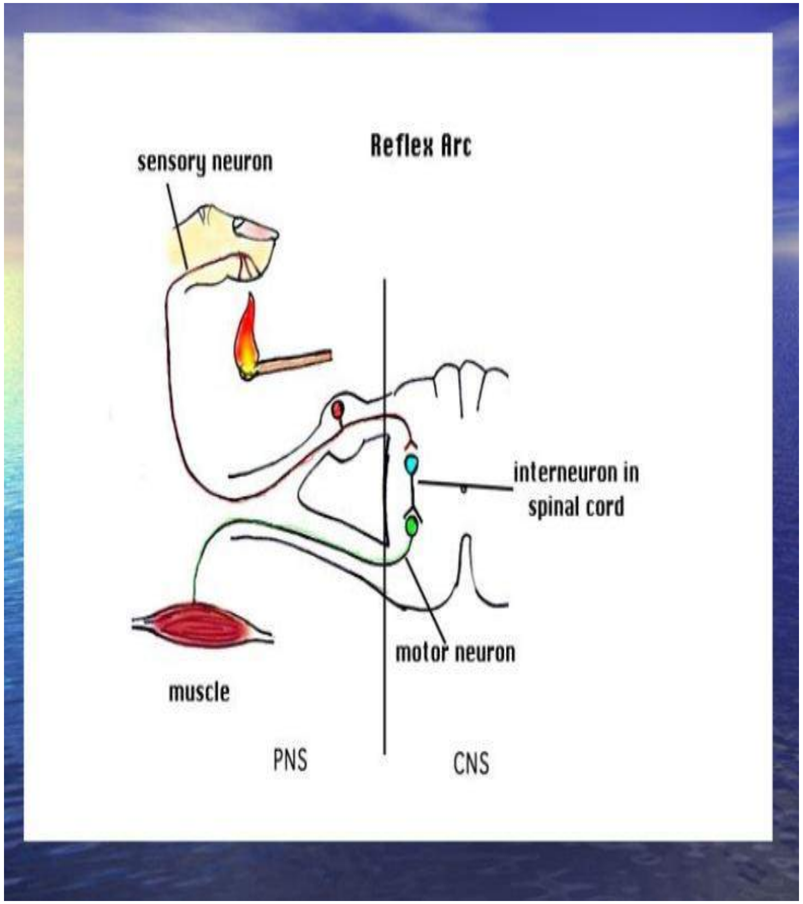
Reflex

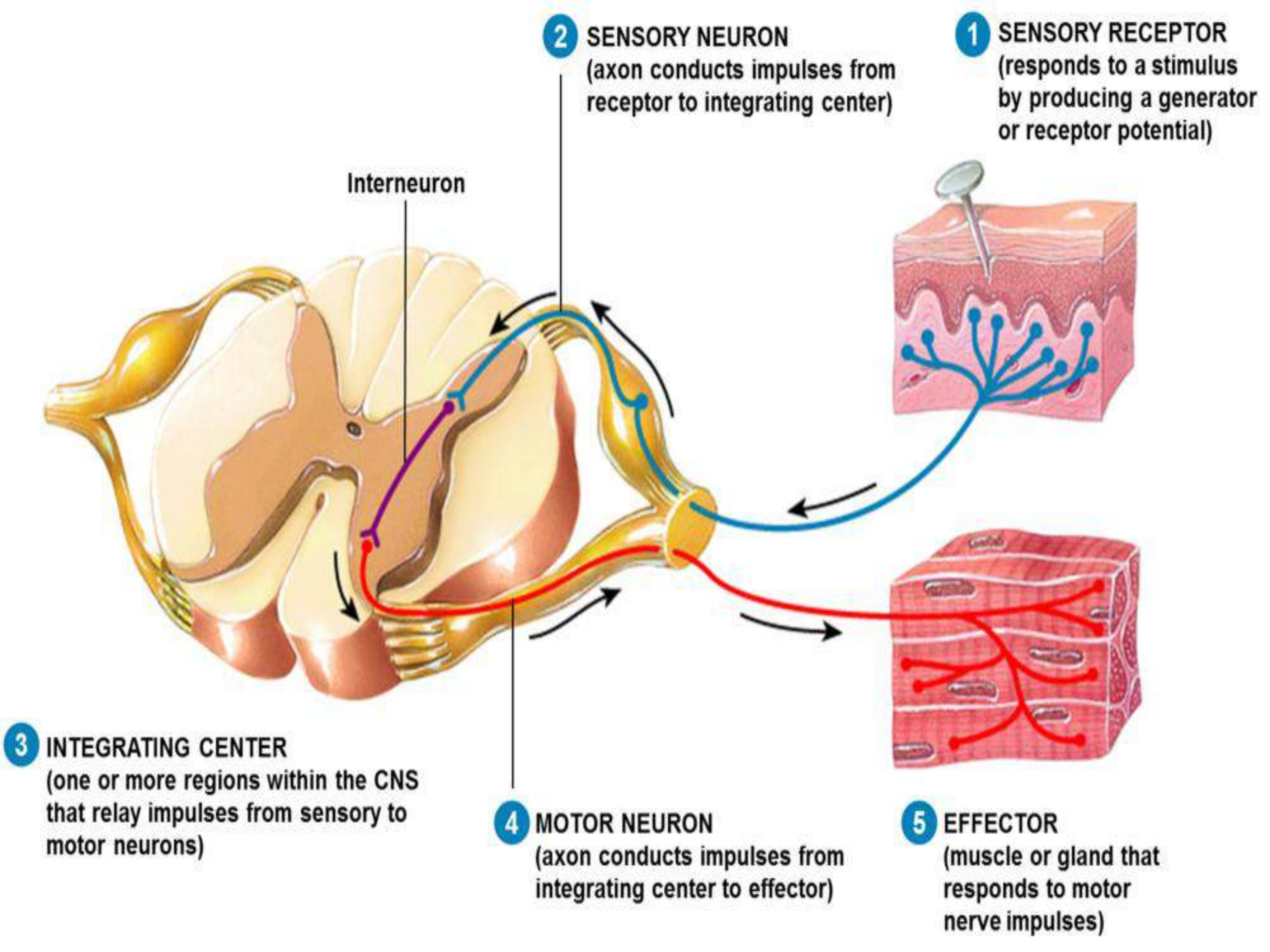
- A reflex is an involuntary response to a sensory stimulus.
- The pathway of neurons involved in a reflex is known as a **reflex arc**. It is the basic unit of integrated reflex activity.
- This arc consists of a **sense organ**, an **afferent neuron**, one or more **synapses**, an **efferent neuron** and an **effector.**
- Reflex arcs-such as quickly-moving your hand when you touch something really hot- involve just three neurons:

1. Sensory (spinal) neuron
2. Interneuron
3. Motor neuron

Stages of Spinal Reflex

- The **stimulus** – Heat from the hot object.
- A **receptor** – Temperature receptors in the skin on the hand, they create a nurve impulse in a sensory neurone.
- A **sensory neuron** – Passes the nerve impulse to the spinal cord.
- An **intermediate (relay) neuron** – Link the sensory neuron to the motor neuron in the spinal cord.
- A **motor neuron** – Carries the nerve impulse from the spinal cord to a muscle in the upper arm.
- An **effector**- The muscle in the upper arm that is stimulated to contract.
- The **response**- Pulling the hand away from the hot object.




1 SENSORY RECEPTOR
(responds to a stimulus by producing a generator or receptor potential)
2 SENSORY NEURON
(axon conducts impulses from receptor to integrating center)
Interneuron
3 INTEGRATING CENTER
(one or more regions within the CNS that relay impulses from sensory to motor neurons)
4 MOTOR NEURON
(axon conducts impulses from integrating center to effector)
5 EFFECTOR
(muscle or gland that responds to motor nerve impulses)

Nervous System Communication via Synapses

How are nerves organized and joined?

Neurons meet other neurons, sensory receptors and tissues at synapses

Synapses: are junctions that allow neurons to communicate with each other, sense receptors, muscles and glands.

Chemicals called **neurotransmitters** are released from the axon terminals of the pre-synaptic neuron into the synapse (synaptic cleft) and are received by dendrites of the post synaptic neuron.

Pre-synaptic Response

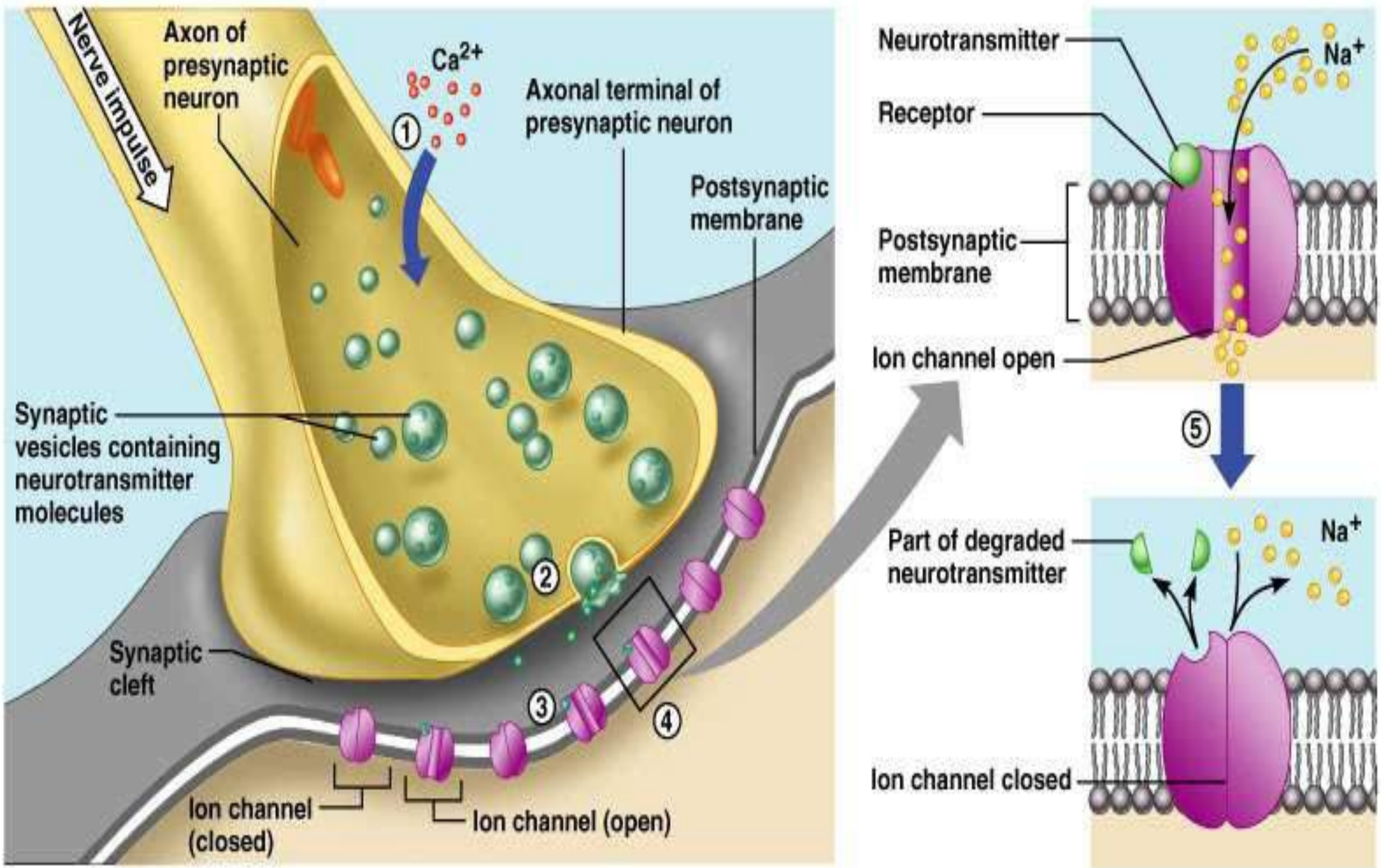
A **nerve impulse**, which begins as an **electrical signal** in the presynaptic neuron, will be translated **chemically** across the synaptic cleft by a neurotransmitter,.

Post-synaptic Response

Once the neurotransmitter binds to receptors on the postsynaptic neuron, the message becomes **electrical** once again. This can result in either an **excitatory** postsynaptic potential or an **inhibitory** postsynaptic potential.

Mechanism of Transmitter Release *(Role of Calcium Ions)*

- The presynaptic terminal contains large number of ***voltage-gated calcium channels.*** When an action potential depolarizes the presynaptic membrane, these Ca^{++} channels open and allow large number of **calcium ions to flow** into the terminal.
- The quantity of the **transmitter substance** that is then **released** from the terminal into the synaptic cleft is directly related to the number of the calcium ions that inter.
- When the **calcium ion** enter the presynaptic terminal, it is believed that they **bind with special protein molecules** on the inside surface of the presynaptic membrane called ***release sites***. This binding in turns causes the release sites to open through the membrane, allowing a few transmitter **vesicles to release their transmitter** into the cleft after each single potential action.


Nerve impulse
Axon of presynaptic neuron
Ca^{2+}
1
Axonal terminal of presynaptic neuron
Postsynaptic membrane
Synaptic vesicles containing neurotransmitter molecules
2
Synaptic cleft
3
4
Ion channel (closed)
Ion channel (open)
Neurotransmitter
Receptor
Na^+
Postsynaptic membrane
Ion channel open
5
Part of degraded neurotransmitter
Na^+
Ion channel closed

Types of Synapses

1. Chemical Synapses

- In these, the first neuron secretes at its nerve ending synapse a chemical substance called a **neurotransmitter**, and this transmitter in turn act on **receptor proteins** in the membrane of the next neuron to **excite** the neuron, **inhibit** it, or **modify** its sensitivity in some other way.

- **Electrical Synapses**
- In contrast, are characterized by direct open channels that conduct electricity from one cell to the next.
- Most of these consist of small protein tubular structures called ***gap junctions*** that allow free movement of ions from the interior of one cell to interior of the next.

Excitatory and inhibitory Synapses

- The release of an **excitatory** neurotransmitter (e.g. glutamate) at the synapses will cause an **inflow** of positively charged sodium ions **(Na+)** making a localized **depolarization** of the membrane. The current then flows to the resting (**polarized)** segment of the axon.
- **Inhibitory synapse** causes an **inflow of Cl-** (chlorine) or **outflow of K+** (potassium) making the synaptic membrane **hyperpolarized**. This increase **prevents depolarization**, causing a **decrease** in the possibility of an **axon discharge**. If they are both equal to their charges, then the operation will cancel itself out.
- This effect is referred to as summation. **Summation** determine whether the excitatory synapses prevail over the inhibitory synapses or vice versa.

Types of Summation

1. **Spatial summation** requires **several excitatory synapses** (firing several times) **to add up**, thus causing an axon discharge. It also occurs within inhibitory synapses, where just the opposite will occur.
2. **Temporal summation**, it causes an **increase of the frequency at the same synapses** until it is large enough to cause a discharge.

Factors affecting synaptic transmission

pH of the interstitial fluid

When pH increase, the excitability of neurons also increase. Under conditions of **acidosis** in which **pH decreases**, the **excitability** of the neurons is **decreased**, rendering them less likely to generate action potentials.

Drug, toxins and diseases

Drugs that bind to a receptor and produce a response similar to the normal activation are called ***agonists***, and drug that bind to the receptor but unable to activate it are ***antagonists***. ***They may:***

1. Altered **release** of neurotransmitter.
2. Altered **interaction** of neurotransmitter with the **receptor.**
3. Altered **removal** of neurotransmitter from synaptic cleft.

Speed of Conduction

This area of depolarization/repolarization/recovery moves along a nerve fiber like a very **fast wave**.

- In **myelinated fibers**, **conduction** is hundreds of times **faster** because the action potential only occurs at the **nodes of Ranvier** by jumping from node to node. This is called **"saltatory" conduction.**
- **Damage to the myelin sheath** by the disease can **cause severe impairment** of nerve cell function.
- Some **poisons and drugs** interfere with nerve impulses by blocking sodium channels in nerves.

Chemical Classification of NT

- Amine ex. Dopamine, Serotonin,Acetylcholin, Epinephrin
- Amino acid ex. Aspartate, Glycine , GABA
- Oligopeptide (neuro active) ex. Motilin, CCK, VIP, CGRP
- Purine ex. Adenosine, ATP
- Gas ex. Nitric oxide, CO

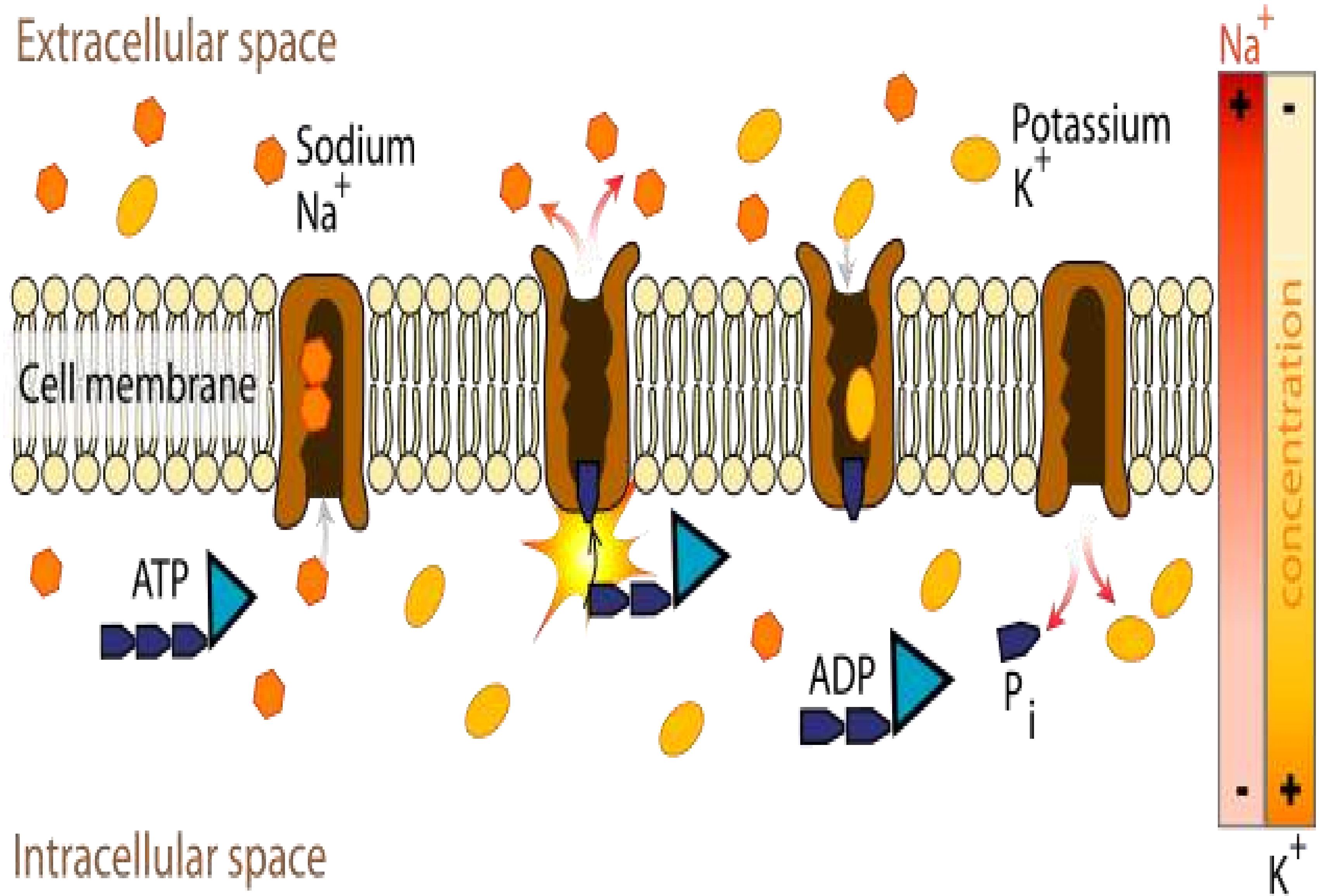
Action of common Neurotransmitter

Action of common Neurotransmitter

NT	Release Sites	Principal Action
Acetylcholin	Brain, ANS, Neuromuscular	Excitatory or inhibitory on internal organs, Excitatory of skeletal muscle
Norepinephrin	Brain, Spinal cord, ANS	Excitatory or Inhibitory depending on receptors, Plays a role in emotions
Serotonin	Brain, Spinal cord	Inhibitory, modes, sleep cycle, appetite

The Action Potential

- When a nerve is **stimulated** by pressure, electricity or chemicals, the **resting potential changes.**
- The rapid **change in polarity** that moves along the nerve fiber is called the "**action potential**."
- In order for an **action potential to occur**, it must reach **threshold**. This means that the **stimulus** is substantial enough to change the **electrical potential** of the cell membrane.
- The stimulus causes **ion channels to open.** The membrane potential of a cellular structure is determined by **the in-flow and out-flow of sodium and potassium.**



sodium potassium pump

Plateau in Action Potential

Depolarization

- The upswing is caused when positively charged sodium ions (Na+) suddenly rush through open sodium gates into a nerve cell. The membrane potential of the stimulated cell undergoes a localized change from -55 millivolts to 0 in a limited area.
- As additional sodium rushes in, the membrane potential actually reverses its polarity so that the outside of the membrane is negative relative to the inside.
- During this change of polarity the membrane actually develops a positive value for a moment(+30 millivolts).

Repolarization

- The downswing is caused by the closing of sodium ion channels and the opening of potassium ion channels. Release of positively charged potassium ions (K+) from the nerve cell when potassium gates open. Again, these are opened in response to the positive voltage--they are voltage gated. This expulsion acts to restore the localized negative membrane potential of the cell (about -65 or -70 mV is typical for nerves).

Plateau in Action Potential

Hyperpolarization & Refractory phase

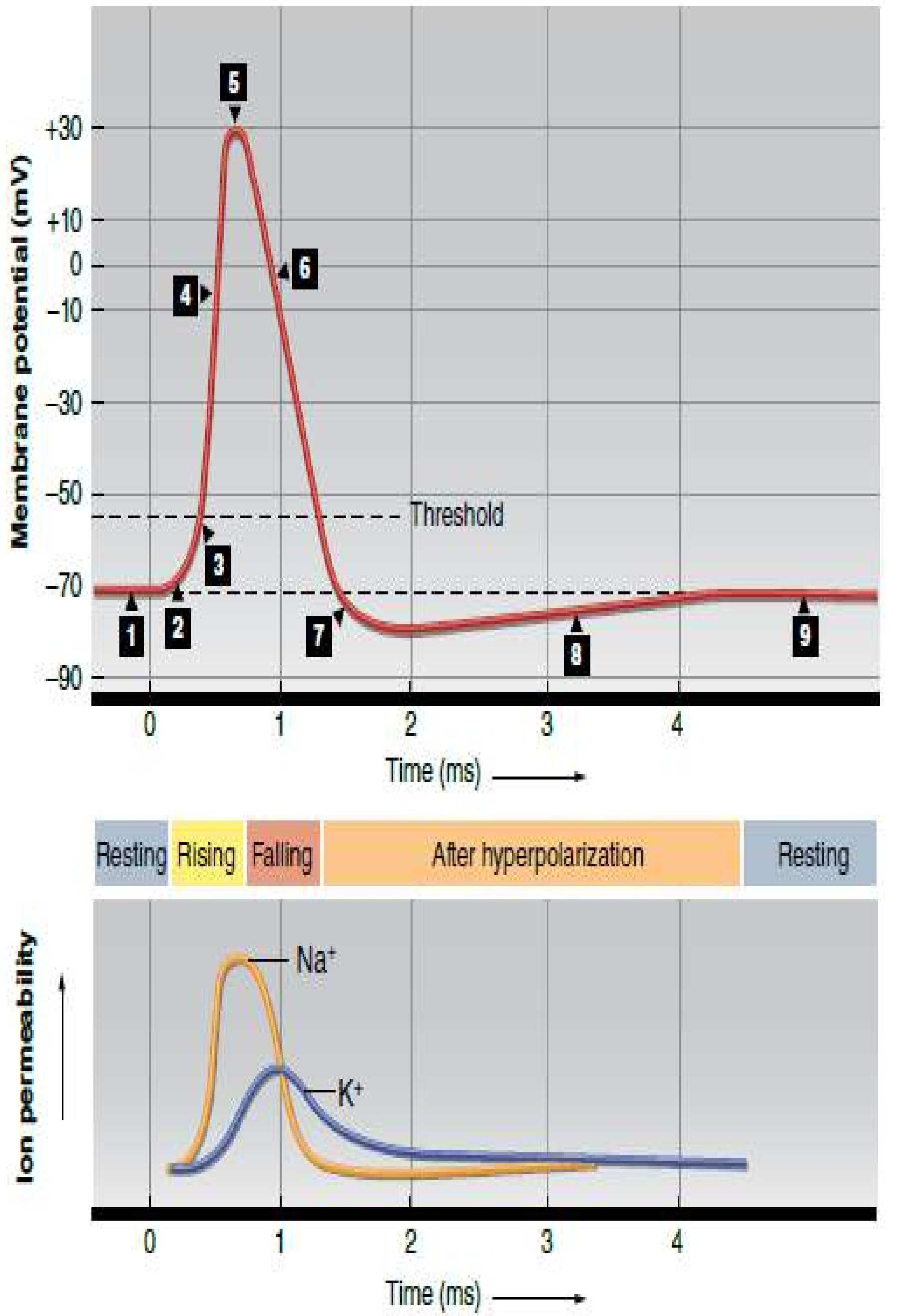
- When the potassium ions are below resting potential (-90 mV). Since the cell is hyper polarized, it goes to a refractory phase.

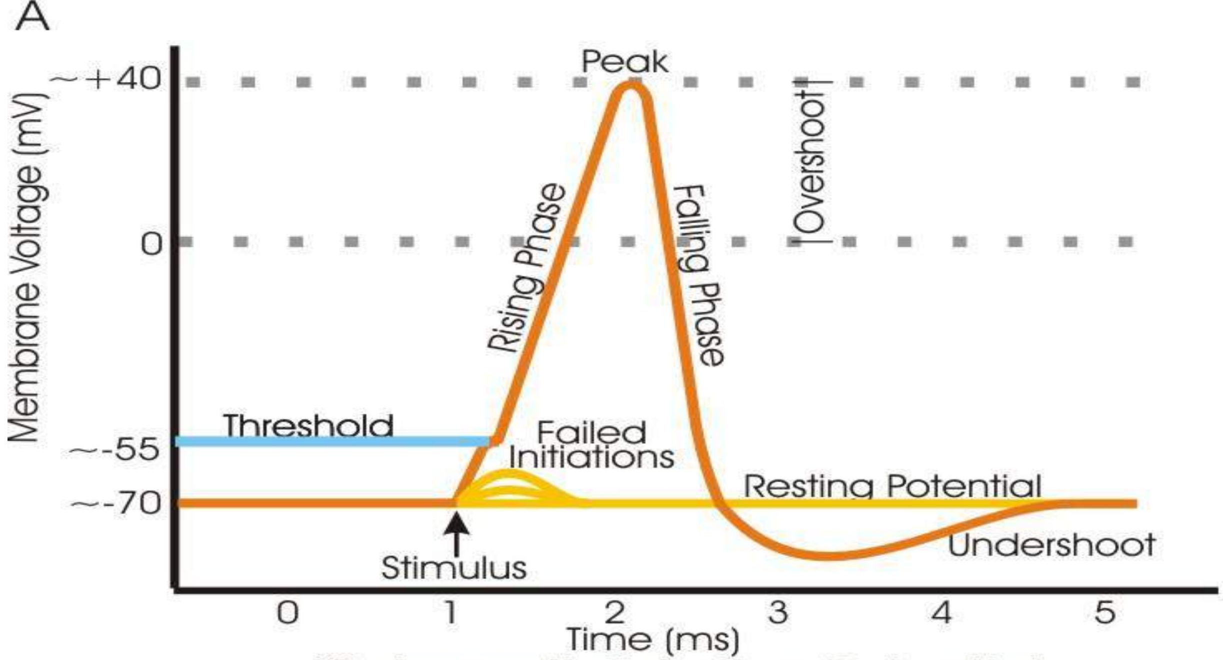
Refractory phase

- The refractory period is a short period of time after the depolarization stage. Shortly after the sodium gates open, they close and go into an inactive conformation. The sodium gates cannot be opened again until the membrane is repolarized to its normal resting potential.
- The sodium-potassium pump returns sodium ions to the outside and potassium ions to the inside. During the refractory phase this particular area of the nerve cell membrane cannot be depolarized.
- This refractory area explains why action potentials can only move forward from the point of stimulation.

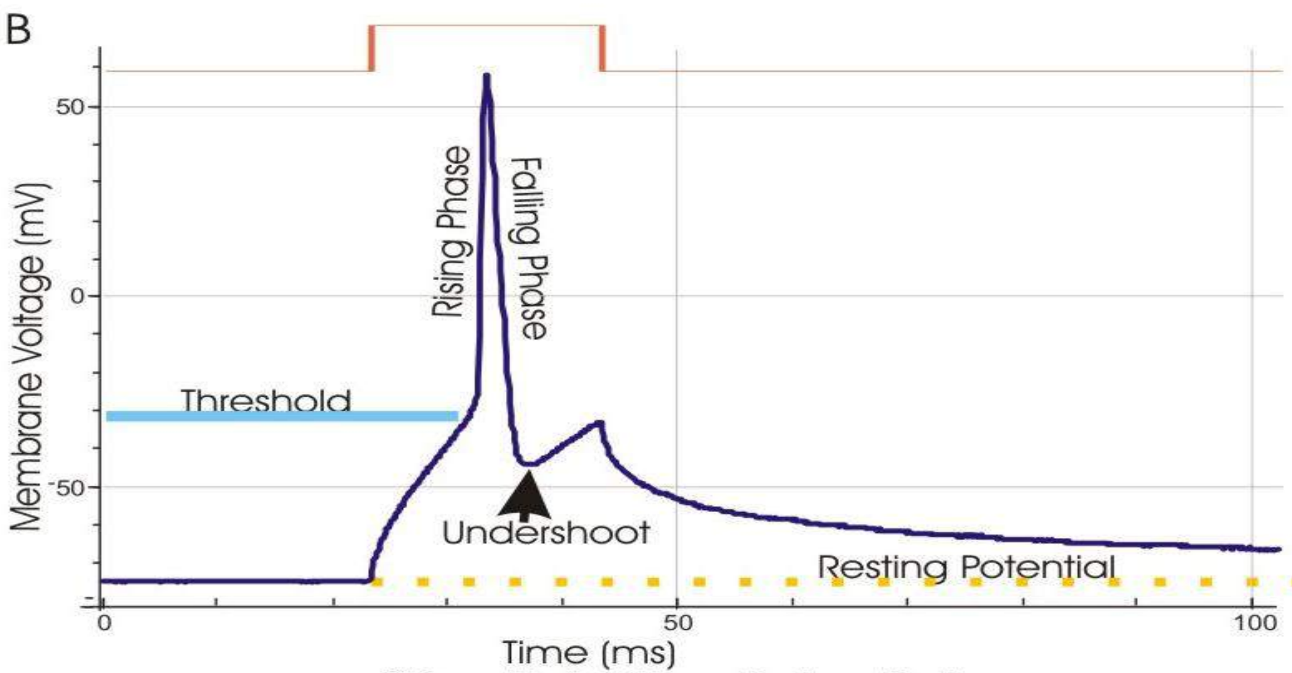
Plateau in Action Potential

1. Resting membrane potential
2. Depolarizing stimulus
3. Membrane depolarized to threshold
4. Rapid Na+ entry
5. Na+ channels close; K+ channels open
6. K+ moves into extracellular fluid
7. Hyperpolarization occurs
8. K+ channels close
9. Cell returns to resting membrane potential





"Schematic" Action Potential



"Real" Action Potential