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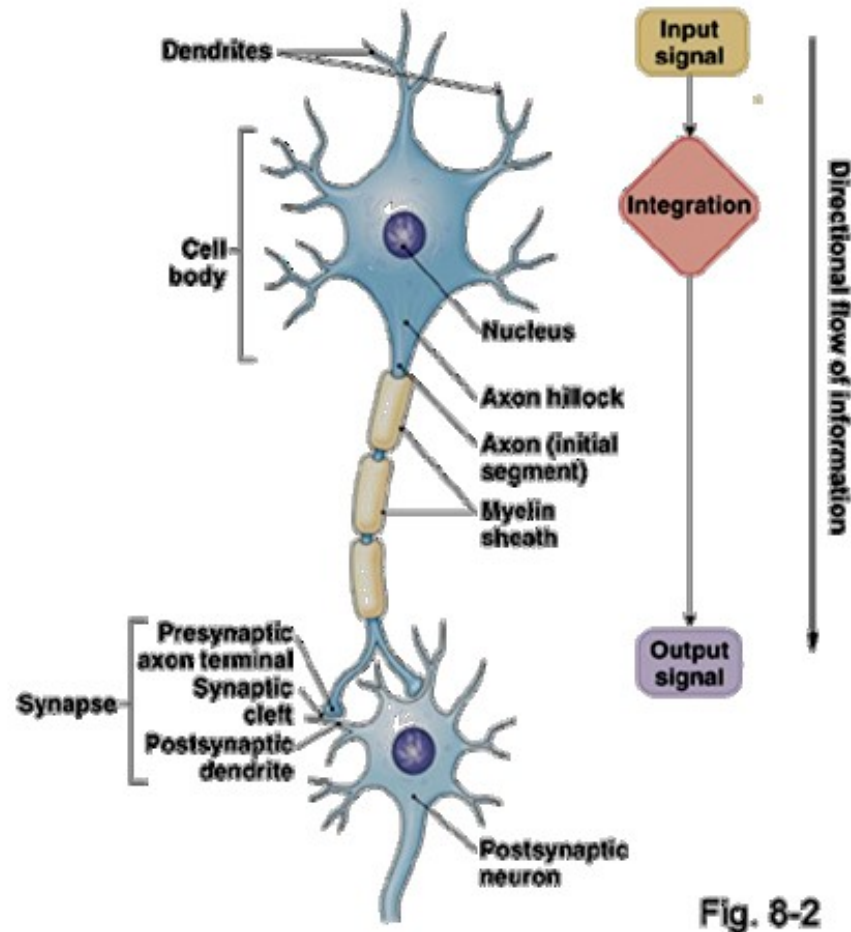
# **Synapse and integration of information at the synaptic level**

## Background Activity

### The inside of the cell

- ✓ ...
- ✓ Synthesis
- ✓ Transport
- ✓ ...

# Neuron



## Information processing and transmission

### The membrane

- ✓ Signal reception
- ✓ Signal integration
- ✓ AP generation
- ✓ AP propagation
- ✓ Signal transmission

# Action potential

- Quick voltage change on the membrane
- Spreads along the axon
- All or nothing principle

Resting potential  
around -70 mV

Threshold potential  
around -55 mV

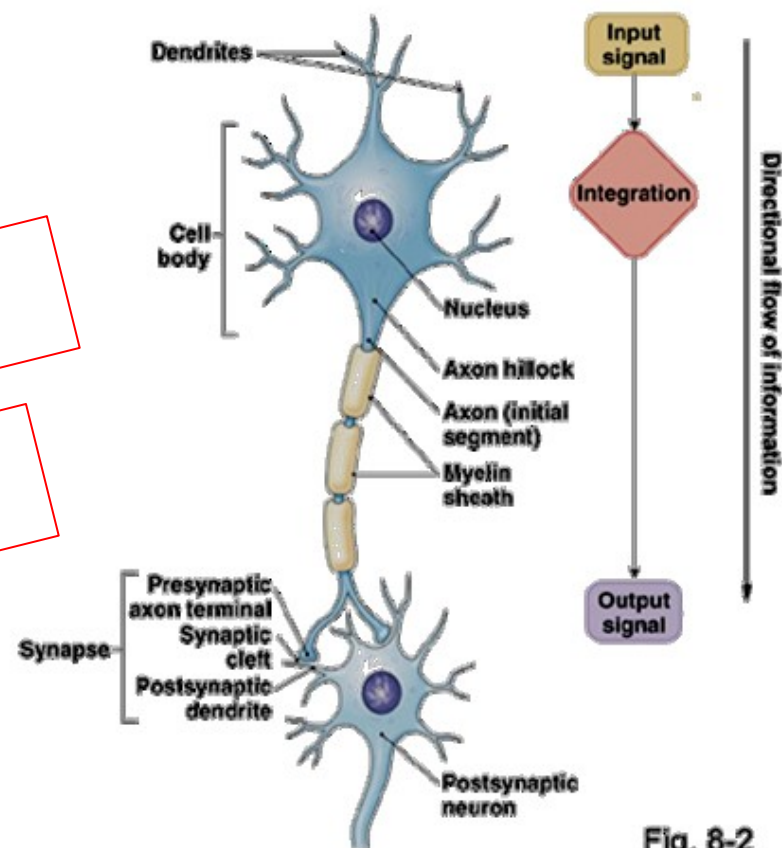
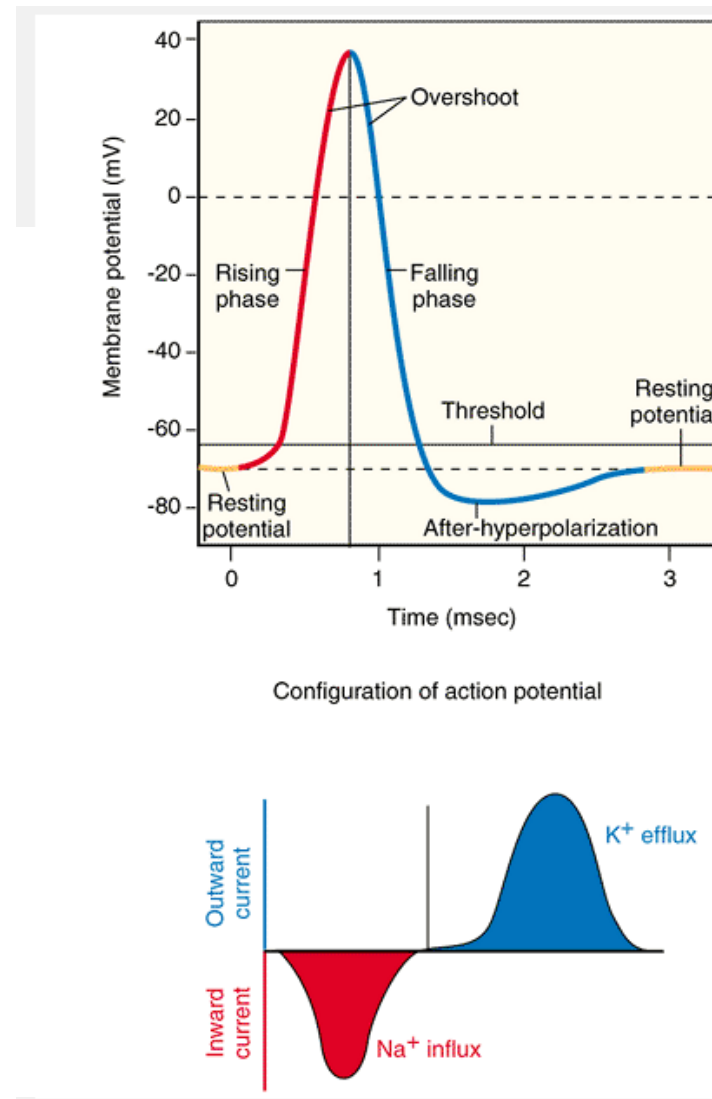


Fig. 8-2



# Synapse

- Communication between neurons

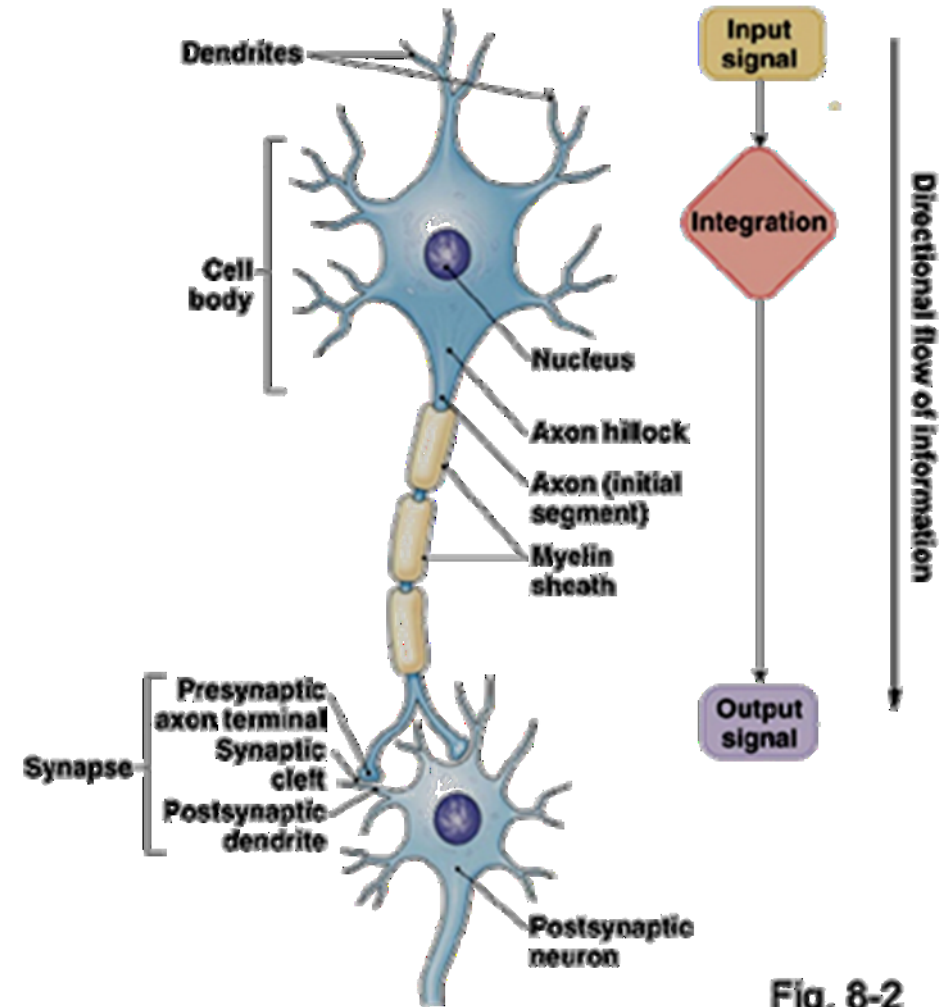


Fig. 8-2

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# Synapse

- Communication between neurons
- Electrical
- Chemical

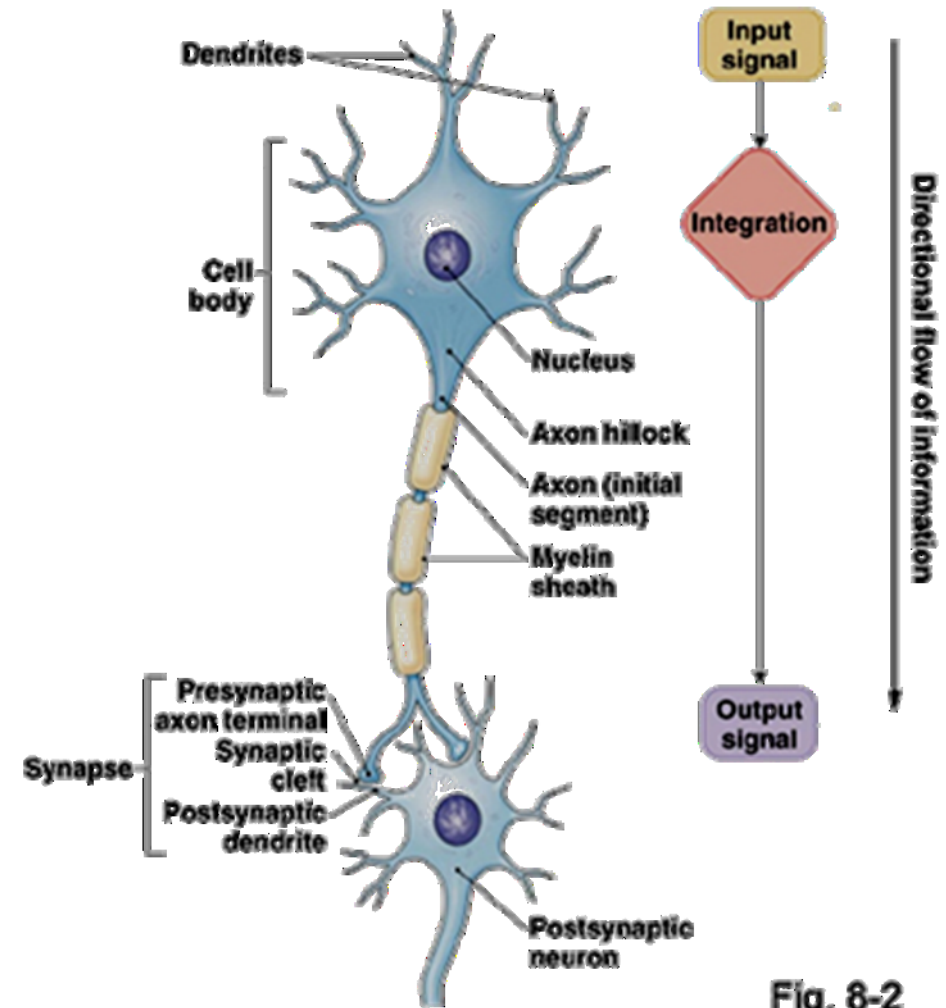
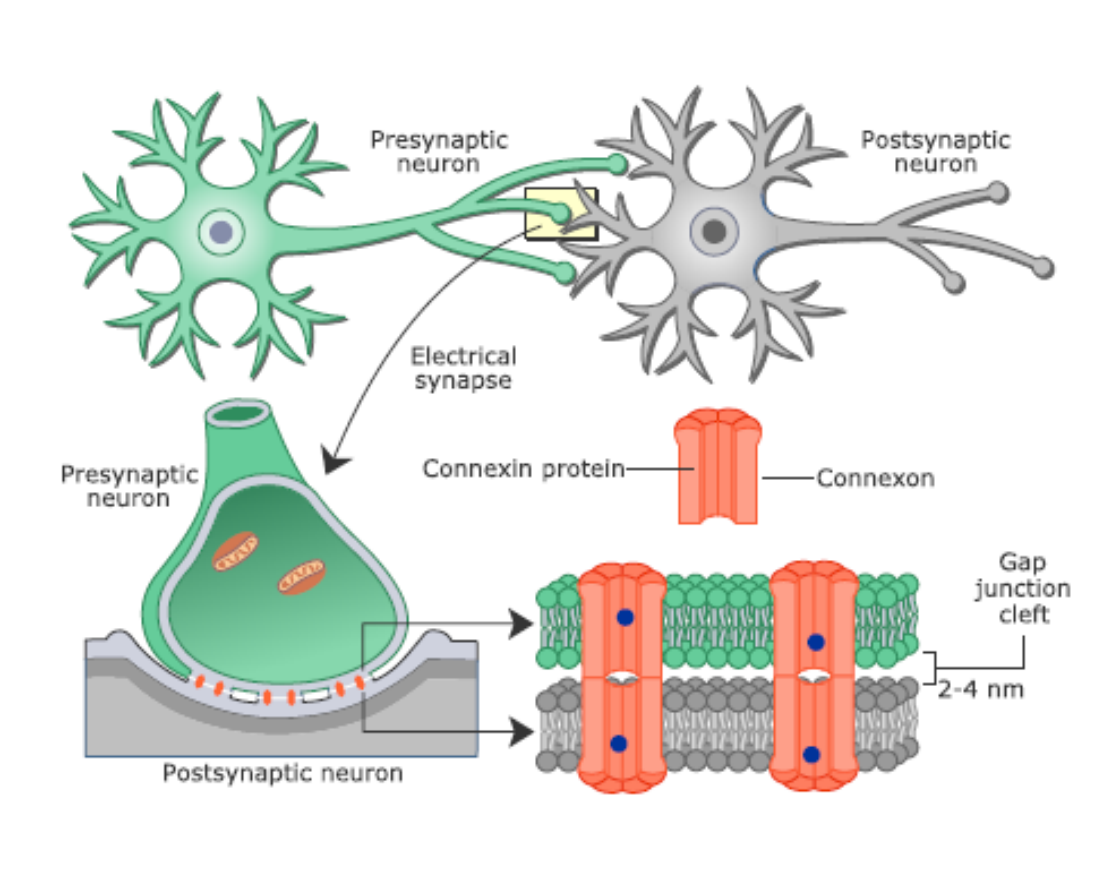


Fig. 8-2

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# Electrical synapse

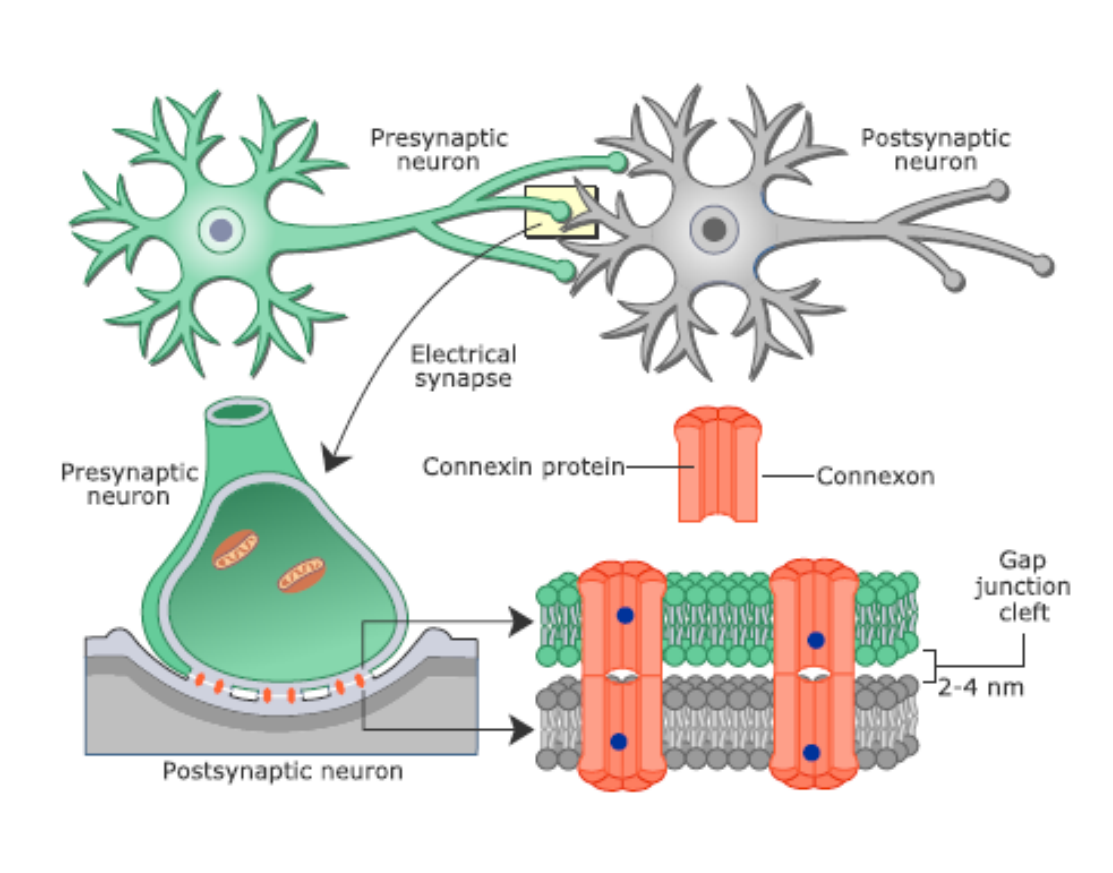
- Evolutionary old
- Less frequent than ch.
- Ubiquitous



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# Electrical synapse

- Evolutionary old
- Less frequent than ch.
- Ubiquitous
- Gap junctions
- Bidirectional transmission
- Fast
- Strength of signal may decrease

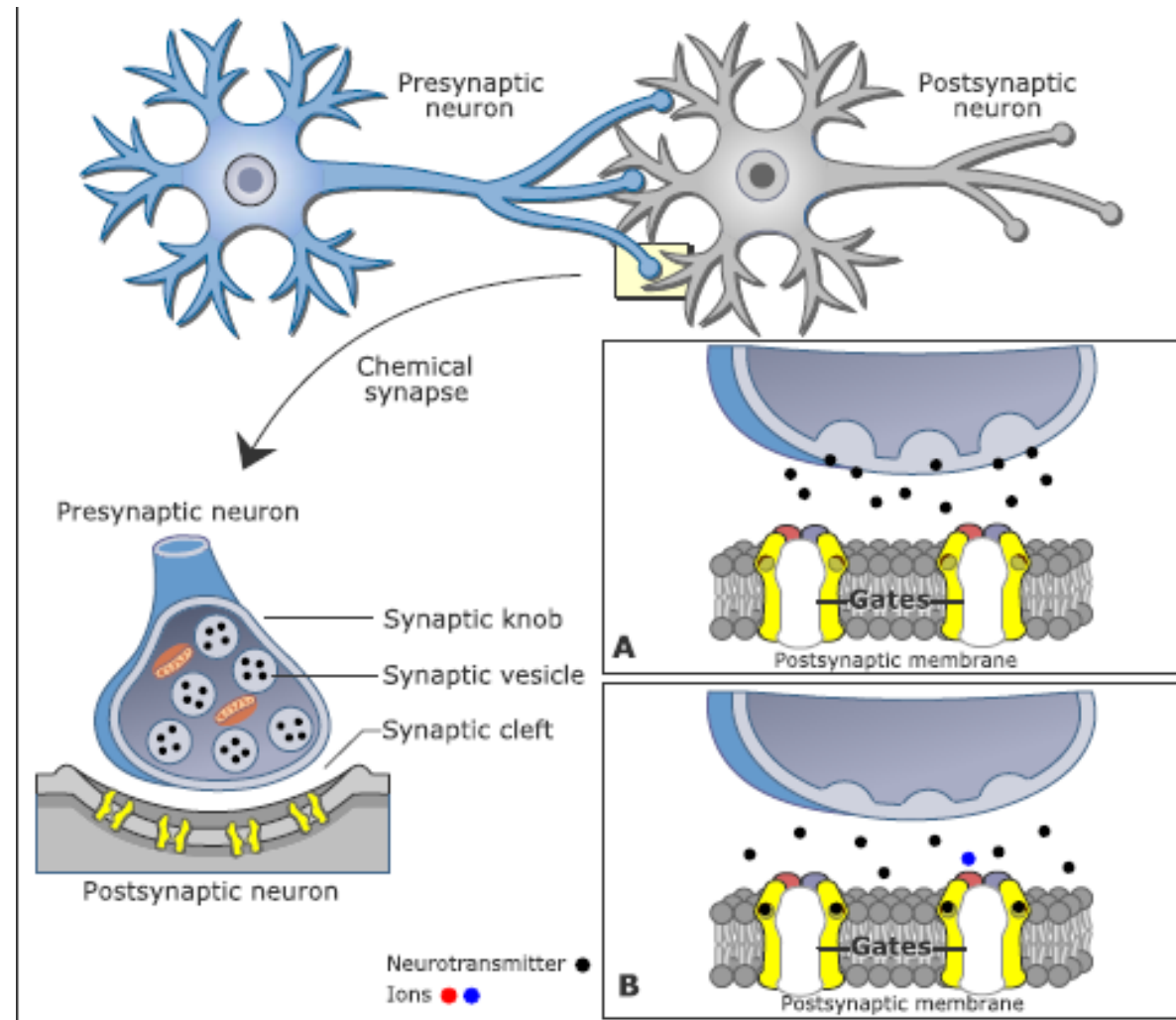


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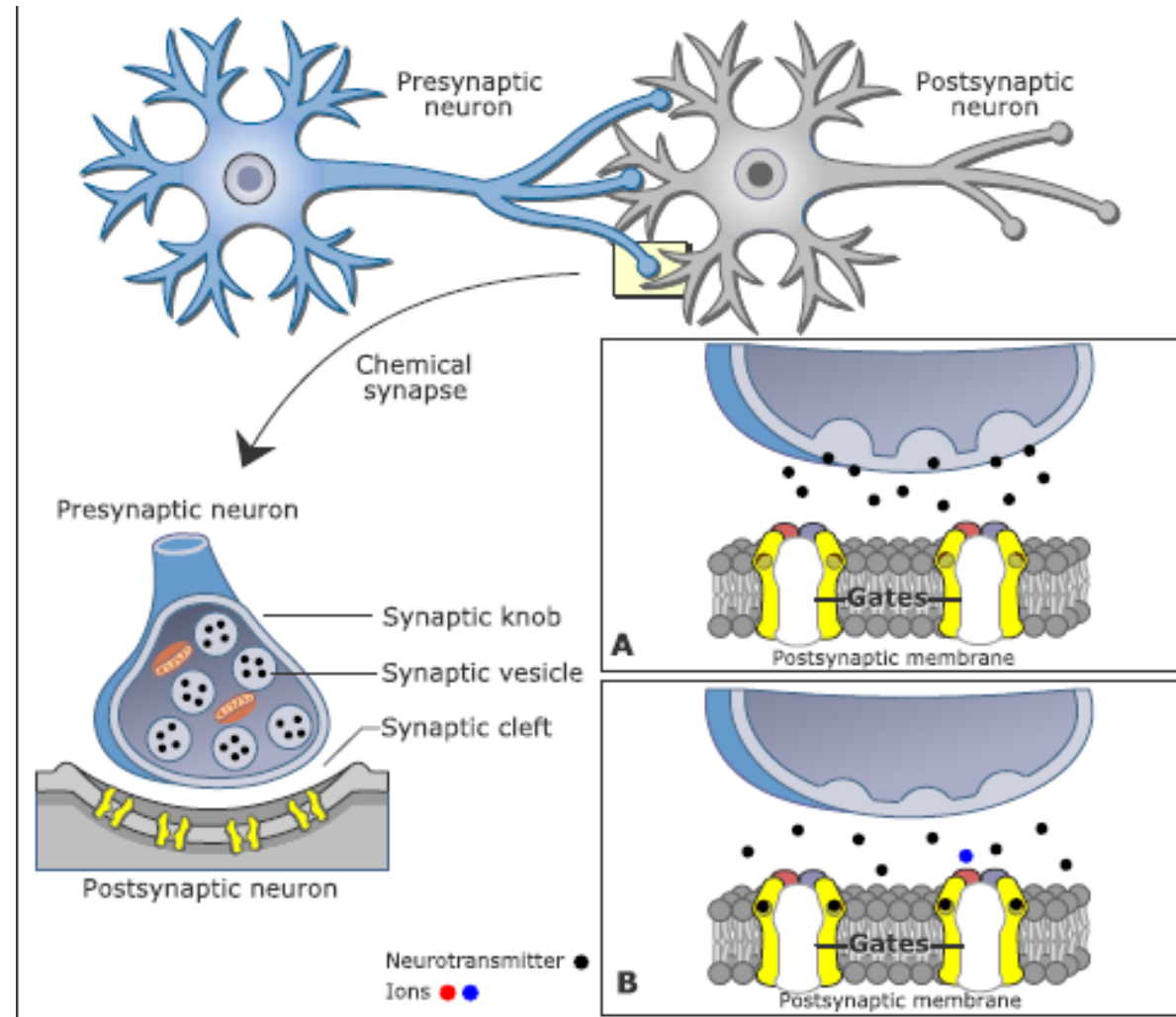
# Chemical synapse

- Evolutionary young
- Majority type of s.

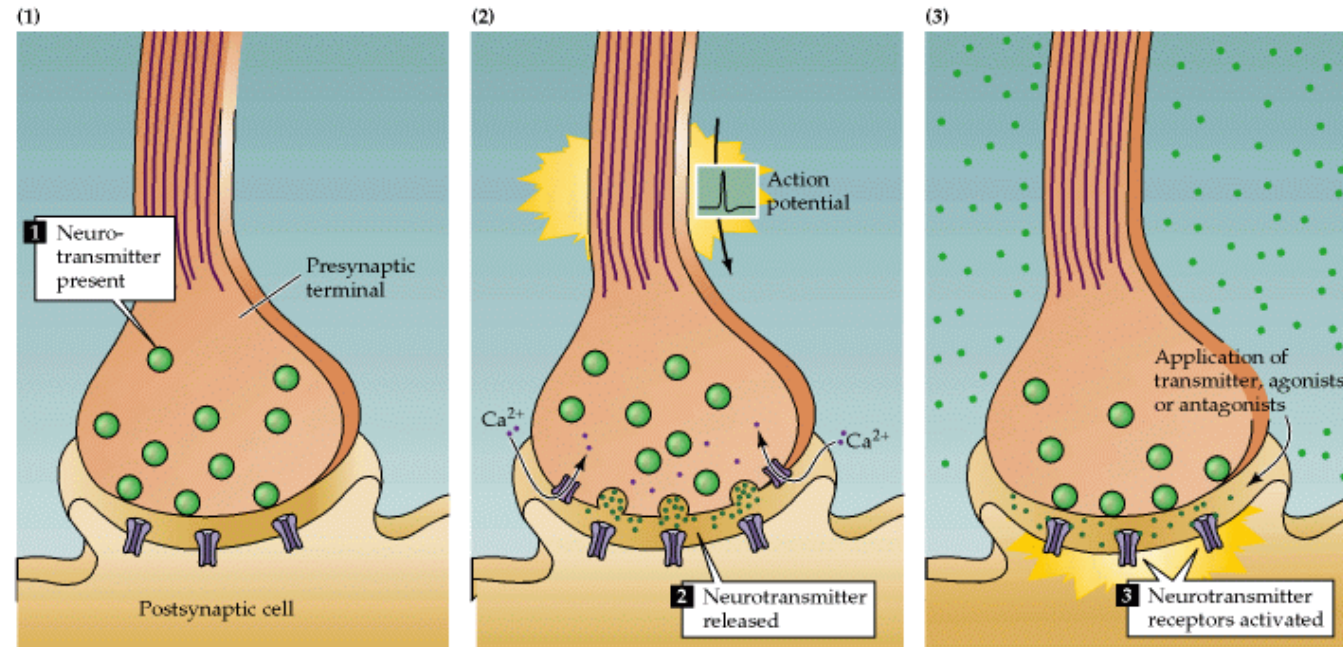


# Chemical synapse

- Evolutionary young
- Majority type of s.
- Unidirectional
- Synaptic cleft
- Neurotransmitter
- Constant signal strength



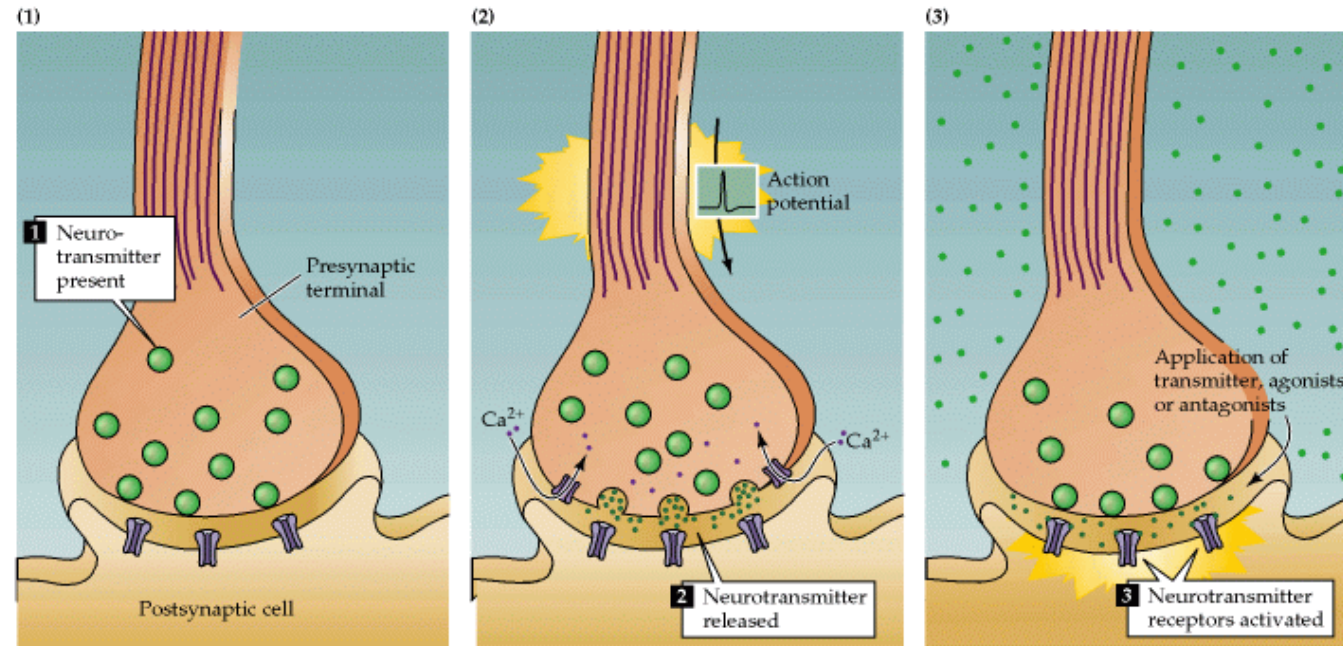
# Neurotransmitter



<http://www.slideshare.net/CsillaEgri/presentations>

- Present in presynaptic neuron

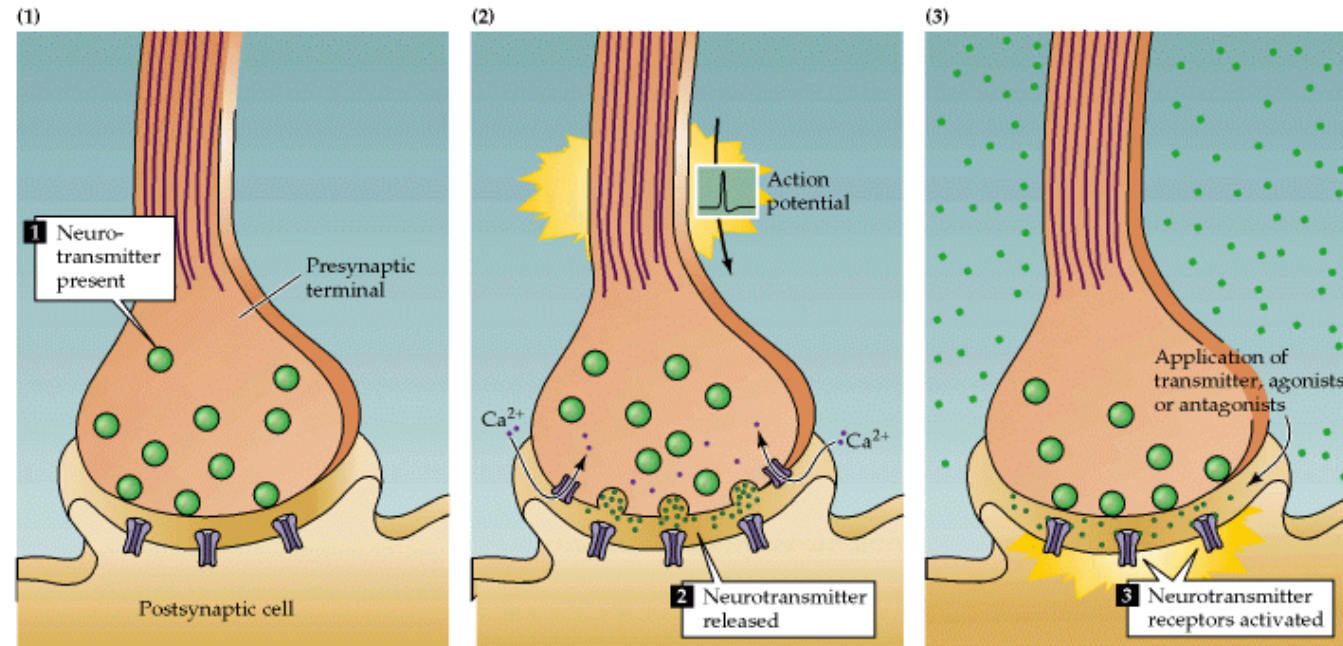
# Neurotransmitter



<http://www.slideshare.net/CsillaEgri/presentations>

- Present in presynaptic neuron
- Released into the synaptic cleft due to depolarization of presynaptic neuron ( $Ca^{2+}$  dependent mechanism)

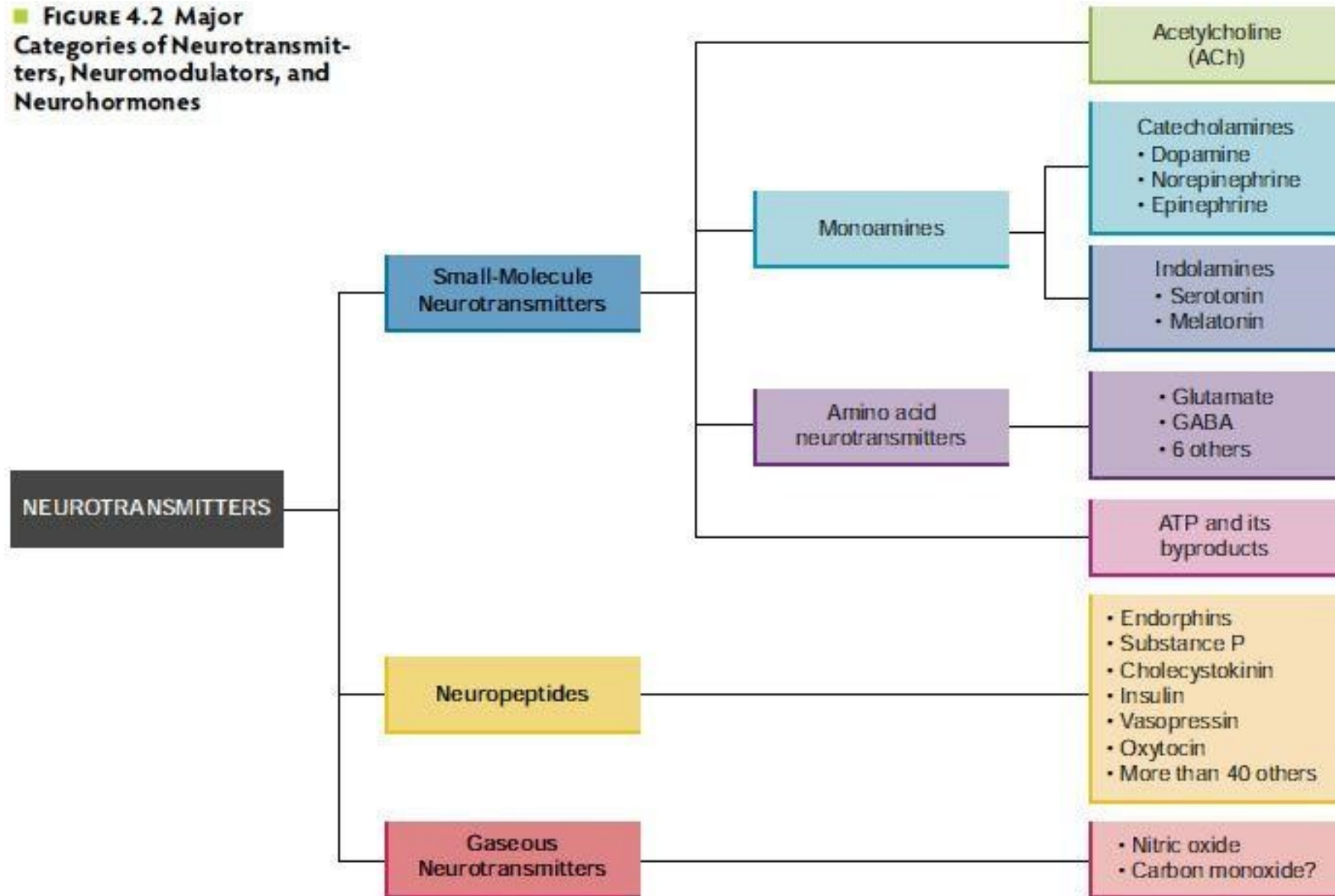
# Neurotransmitter



<http://www.slideshare.net/CsillaEgri/presentations>

- Present in presynaptic neuron
- Released into the synaptic cleft due to depolarization of presynaptic neuron ( $Ca^{2+}$  dependent mechanism)
- Specific receptor has to be present in postsynaptic membrane

■ **FIGURE 4.2 Major Categories of Neurotransmitters, Neuromodulators, and Neurohormones**



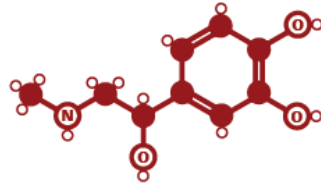
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# THE STRUCTURES OF NEUROTRANSMITTERS

STRUCTURE KEY: ● Carbon atom ○ Hydrogen atom ○ Oxygen atom (N) Nitrogen atom (R) Rest of molecule

## ADRENALINE

Fight or flight neurotransmitter



Produced in stressful or exciting situations. Increases heart rate & blood flow, leading to a physical boost & heightened awareness.

## NORADRENALINE

Concentration neurotransmitter



Affects attention & responding actions in the brain, & involved in fight or flight response. Contracts blood vessels, increasing blood flow.

## DOPAMINE

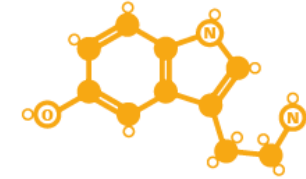
Pleasure neurotransmitter



Feelings of pleasure, and also addiction, movement, and motivation. People repeat behaviours that lead to dopamine release.

## SEROTONIN

Mood neurotransmitter



Contributes to well-being & happiness; helps sleep cycle & digestive system regulation. Affected by exercise & light exposure.

## GABA

Calming neurotransmitter



Calms firing nerves in CNS. High levels improve focus; low levels cause anxiety. Also contributes to motor control & vision.

## ACETYLCHOLINE

Learning neurotransmitter



Involved in thought, learning, & memory. Activates muscle action in the body. Also associated with attention and awakening.

## GLUTAMATE

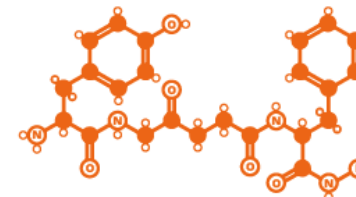
Memory neurotransmitter



Most common brain neurotransmitter. Involved in learning & memory, regulates development & creation of nerve contacts.

## ENDORPHINS

Euphoria neurotransmitters



Released during exercise, excitement, & sex, producing well-being & euphoria, reducing pain. Biologically active section shown.



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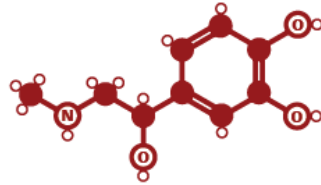


# THE STRUCTURES OF NEUROTRANSMITTERS

STRUCTURE KEY: ● Carbon atom ○ Hydrogen atom ⊙ Oxygen atom ⊙ Nitrogen atom ⊙ Rest of molecule

## ADRENALINE

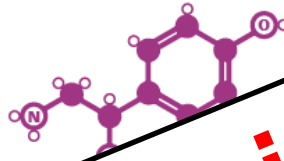
Fight or flight neurotransmitter



Produced in stressful or exciting situations. Increases heart rate & blood flow, leading to a physical boost & heightened awareness.

## NORADRENALINE

Concentration neurotransmitter



**Excitatory**  
(Glutamate, acetylcholin)

**x**  
**Inhibitory**  
(GABA)

## GABA

Calming neurotransmitter



Calms firing nerves in CNS. High levels improve focus; low levels cause anxiety. Also contributes to motor control & vision.

## DOPAMINE

Pleasure neurotransmitter



Most common brain neurotransmitter. Involved in learning & memory, regulates development & creation of nerve contacts.

## SEROTONIN

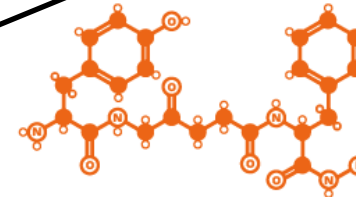
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Released during exercise, excitement, & sex, producing well-being & euphoria, reducing pain. Biologically active section shown.

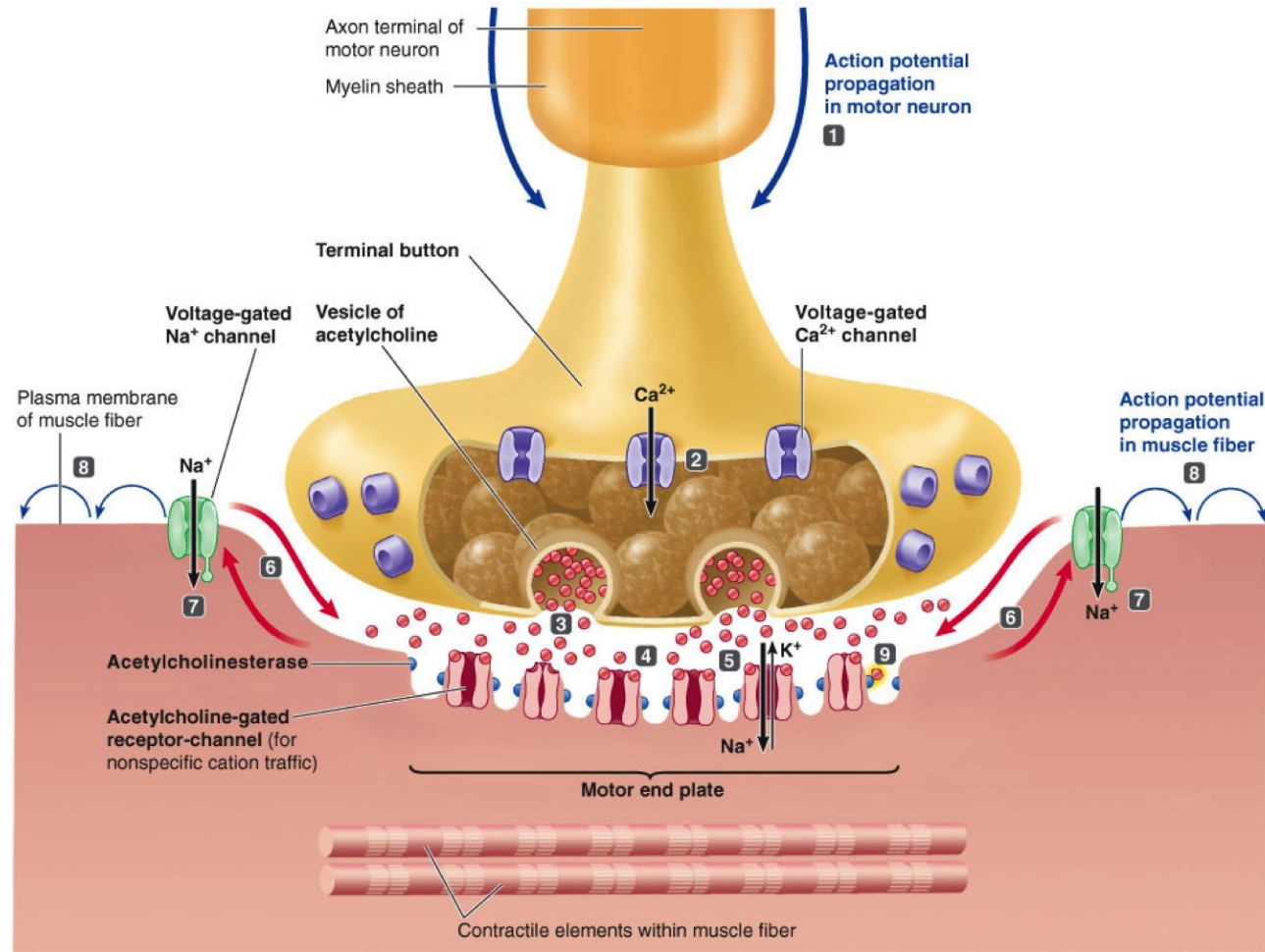


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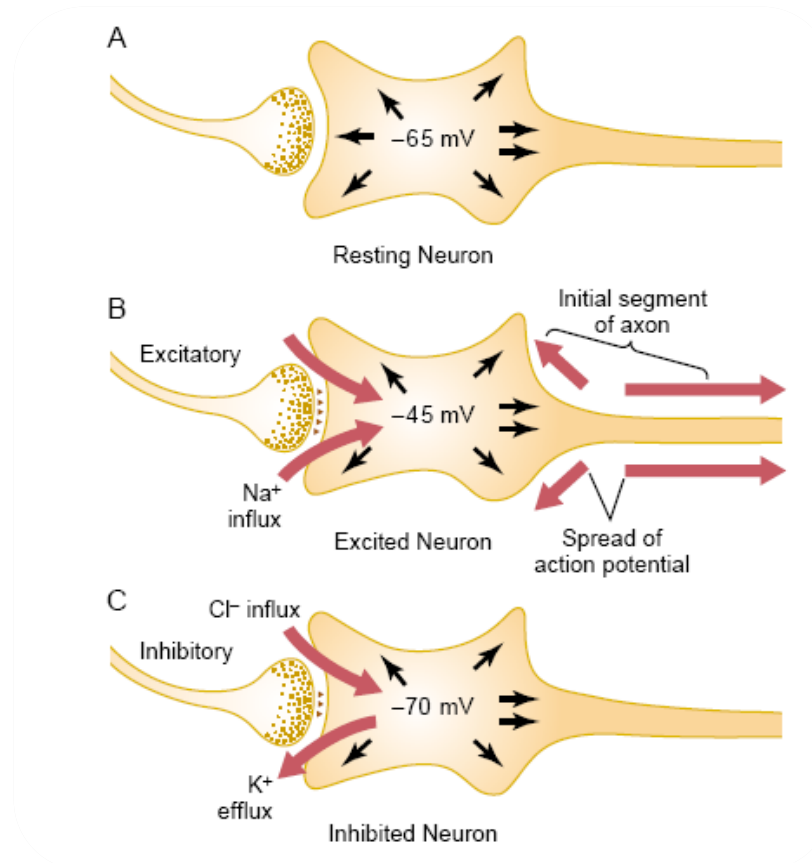


# Neuromuscular junction



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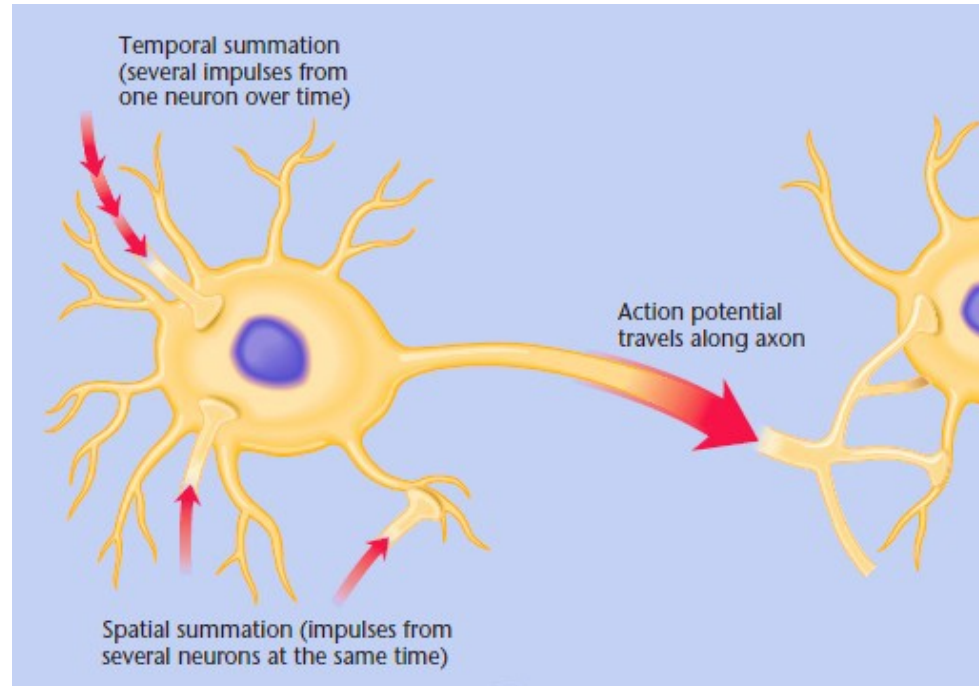
# Excitatory/inhibitory postsynaptic potential



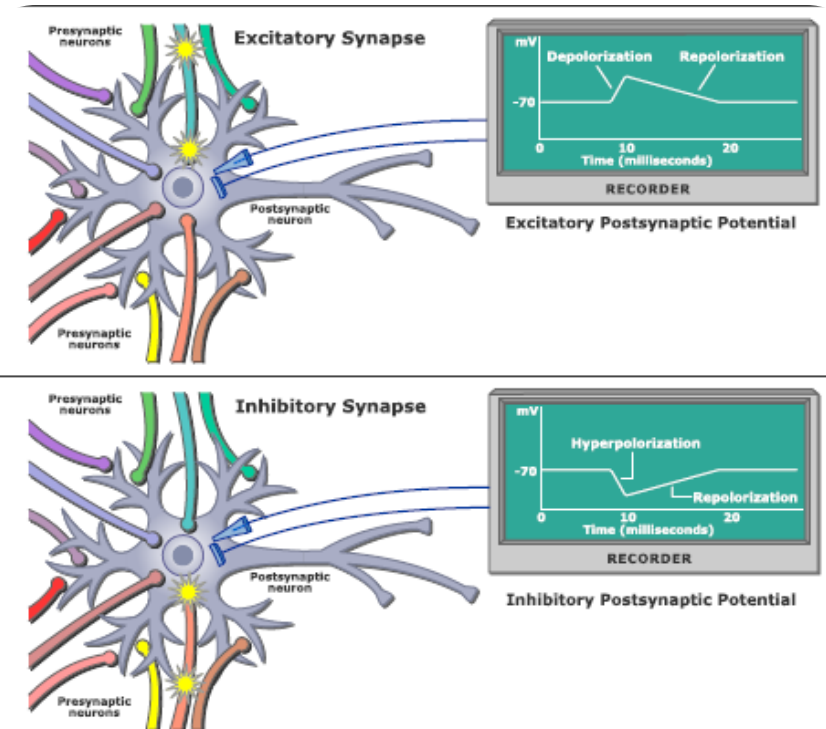
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# Signal summation

- Temporal
- Spatial

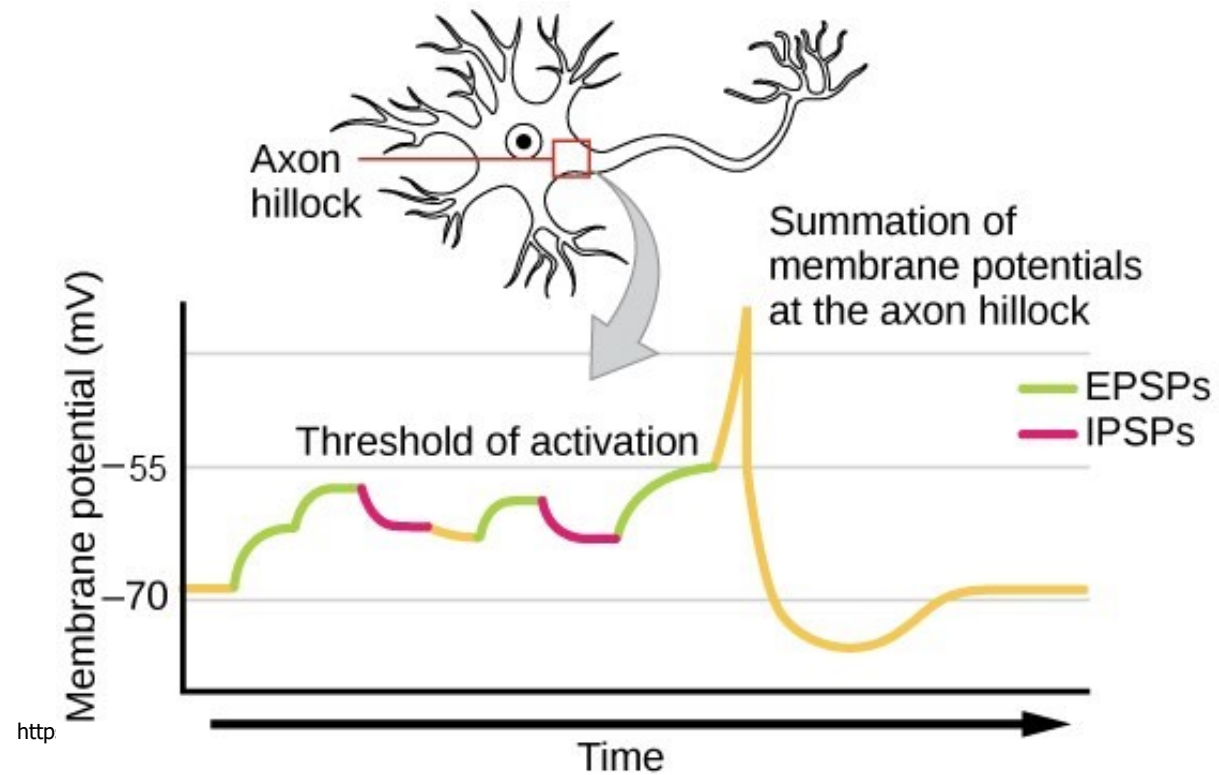


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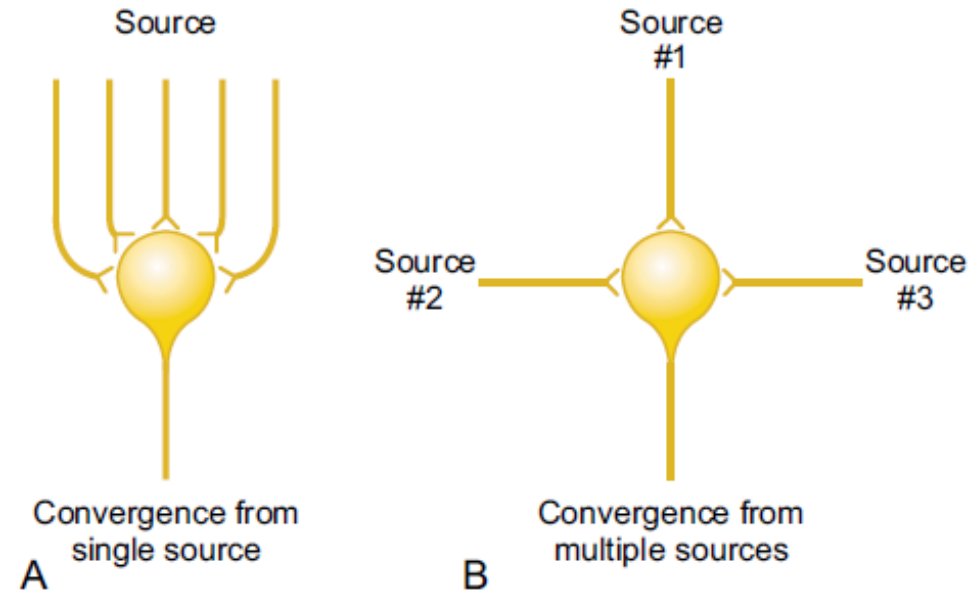
<http://www.slideshare.net/drpsdeb/presentations>

# Signal summation



<http://www.geon.us/Memory/images/Summation.jpg>

# Synaptic convergence



**Figure 46-12**

“Convergence” of multiple input fibers onto a single neuron. *A*, Multiple input fibers from a single source. *B*, Input fibers from multiple separate sources.

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# Synaptic convergence

Average number of synapses in one neuronal cell in primates

- ✓ Primary visual cortex (area17)
  - aprox. 4 000
- ✓ Primary motor cortex (area4)
  - aprox. 60 000

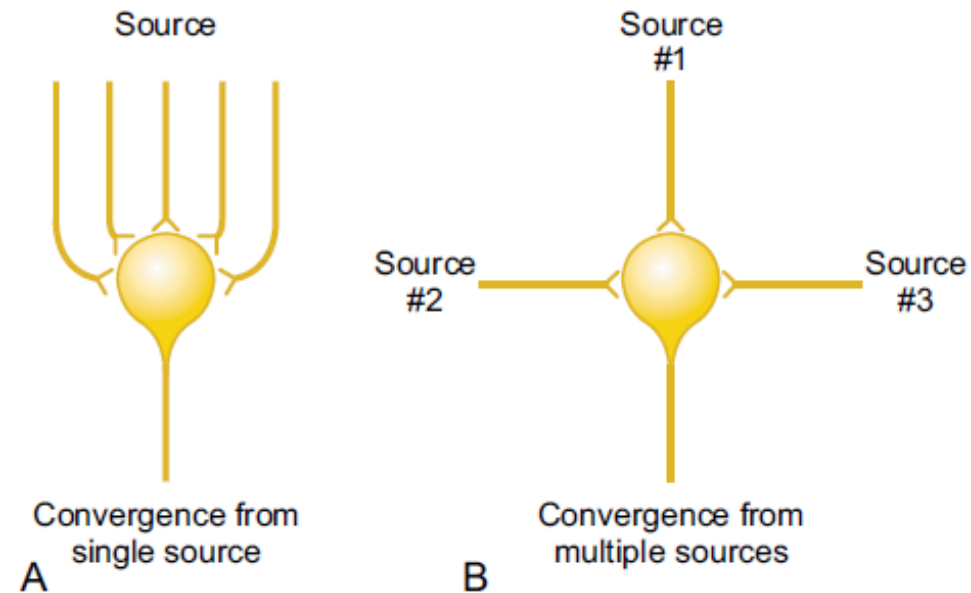
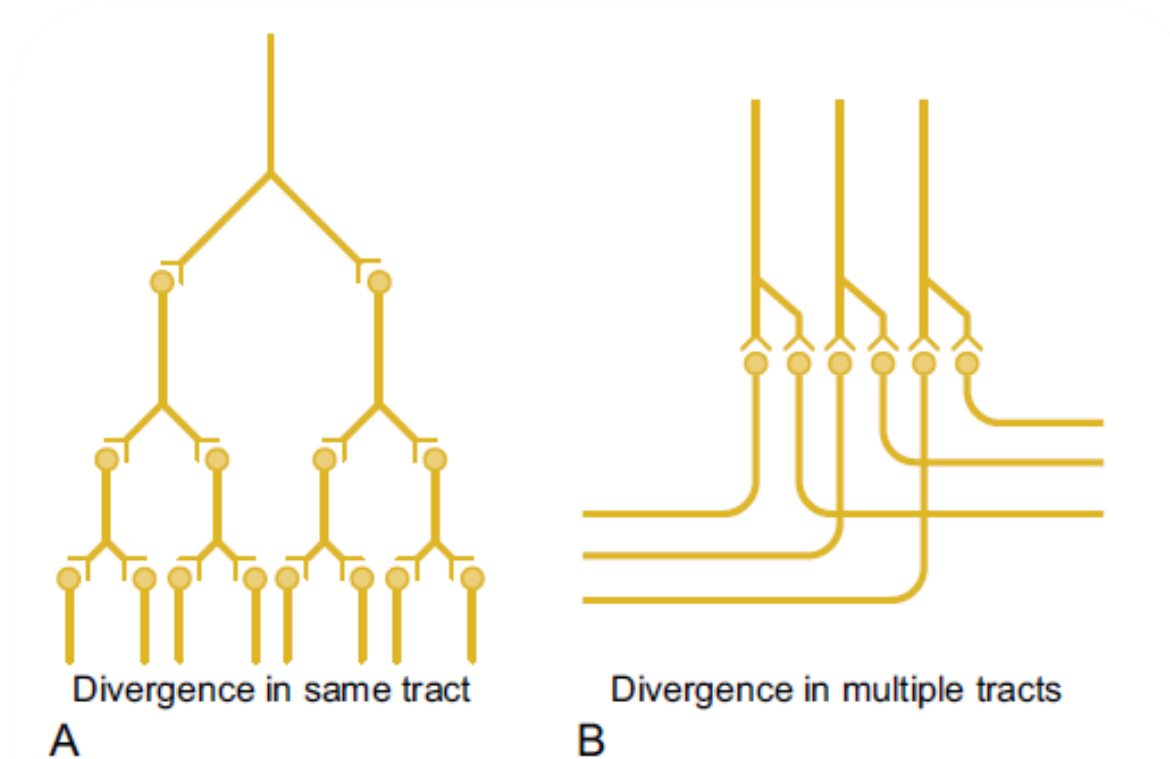


Figure 46-12

"Convergence" of multiple input fibers onto a single neuron. *A*, Multiple input fibers from a single source. *B*, Input fibers from multiple separate sources.

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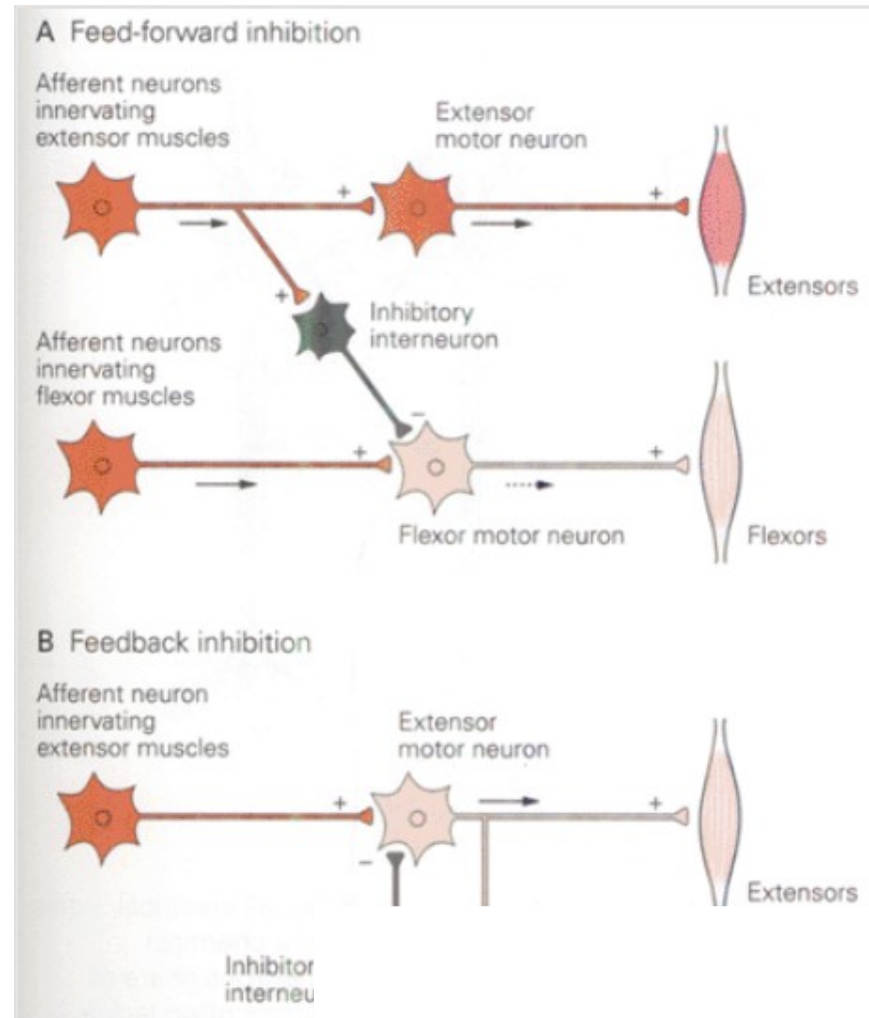
# Synaptic divergence



**Figure 46-11**

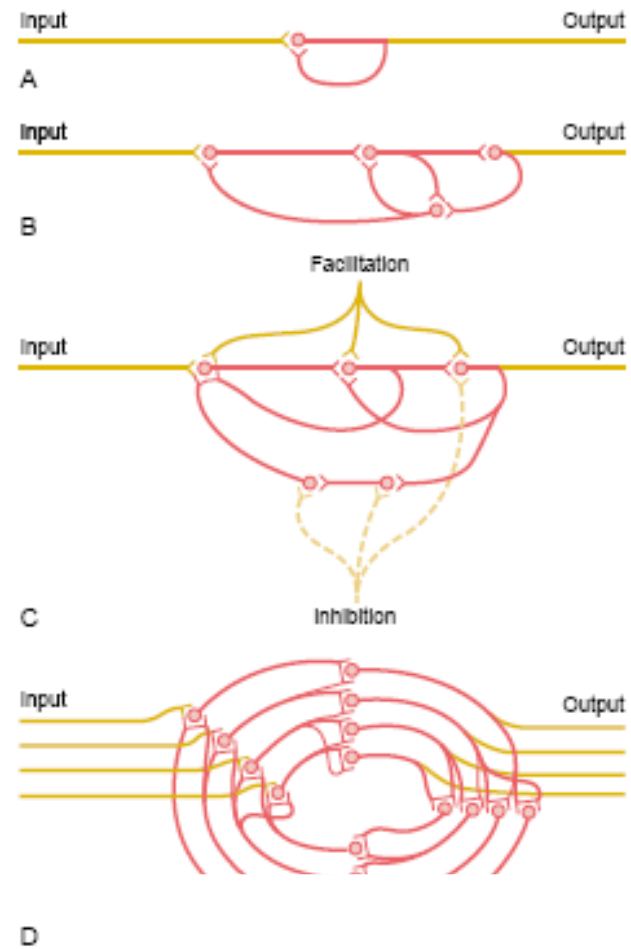
“Divergence” in neuronal pathways. *A*, Divergence within a pathway to cause “amplification” of the signal. *B*, Divergence into multiple tracts to transmit the signal to separate areas.

# Networking





# Networking



# Neurotransmission

# vs. Neuromodulation

- Information transmission

- Regulation of NS activity

# Neurotransmission

# vs. Neuromodulation

- Information transmission
- Specific

- Regulation of NS activity
- Diffuse (volume transmission)

# Neurotransmission

# vs. Neuromodulation

- Information transmission
- Specific
- Receptors – ion channels

- Regulation of NS activity
- Diffuse (volume transmission)
- Receptors – G-proteins

# Neurotransmission

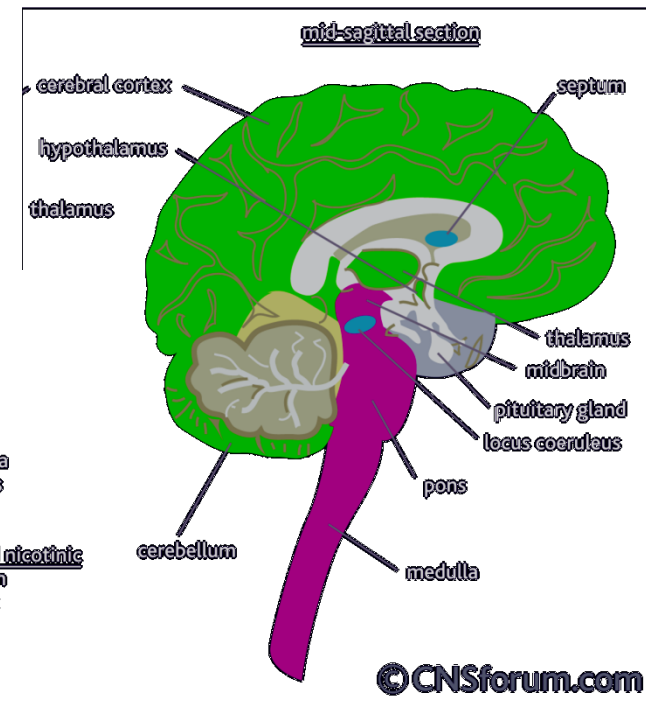
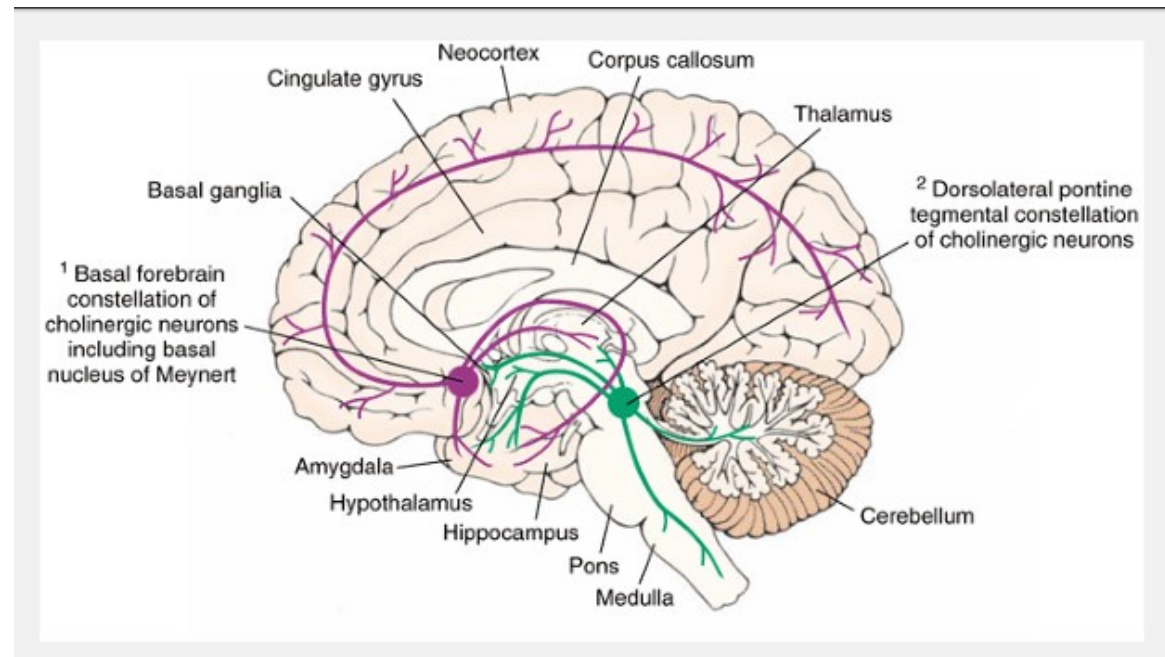
# vs. Neuromodulation

- Information transmission
- Specific
- Receptors – ion channels
- Short duration
  - membrane potential changes

- Regulation of NS activity
- Diffuse (volume transmission)
- Receptors – G-proteins
- Longer duration
  - changes in synaptic properties

# Acetylcholine

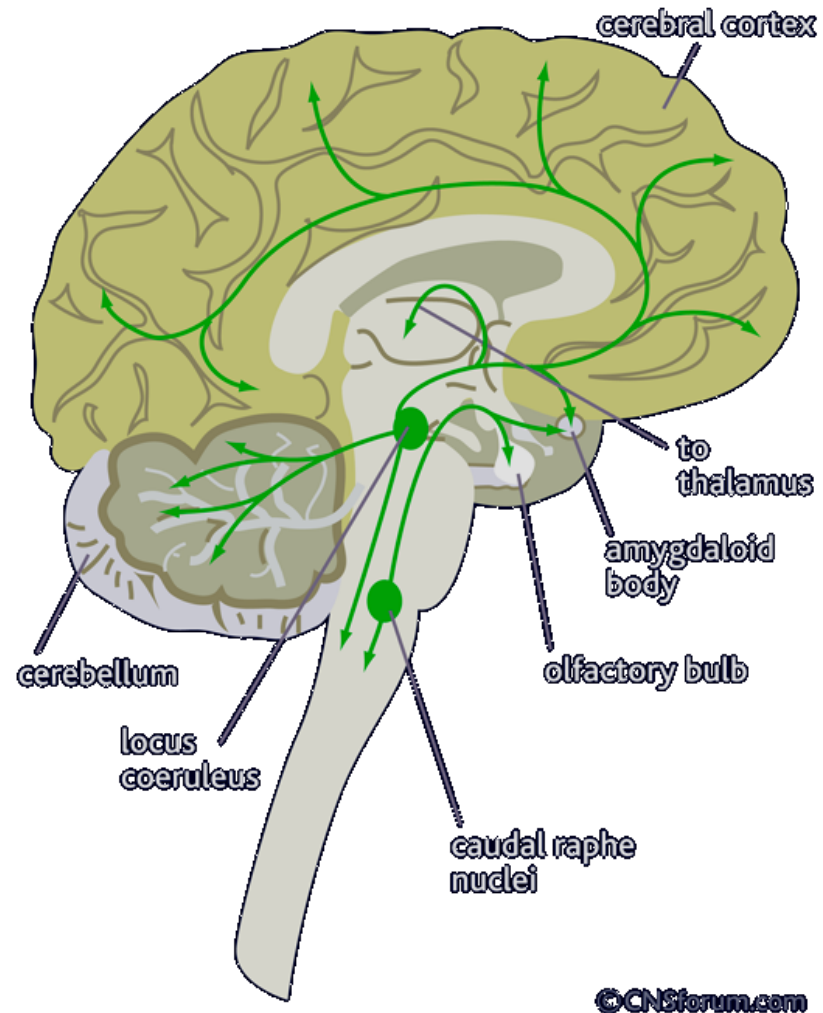
- Nucleus basalis (Meynerti) and other nuclei
  - Nicotin receptors
  - Muscarin receptors
- 
- Sleep/wake regulation
  - Cognitive functions
  - Behavior
  - Emotions



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# Noradrenalin

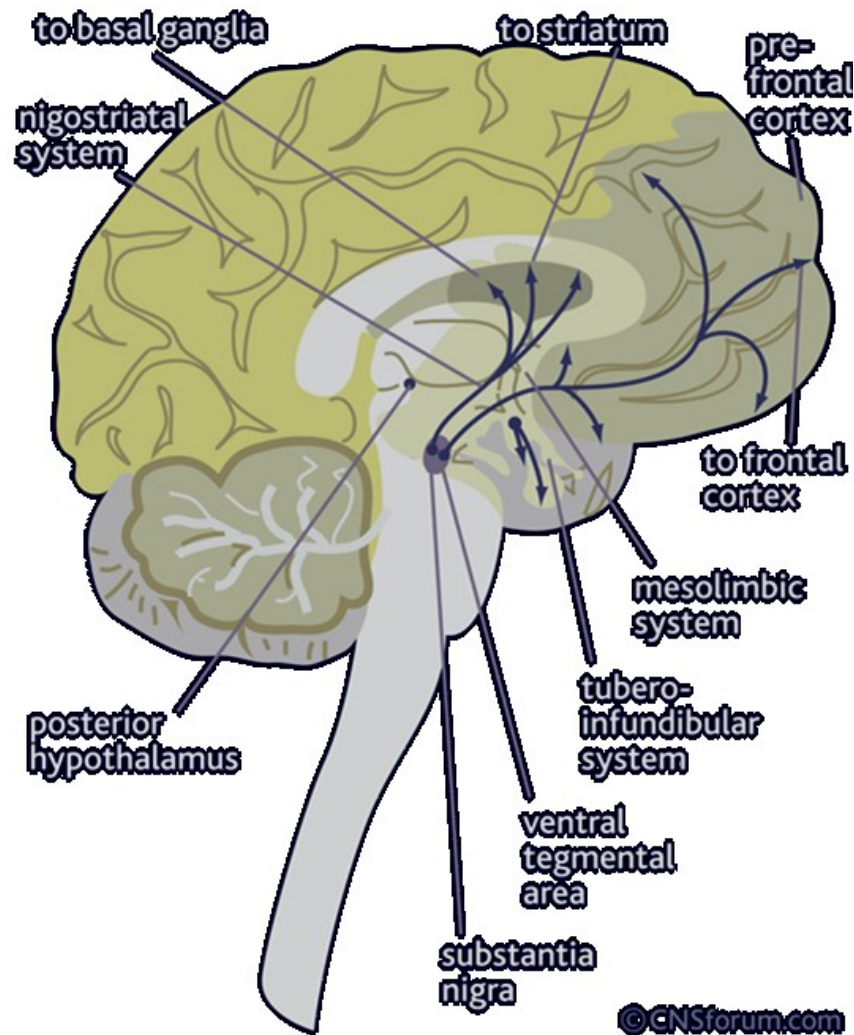
- Locus coeruleus
- Nuclei raphe caudalis
  
- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning



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# Dopamin

- Nigrostriatal system
  - Movement
  - Sensory stimuli
- Ventro- tegmentno-mesolimbic-frontal system
  - Reward
  - Cognitive function
  - Emotional behavior
- Tubero-infundibular system
  - Hypothalamic-pituitary regulation
- D1 receptors – excitatory
- D2 receptors - inhibitory

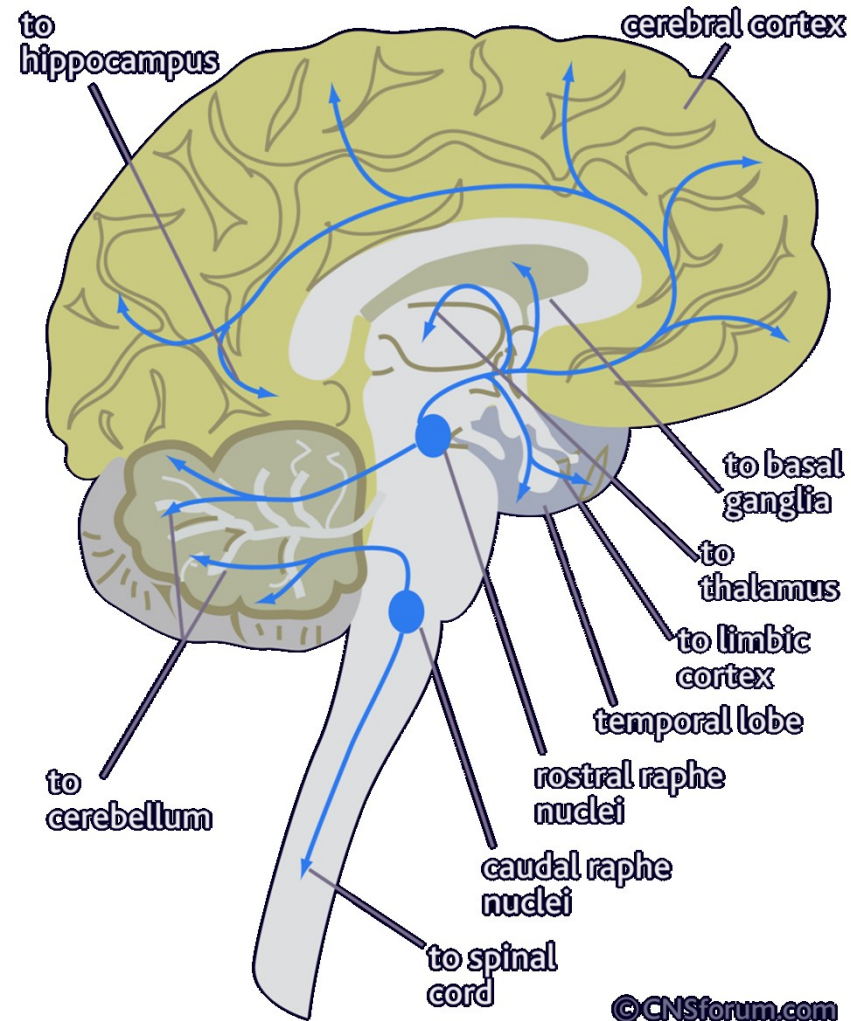


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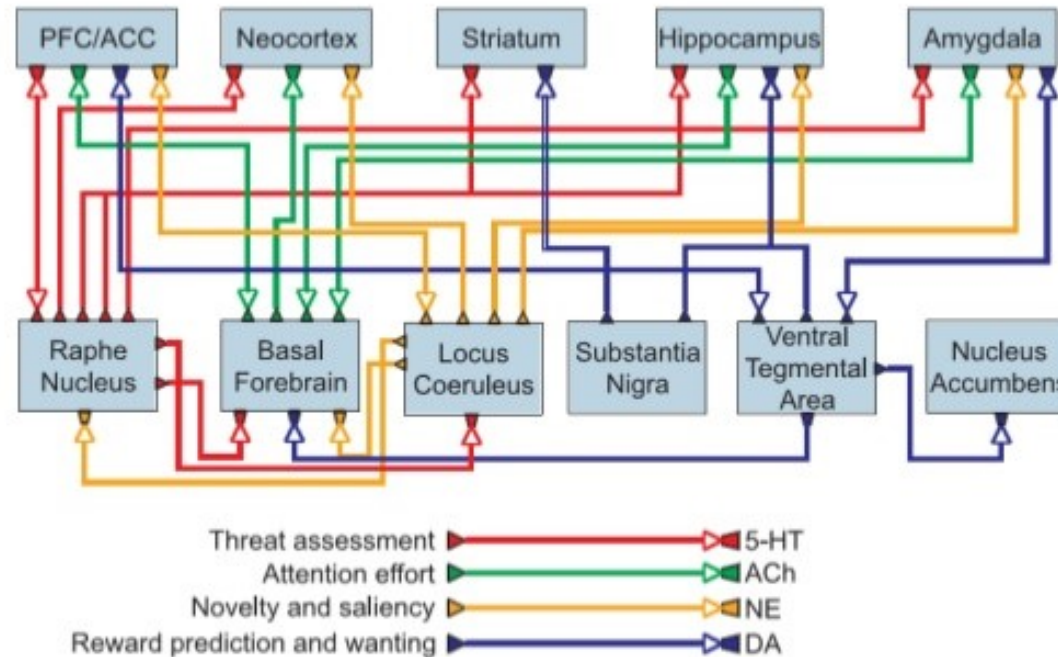
# Serotonin

- Nuclei raphe rostralis
- Nuclei raphe caudalis
  
- Anxiety/relaxation
- Impulsive behavior
- Sleep



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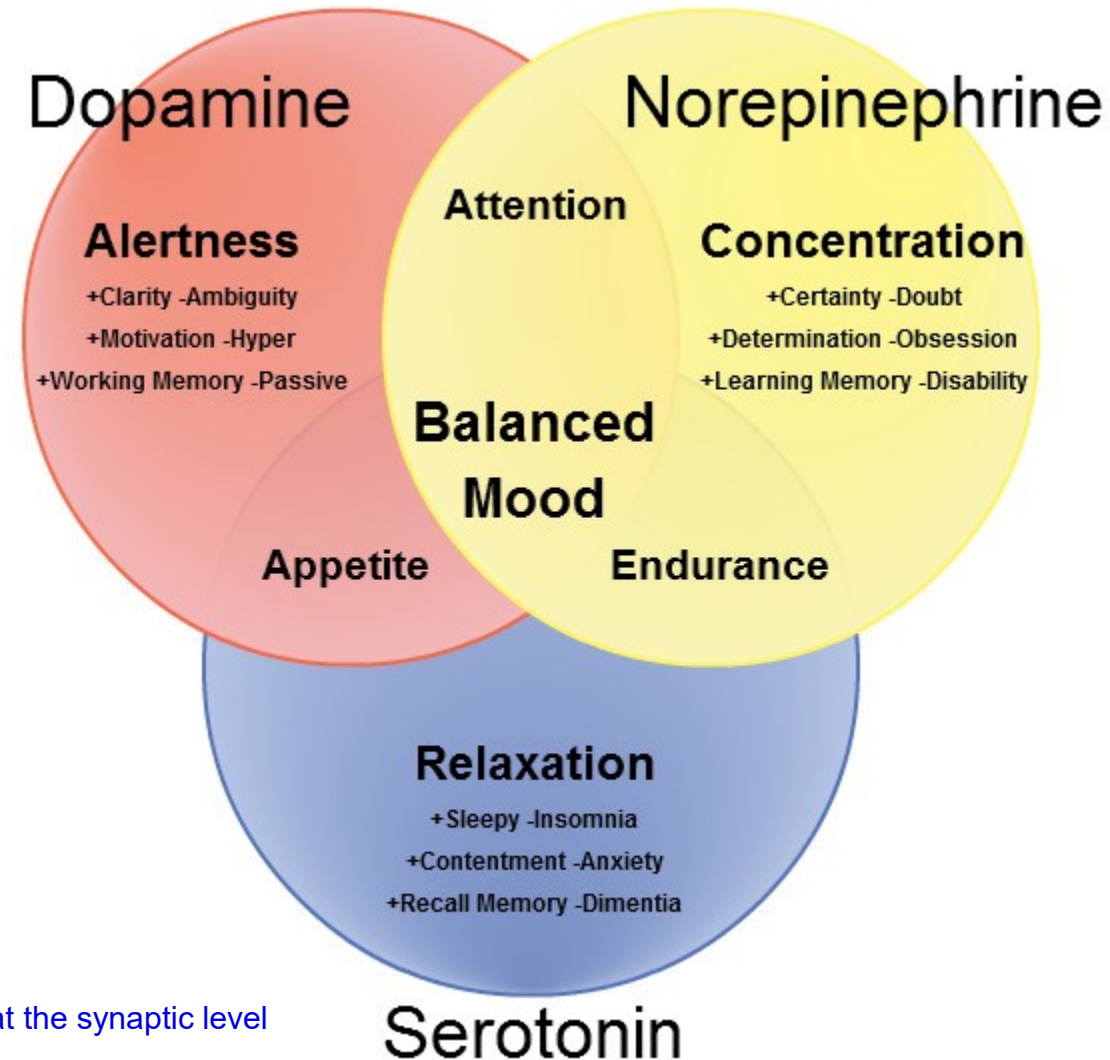
# Neuromodulatory systems



Jeffrey L. Krichmar, Adaptive Behavior 2008; 16; 385

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# Neuromodulatory systems



## 71. Structure of synapse and integration of information on the synaptic level, neurotransmission vs. neuromodulation

- ✓ Synapse
  - Definition
  - Electrical vs. chemical
- ✓ Definition and basic classifications of neurotransmitters
- ✓ Excitatory/inhibitory postsynaptic potentials vs. action potential
  - Temporal and spatial signal summation
- ✓ Signal convergence vs. divergence
- ✓ Neurotransmission vs. neuromodulation
  - Examples of neuromodulatory systems

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