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# Introduction to neurophysiology
# Cellular base of nervous system
# Synapse

# Contact

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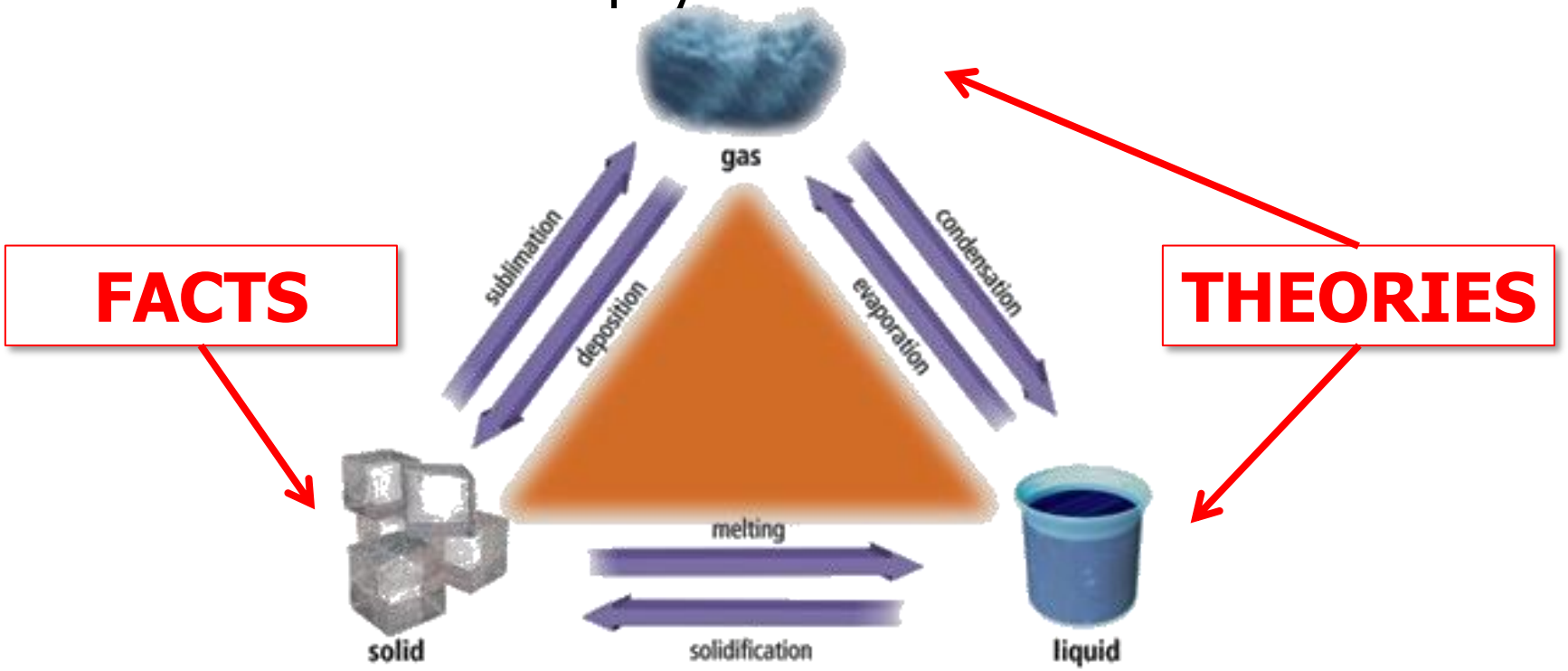
# Why and how to STUDY neuroscience

Philosophy : Mind behind Mind




**PS Deb**

Neuroscience: Brain

Psychology : Mind

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



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# What is nervous system good for?

# The role of nervous system

## Unicellular organism

- One cell has to do everything- lower effectivity
- Total dependence on environment
- High level of stress
- Short life time

## Multicellular organism

- Functional specialization of particular cells – higher effectivity
- Inner environment – homeostasis
- Lower level of stress
- Longer life time



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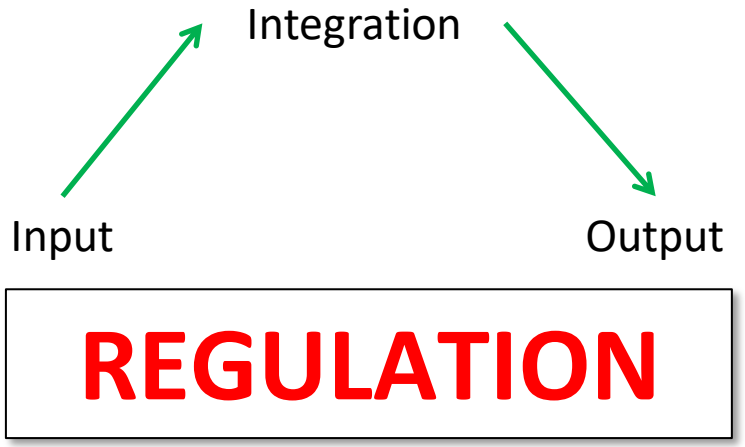
# The role of nervous system

- Essentials for survival of multicellular organism

➢ Maintaining homeostasis
  - The composition of inner environment
  - The integrity of organ/ bodily barriers

➢ Coordination of bodily functions
  - To receive signals from outer and inner environment
  - To process this information
  - To respond in a coordinate manner to these stimuli



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# The role of nervous system

- Regulation
  - Nervous
  - Humoral



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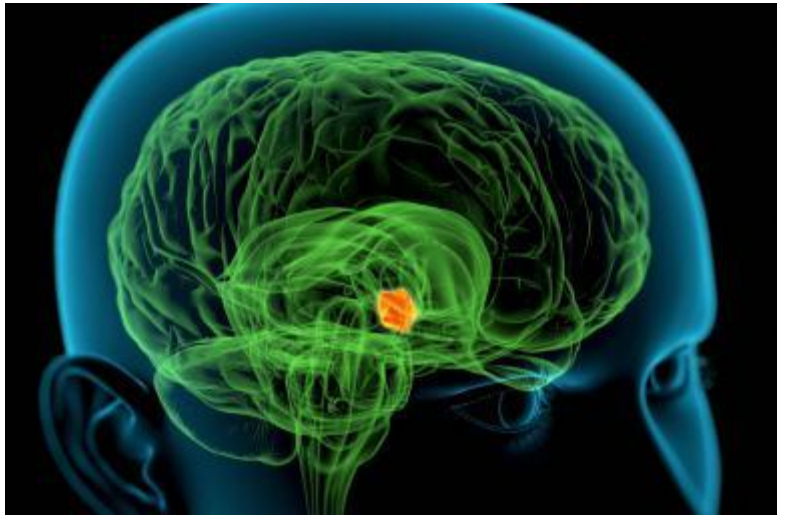
# The role of nervous system

- Regulation
  - Nervous
  - Humoral



http://biology.about.com/od/anatomy/p/Hypothalamus.htm

**Central nervous system controls both types of regulations**



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# The role of nervous system

**Humoral regulations**

- Hormone
- Non-specific channel of conduction (blood stream)
- Target site defined by specific receptor

**Nervous regylations**

- Neurtransmitters
- Specific channel of conduction
- Target site defined by infrastructure

# The role of nervous system

**Humoral regulations**

- Hormone
- Non-specific channel of conduction (blood stream)
- Target site defined by specific receptor
- Low energetical demands
- Slow
- Long duration

**Nervous regylations**

- Neurtransmitters
- Specific channel of conduction
- Target site defined by infrastructure
- High energetical demands
- Fast
- Short duration



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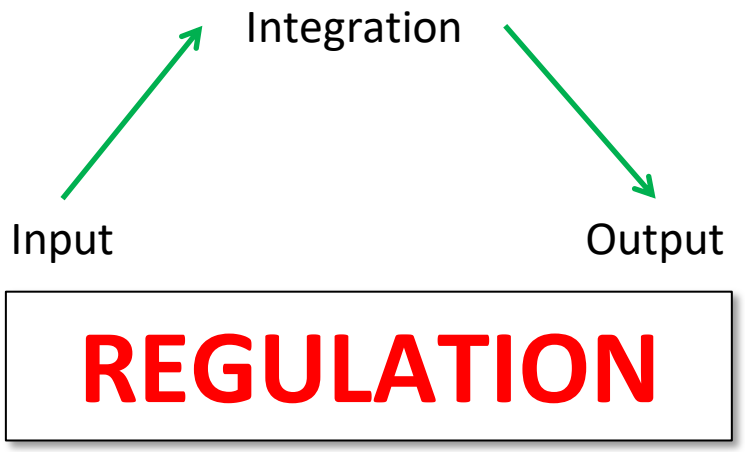
# The role of nervous system



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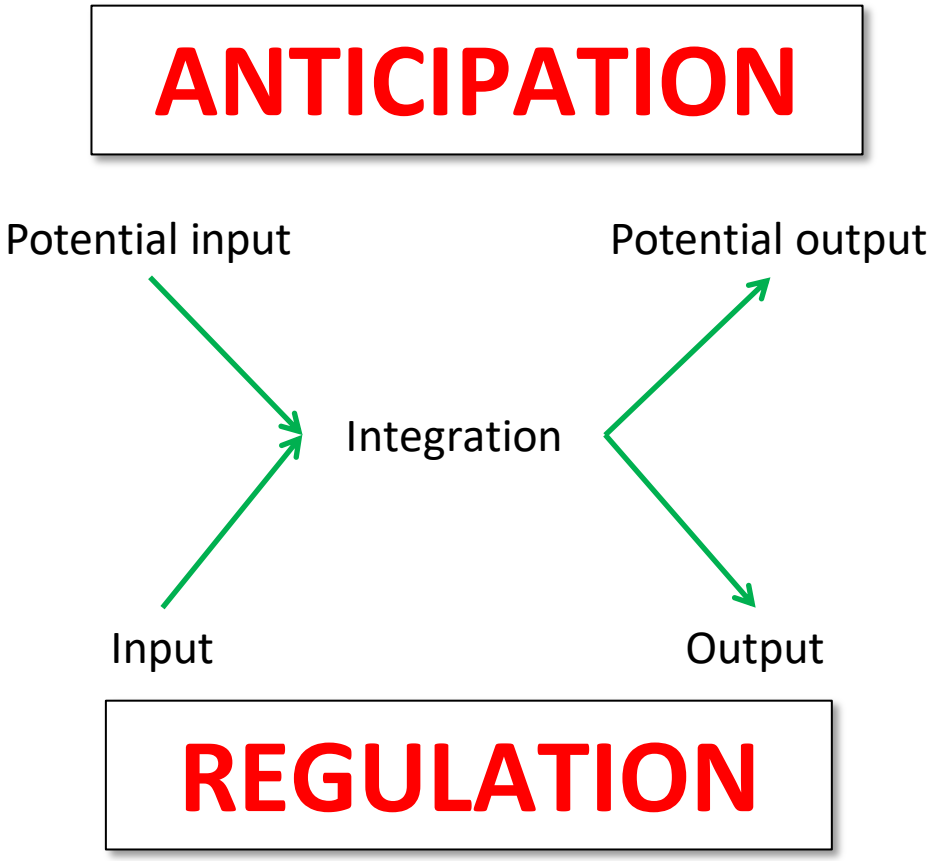
# The role of nervous system



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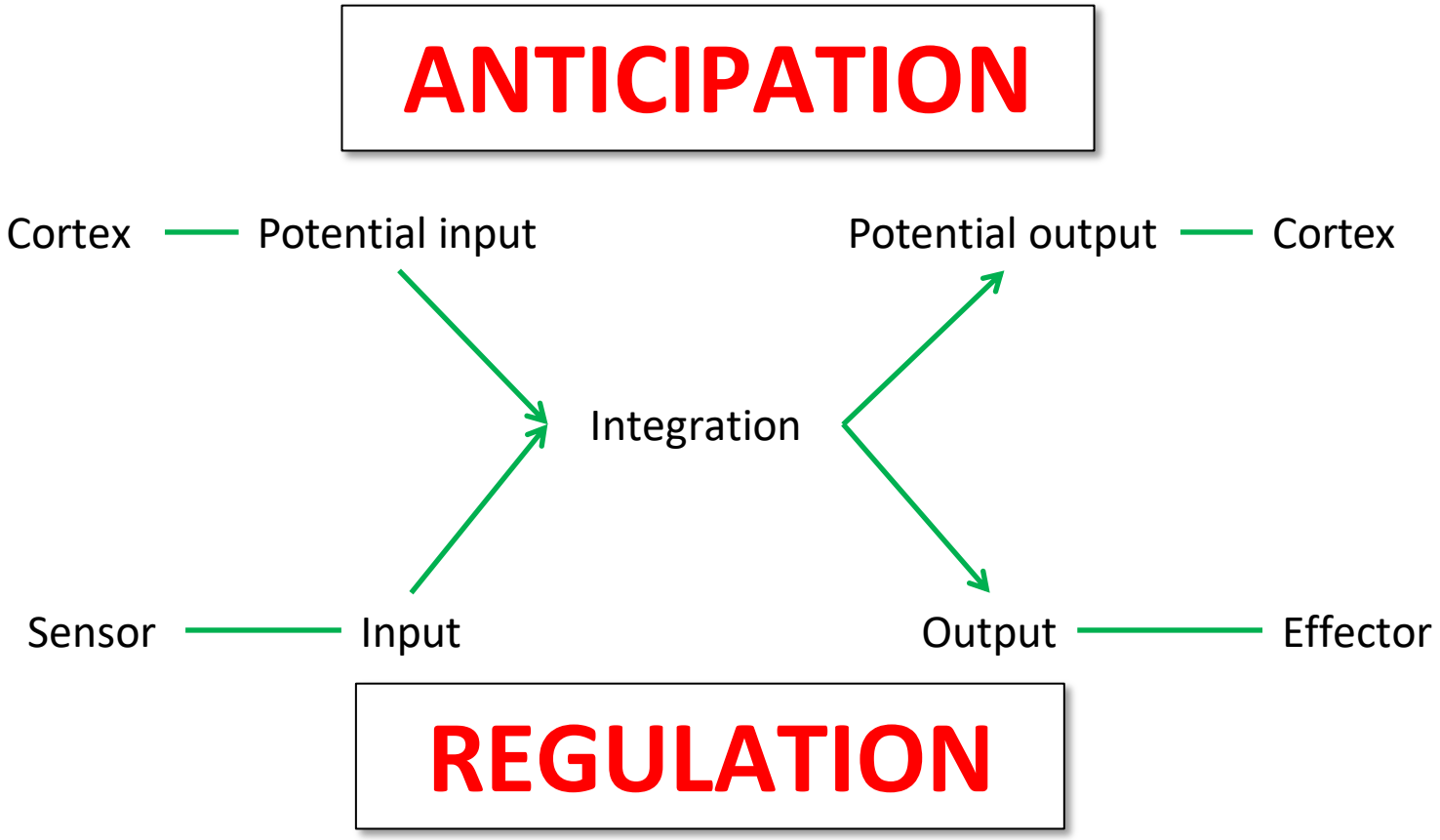
# The role of nervous system



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# Evolutionary approach

- Evolutionary old structures have not been replaced by new ones during evolution, but the old has been kept and the new added

# Evolutionary approach

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- Evolutionary younger structures were associated with new functions or with the improvement in existing functions



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# Evolutionary approach

- Evolutionary old structures have not been replaced by new ones during evolution, but the old has been kept and the new added

- Evolutionary younger structures were associated with new functions or with the improvement in existing functions

- It is important to ask what is any particular function good for and how it has been improved in course of evolution

# Evolutionary approach
# Evolution is not revolution



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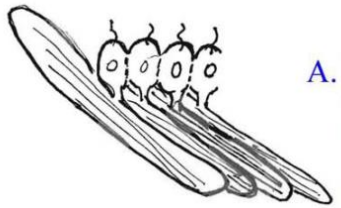
# Evolution of the nervous system

Input → Integration → Output



A. Myoepithelium:
contractile epithelial cells
responding to stimulation and
interconnected by electrical
synapses (gap junctions)

Gerald Schneider. *9.14 Brain Structure and Its Origins, Spring 2014*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed). License:Creative Commons BY-NC-SA

## Four basic types of tissue

- ✓ **Epithelial**
- ✓ **Connective**
- ✓ **Muscular**
- ✓ **Nervous**



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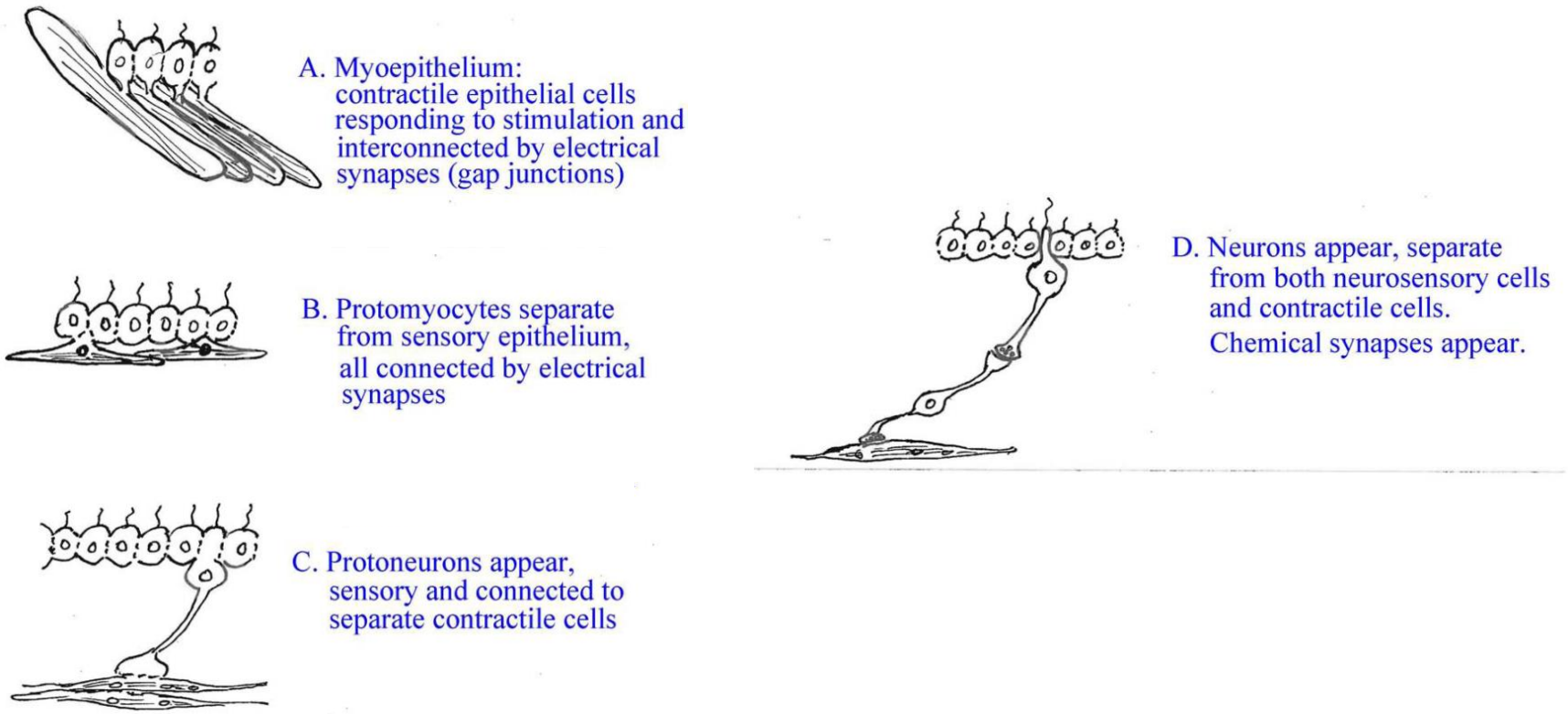
# Evolution of the nervous system

Input → Integration → Output





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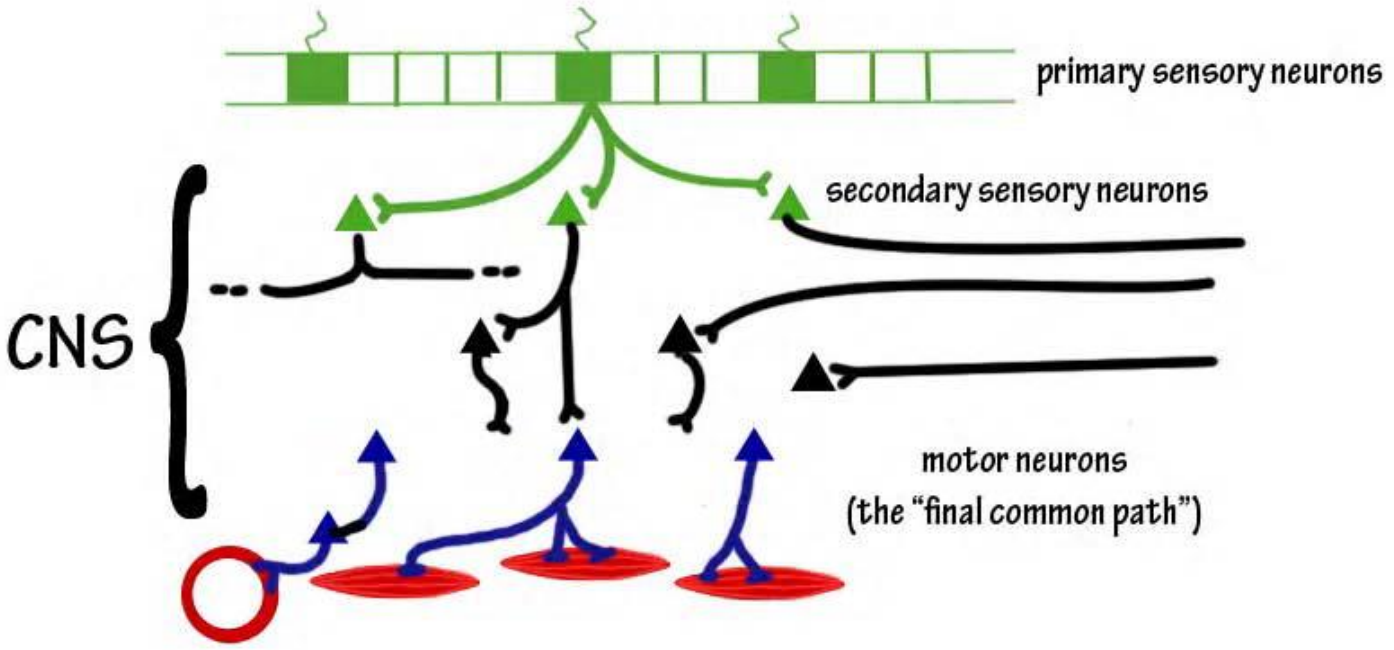
# Evolution of the nervous system




Input

Integration

Output

Gerald Schneider. *9.14 Brain Structure and Its Origins, Spring 2014*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed). License:Creative Commons BY-NC-SA



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# Compartmentalization

- Cellular specialization leads to compartmentalization on several levels
  - Tissue level
  - Organ level
  - Organ system level
- There are barriers in between compartments
- Properties/content may vary among different compartments



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# Compartmentalization

- Cellular specialization leads to compartmentalization
  - Tissue level
  - Organ level
  - Organ
- There are
- Properties/c among different compartments

**The brain homeostasis is maintained within a narrow range thanks to hematoencephalic barrier and astrocyte activity**

**This allows neuronal cells to live for the entire life of the individual**



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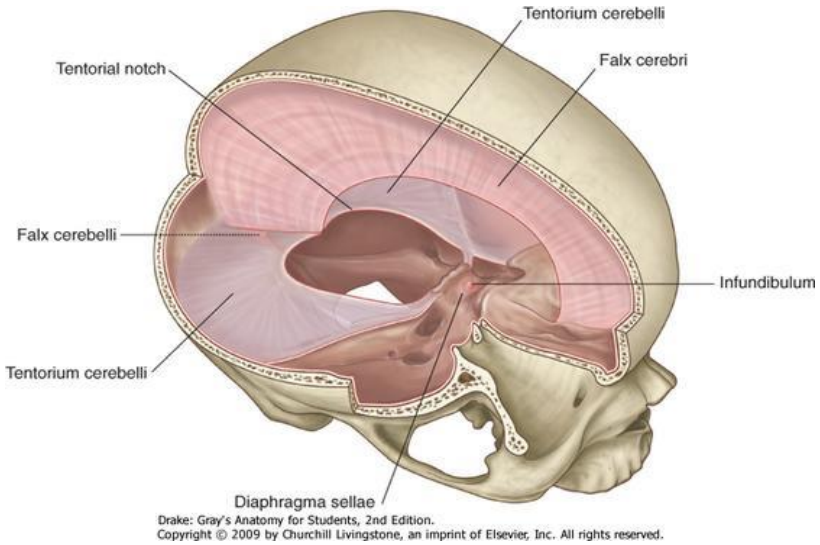
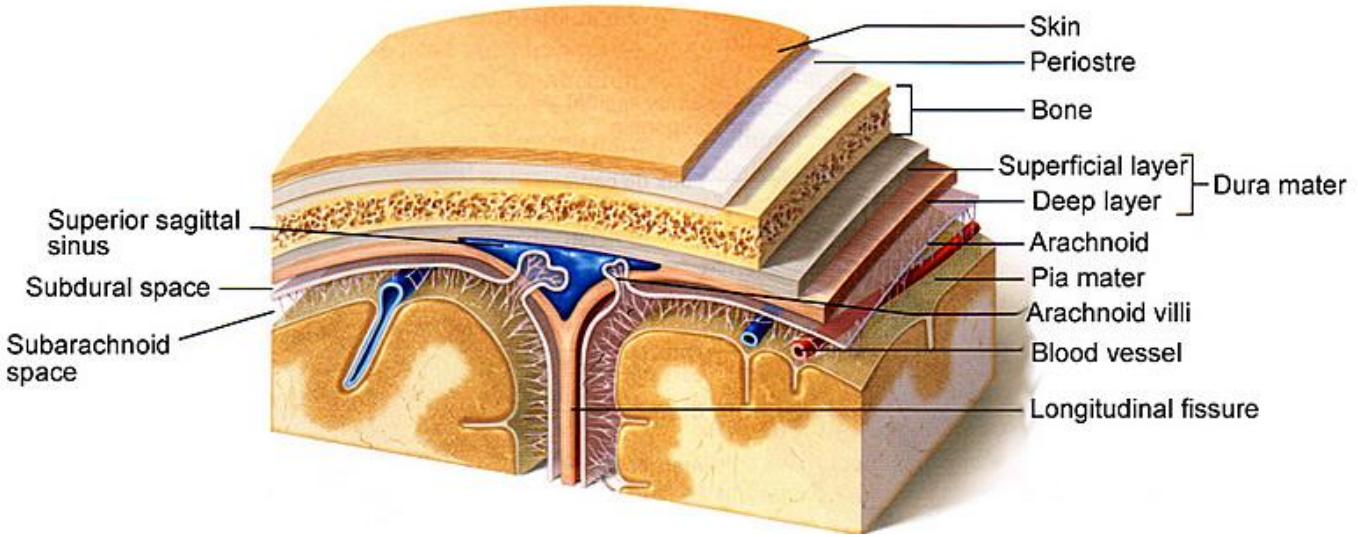
# Intracranial compartment

- ✓ „Very specific region“
- ✓ Brain
- ✓ Cerebrospinal fluid
- ✓ Blood (intravasculary)
- ✓ Barriers
  - Meningeal
  - Hematoliquor
  - Hematoencephalic




http://edutoolanatomy.wikispaces.com




http://www.corpshumain.ca/en/Cerveau3_en.php



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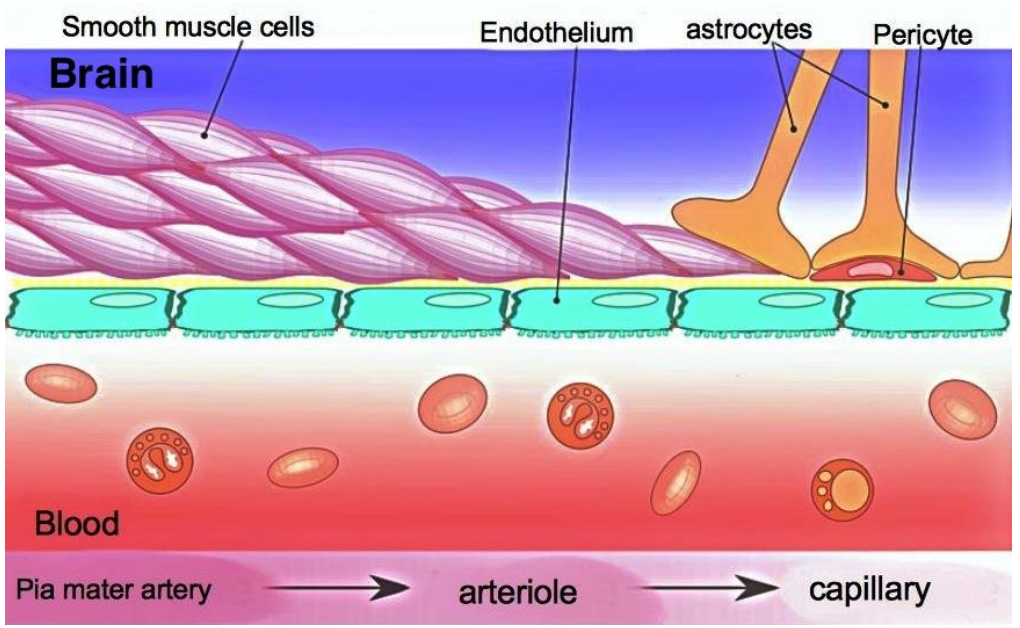
# Hematoencephalic barrier

- Highly organised structure
  - Endothelial cells (low permeability thanks to zonlua occludens)
  - Basal membrane
  - Astrocytes
  - Pericytes




https://upload.wikimedia.org/wikipedia/commons/1/12/Blood_vessels_brain_english.jpg



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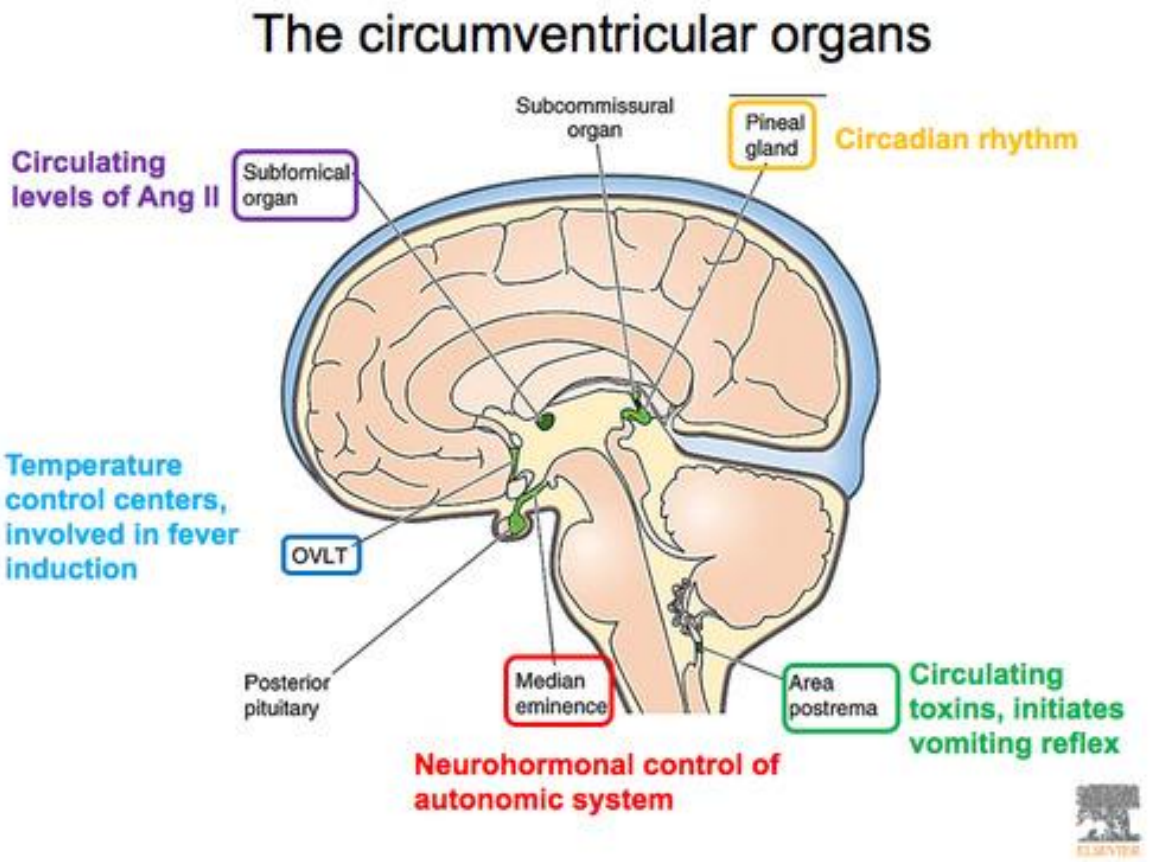
# Circumventricular organs

- Rich vascularisation
- Modified hematoencephalic barrier
- Sensors
- Secretion




http://www.neuros.org/index.php?option=com_photos&view=photos&oid=hafizbilal



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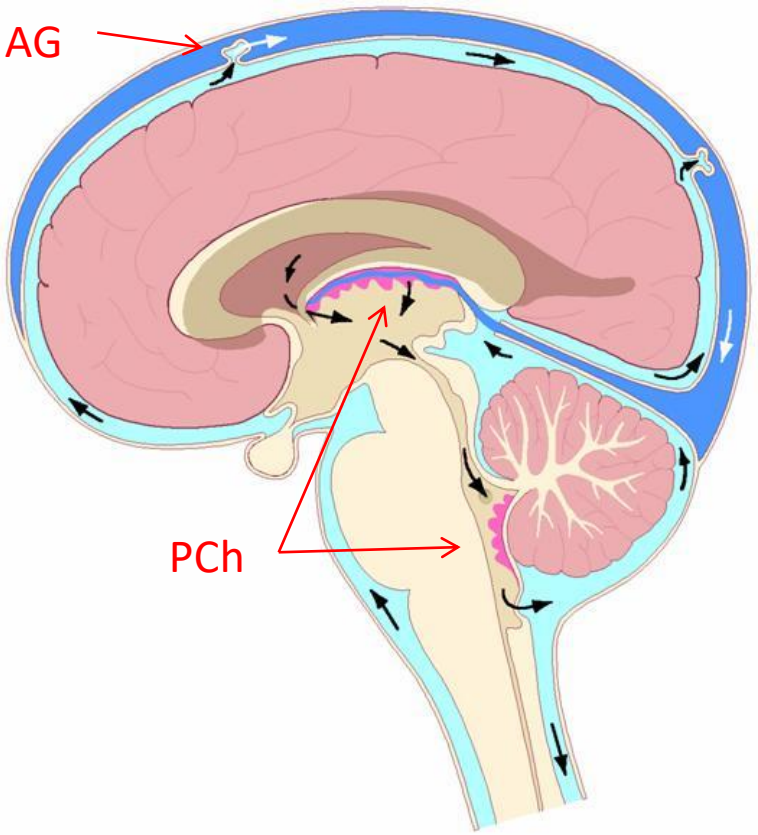
# Cerebrospinal fluid

- Content
  - ✓ High levels of $Mg^{+}$ and $Na^{+}$
  - ✓ Low levels of $K^{+}$ and $Ca^{2+}$
  - ✓ Almost no cells (max 5/ml)
- Function
  - ✓ Protection
  - ✓ Microenvironment of neurons and glia
    - – Metabolic function
    - – Immunologic function
    - – Transport function and so on




http://www.control.tfe.umu.se



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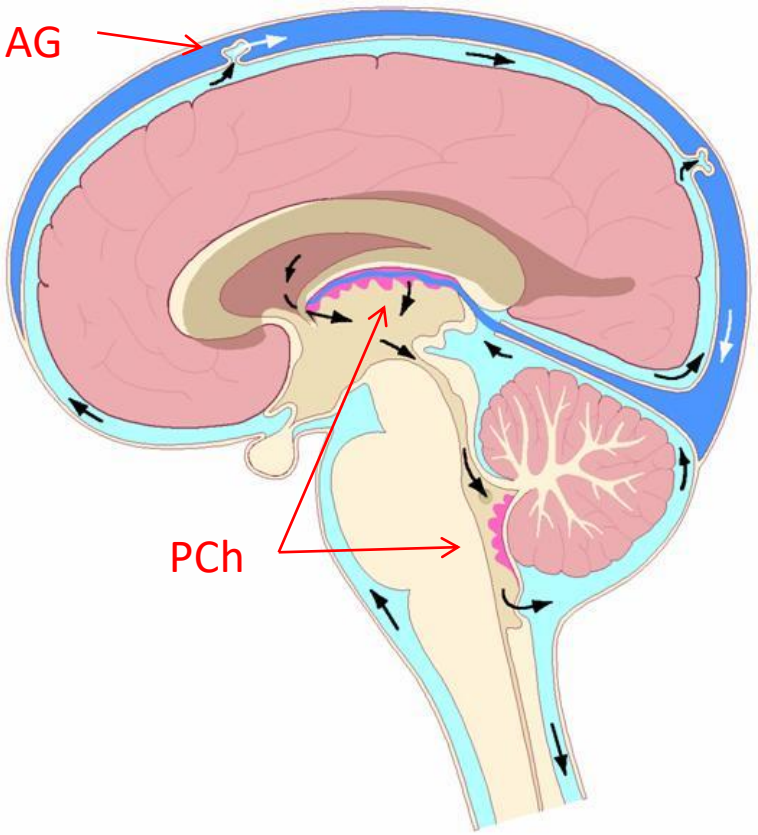
# Cerebrospinal fluid

- Clear fluidproduced by active secretion
- Liquor space
  - ➢ lined by ependymal cells
  - ➢ 150-250 ml
- Production
  - ✓ Plexus choroideus (PCh) -70%
  - ✓ Cell metabolism
  - ✓ Cappilary filtration
  - ➢ 450-750 ml/day
- Resorbtion
  - ✓ Archnoid granulations (AG)




http://www.control.tfe.umu.se



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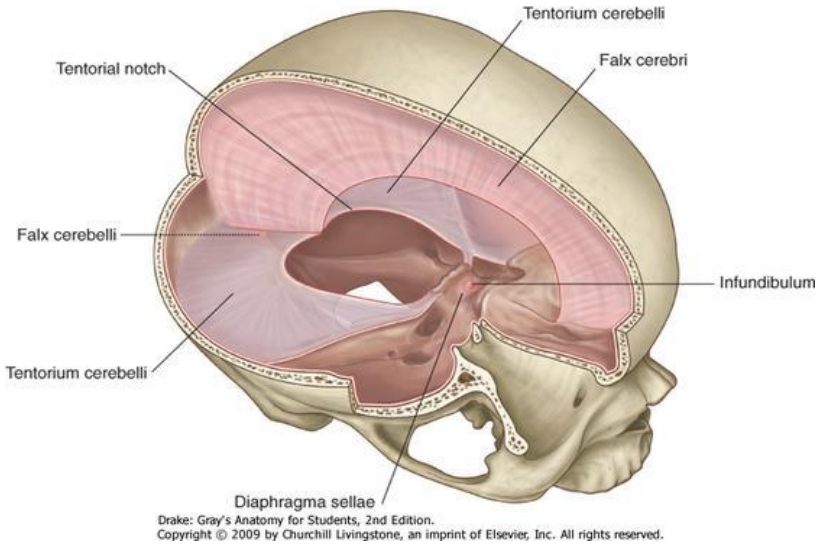
# Intracranial compartment

- Brain
- Cerebrospinal fluid
- Blood (intravascular)

- Intracranial pressure (ICP)
  - Critical determinant of cerebral perfusion

- Cerebral perfusion pressure (CPP) pressure gradient driving blood flow intracranialy



http://edutoolanatomy.wikispaces.com

**!!! CPP = MAP – ICP !!!**

Cerebral perfusion pressure | Intracranial pressure

Mean arterial pressure



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# Cellular base of nervous system
# Synapse

# Cellular base of nervous system

- Neuronal cells
  - Reception, integration and propagation of information
  - Unique, irreplaceable
- Neuroglial cells
  - Support for neuronal cells
  - Easily replacable
- The total amount of neuronal cells - 100 billions ($10^{11}$)
- Neruon/glia ratio
  - 1/10 - 50 (Principles of Neural Science, 4th ed., 2012)
  - 1/2 – 10 (Principles of Neural Science, 5th ed., 2012)
  - 1/1 (Nolte´s Human Brain, 7th ed., 2015)

# Neuroglial cells

## Central nervous system

- Astrocytes
  - Hematoencephalic b.
  - Homeostasis maintaining
  - Metabolism of neurotransmitters
  - Important during brain development
- Oligodendrocytes
  - Myelin sheat
- Microglia
  - Immune funtion
- Ependymal cells
  - Choroid plexus
  - (hemato-liquor barrier)
  - Ventricular lining

    (liquro-encephalic barrier)

## Peripheral nervous system

- Satelite cells
  - Support functions in PNS
- Schwan cells
  - Myelin sheat

# Neuron

**Background Activity**

## The inside of the cell

- ✓ …
- ✓ Synthesis
- ✓ Transport
- ✓ …

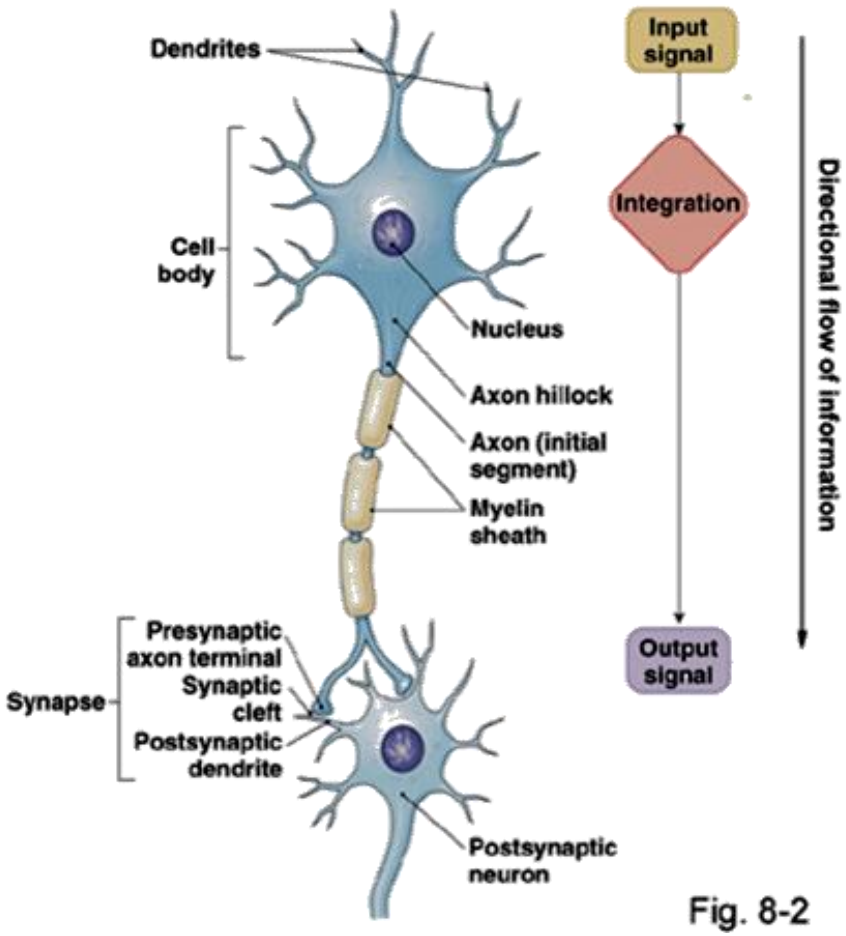


Fig. 8-2

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

**Information processing and transmission**

## The membrane

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



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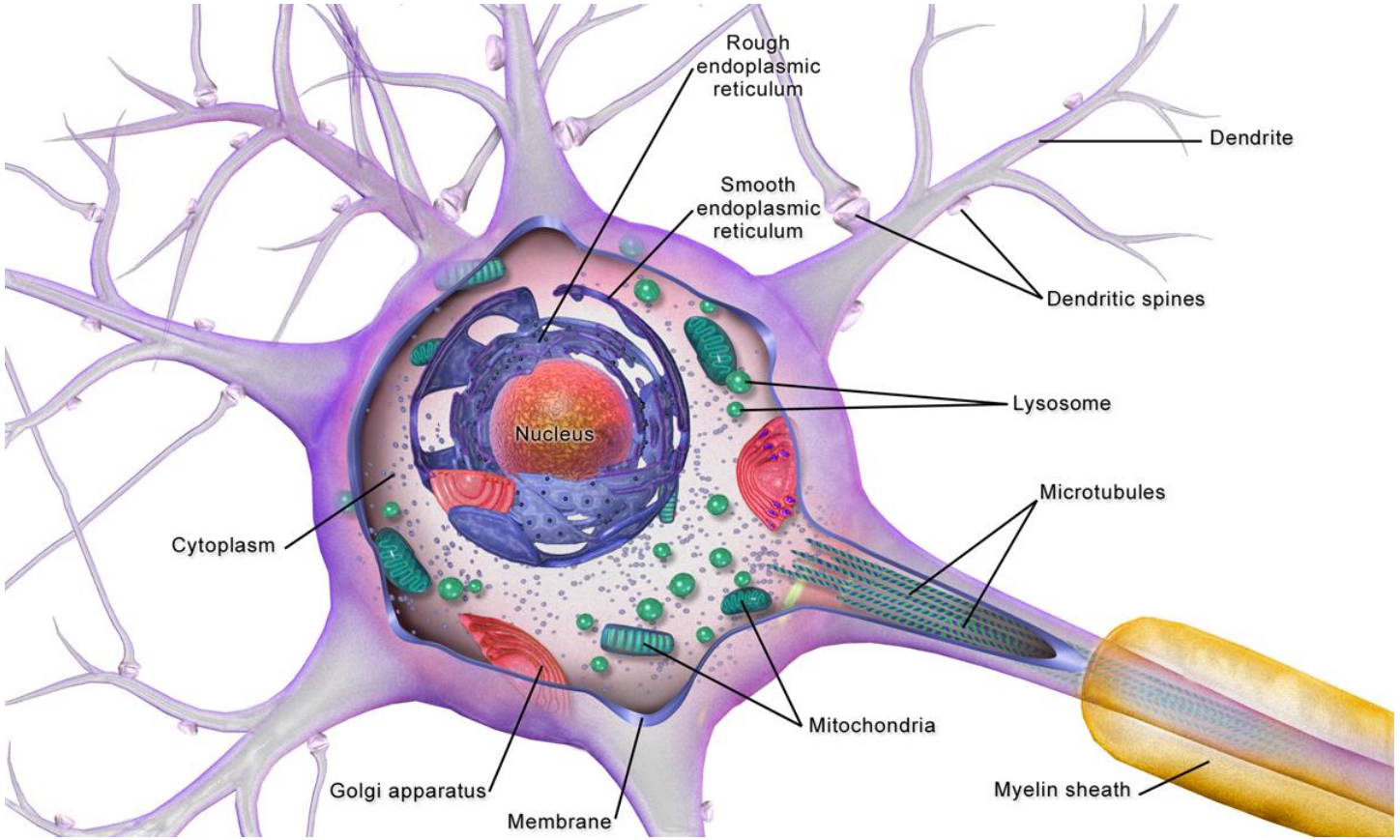
# Background Activity




https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron_Cell_Body.png



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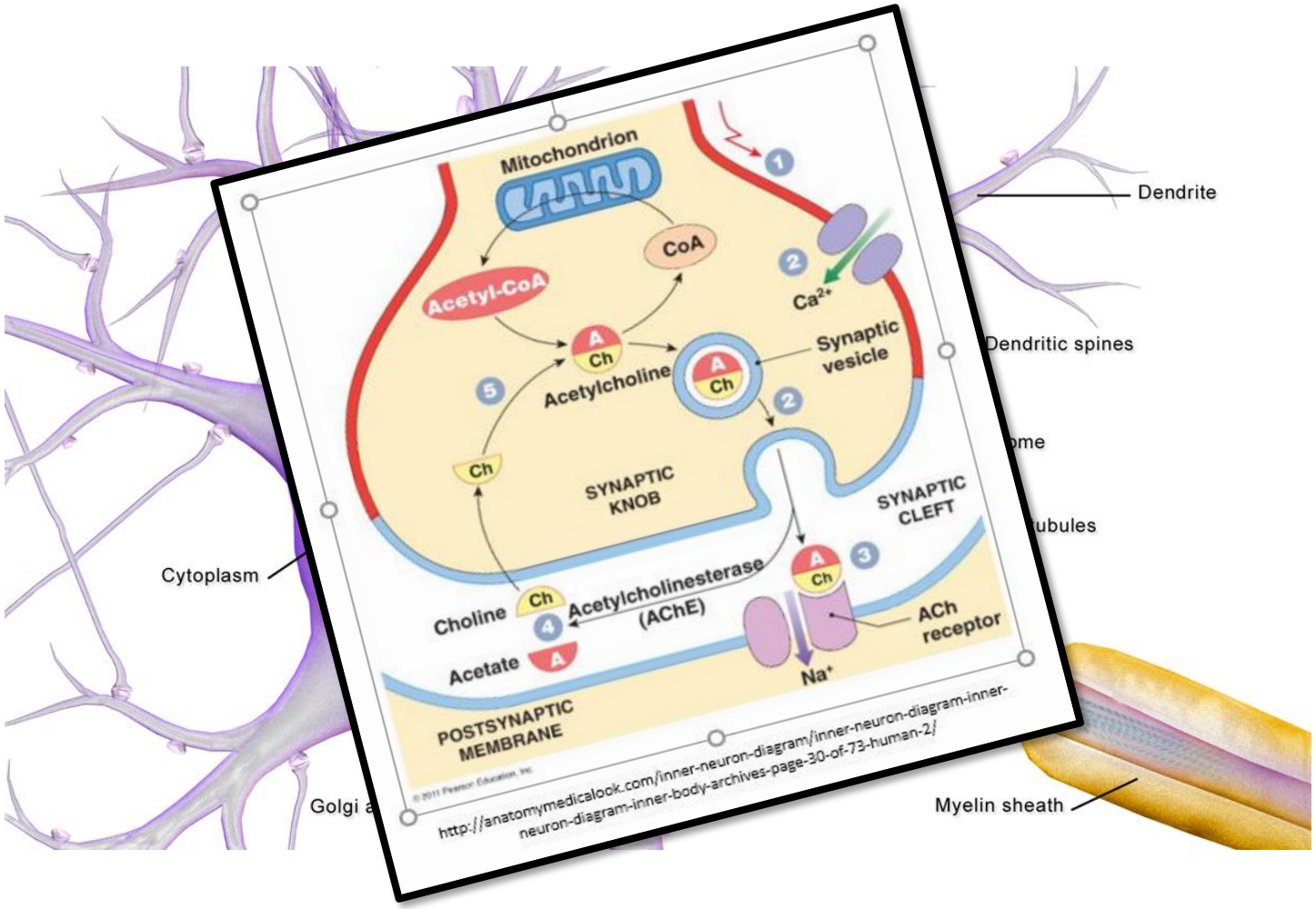
# Background Activity




https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron_Cell_Body.png



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# Background Activity

**Fast axonal transport**

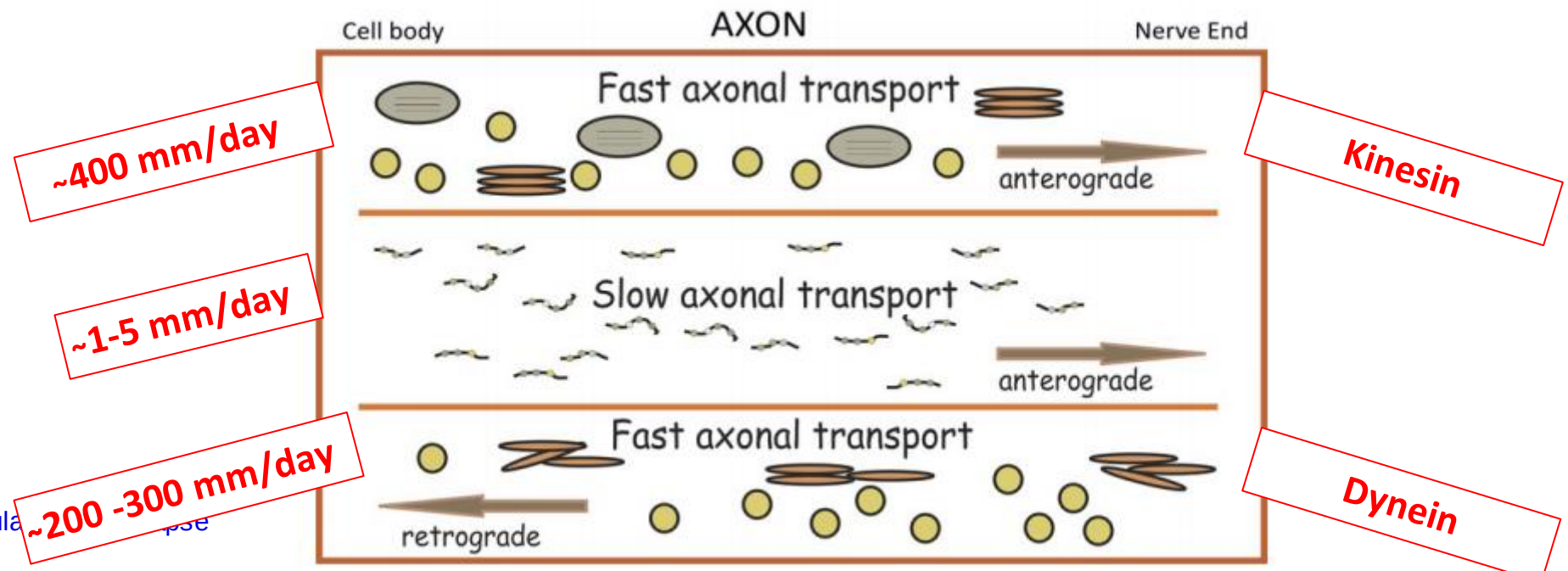
- bidirectional
- ATP dependant
- associated with microtubules: dynein and kinesin

**Slow axonal transport**

- unidirectional,
- ATP independant
- conducted by sliding, polimerizing and protein interacting

**Fast axonal transport**
Golgi derived vesicles
lysosmes, mitochondria
structural elements of
endoplasmic reticulum

**Slow axonal transport**
microfilaments, microtubules
neurofilaments
cytosolic protein complexes




http://www.oapublishinglondon.com/images/article/pdf/1397255957.pdf



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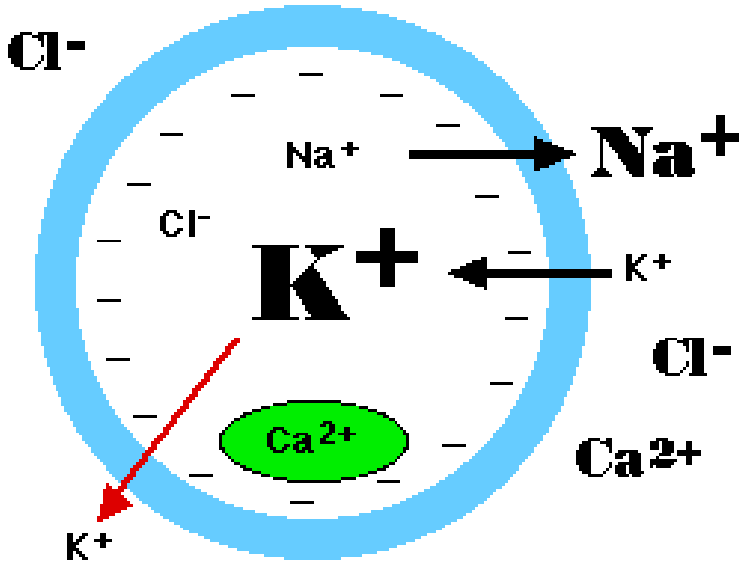
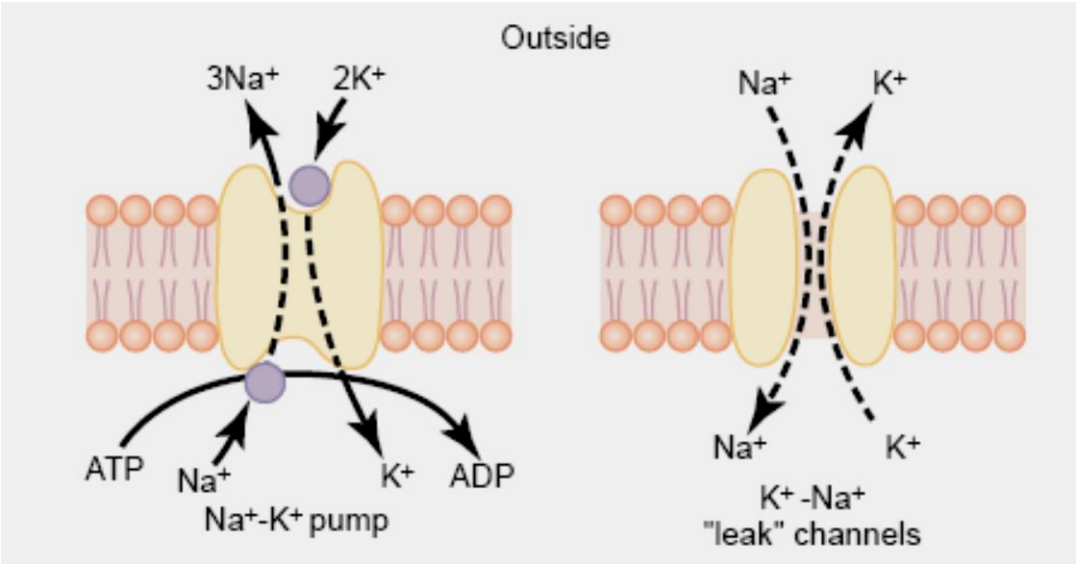
# Membrane potential

- Due to differences in the concentrations of ions on opposite sides of a cellular membrane

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# Resting membrane potential of a neuron

http://assassinscreed.ubi.com

Resting potential around -70 mV

- Highly instable state of membrane
- Why? – Speed!
- High energetical demands
  - ✓ Oxygen - 20%  of total body consumption
  - ✓ Glucose – 25% of total body consumption



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# Action potential

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

**Resting potential around -70 mV**

**Treshold potential around -55 mV**

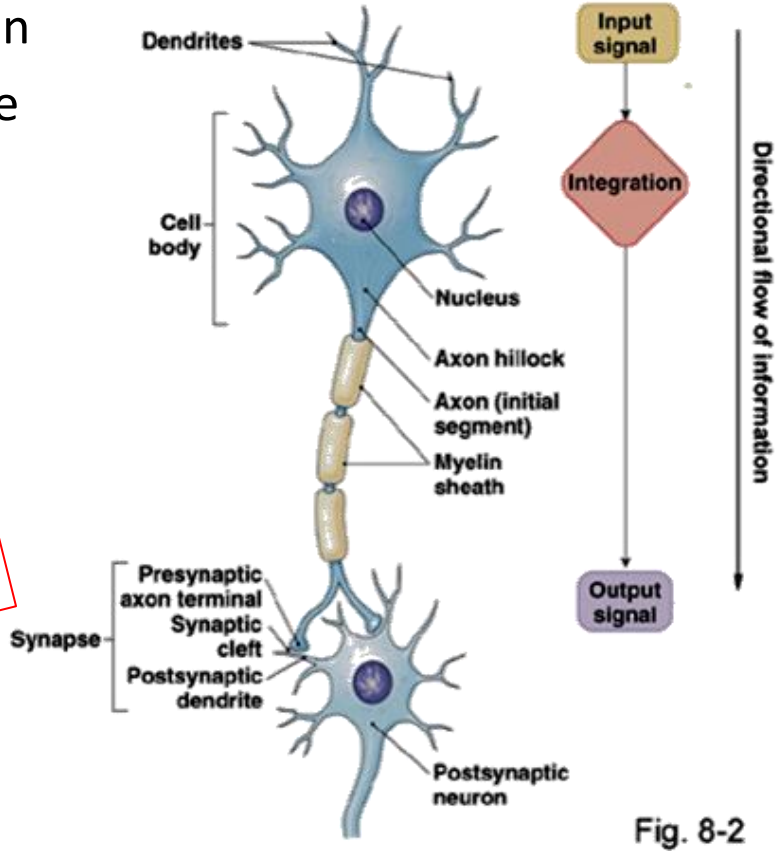
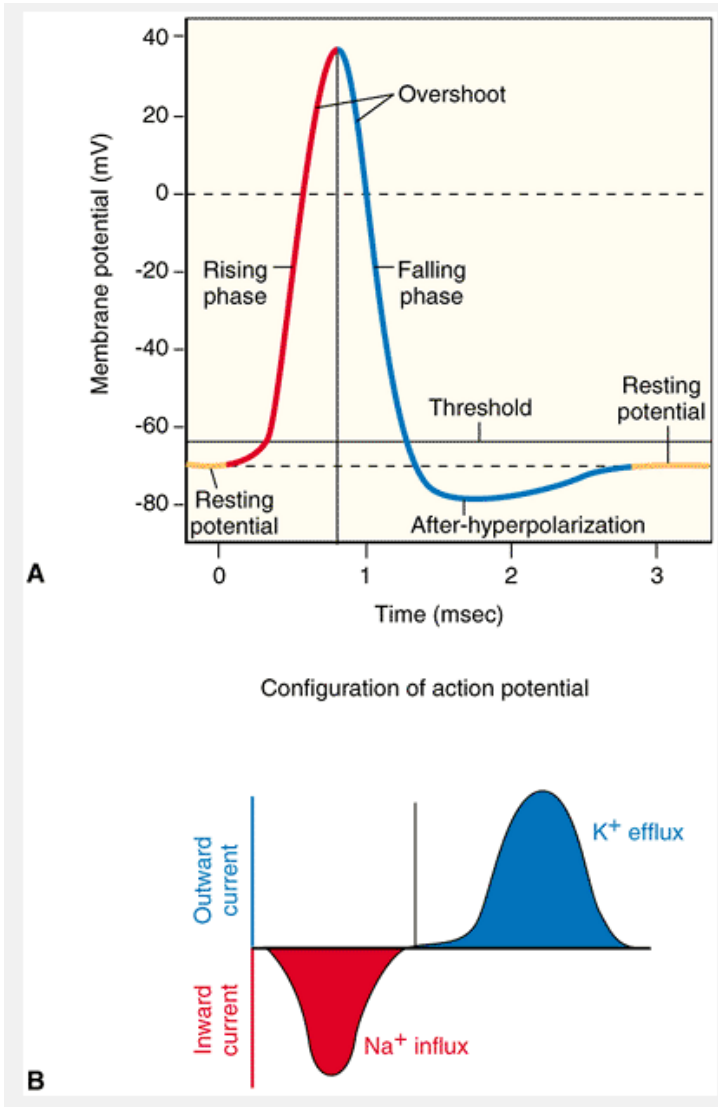



Fig. 8-2

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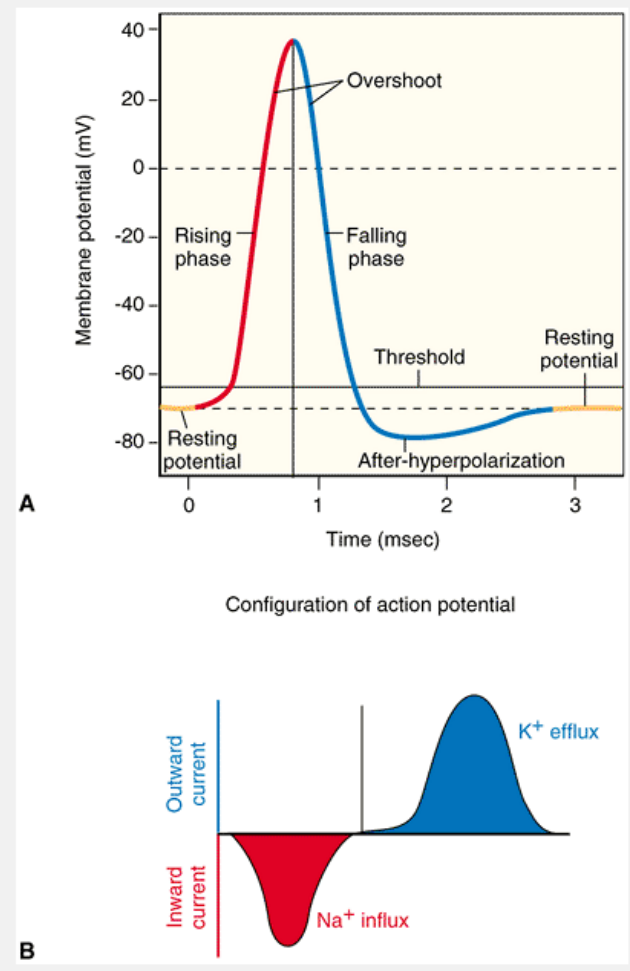
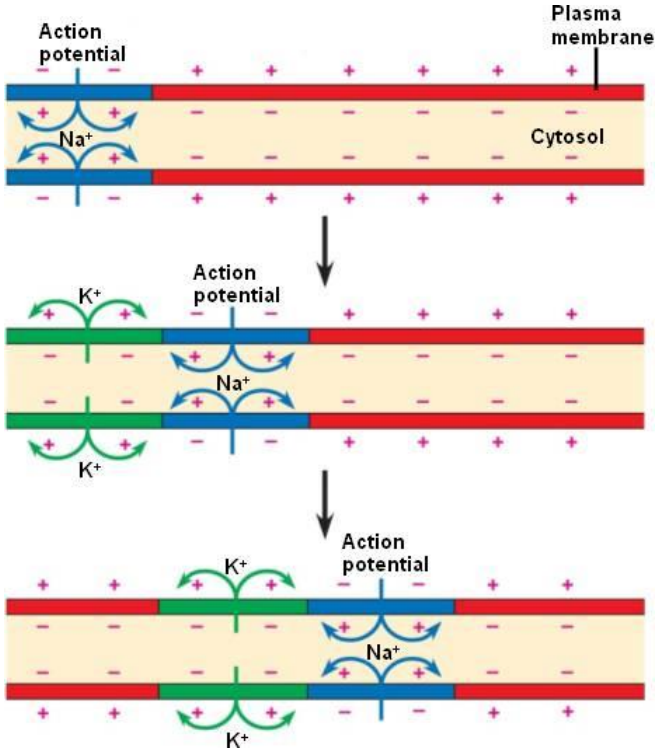
# Action potential spreading




- Local currents
- Anterograde



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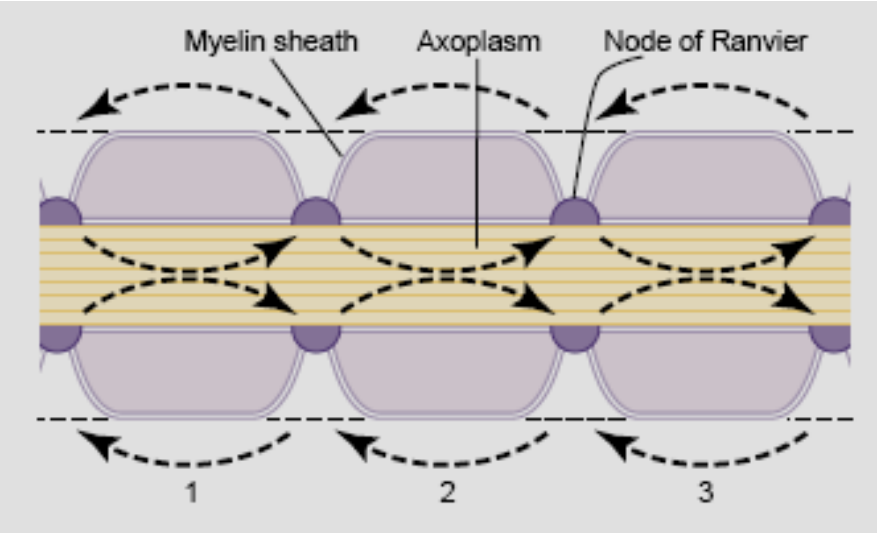
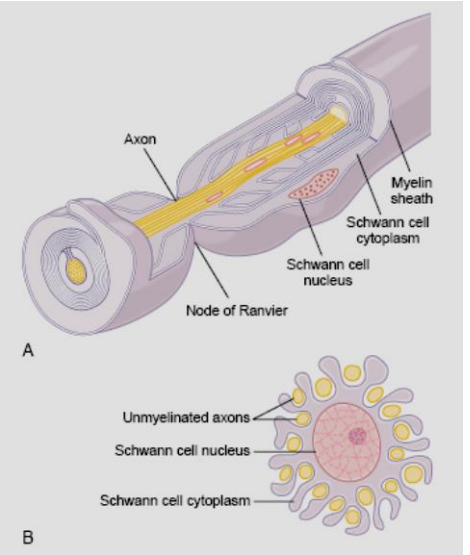
# Saltatory conduction

- Myelin sheat
- Nodes of ranvier

- Economy
- Speed of conduction

- Speed of conduction also dependent of nerve fibre diameter
  - the electrical resistance is inversly proportional to area of cross-section

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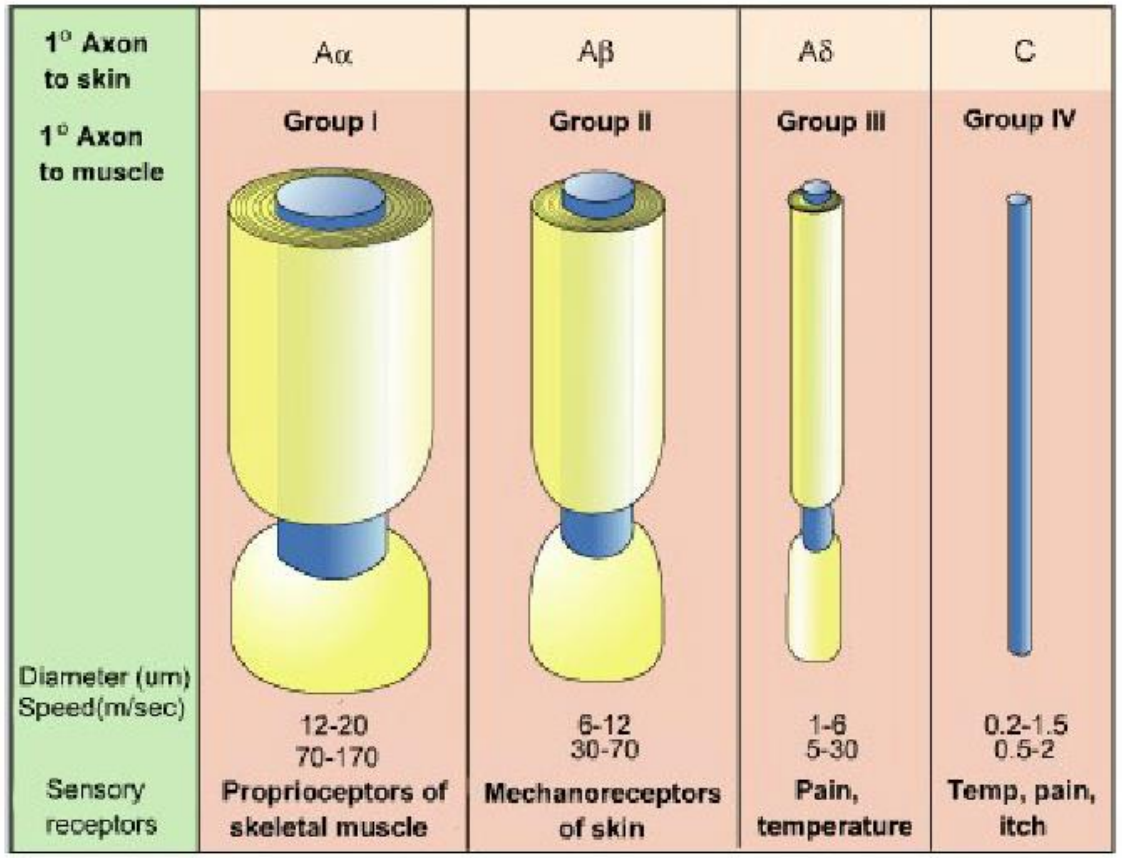
# Classification of nerve fibers

- In humans mostly myelinated
- All fibers are myelinated in CNS
- Non-myelinated are evolutionary old ones




http://neuroscience.uth.tmc.edu/s2/chapter04.html



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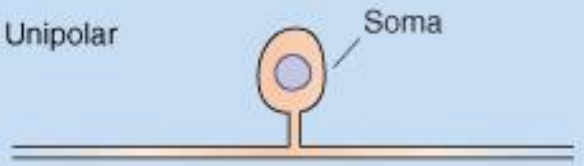
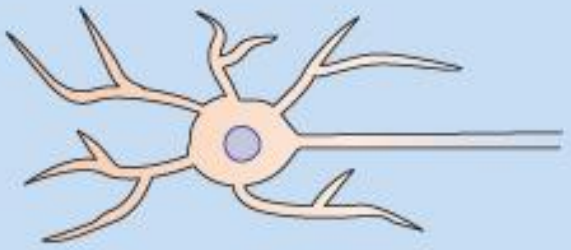
# Neuronal classification

| Basis for classification | Example | Functional implication | Structure |
|---|---|---|---|
| **3. Number of processes** | | | |
| One process exits the cell body | Unipolar neuron (dorsal root ganglion cell) | Small area for receiving synaptic input: highly specialized function | Unipolar   |
| Two processes exit the cell body | Bipolar neuron (retinal bipolar cell) | Small area for receiving synaptic input: highly specialized function | Bipolar  |
| Many processes exit the cell body | Multipolar neuron (spinal motor neuron) | Large area for receiving synaptic input; determines the pattern of incoming axons that can interact with the cell | Multipolar  |

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



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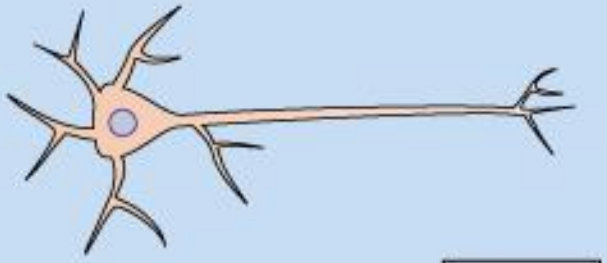
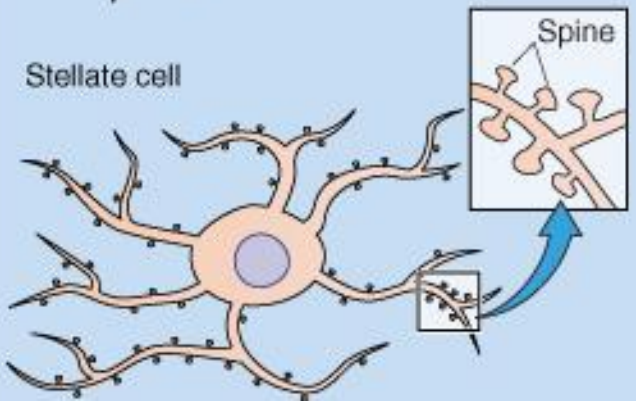
# Neuronal classification

| Basis for classification | Example | Functional implication | Structure |
|---|---|---|---|
| **2. Dendritic pattern** | | | Pyramidal cell |
| Pyramid-shaped spread of dendrites | Pyramidal cell (hippocampal pyramidal neuron) | Large area for receiving synaptic input; determines the pattern of incoming axons that can interact with the cell (i.e., pyramid-shaped) |  |
| Radial-shaped spread of dendrites | Stellate cell (cortical stellate cell) | Large area for receiving synaptic input; determines pattern of incoming axons that can interact with the cell (i.e., star-shaped) | Stellate cell   |

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



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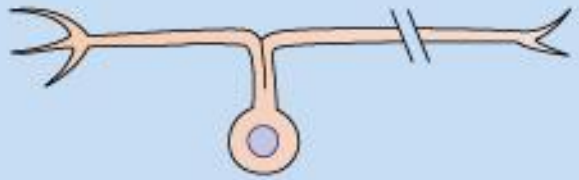
# Neuronal classification

| Basis for classification | Example | Functional implication | Structure |
|---|---|---|---|
| **1. Axonal projection** | | | |
| Goes to a distant brain area | Projection neuron or Principal neuron or Golgi type I cell (cortical motor neuron) | Affects different brain areas | Dorsal root ganglion cell  |
| Stays in a local brain area | Intrinsic neuron or Interneuron or Golgi type II cell (cortical inhibitory neuron) | Affects only nearby neurons | Retinal bipolar cell  |

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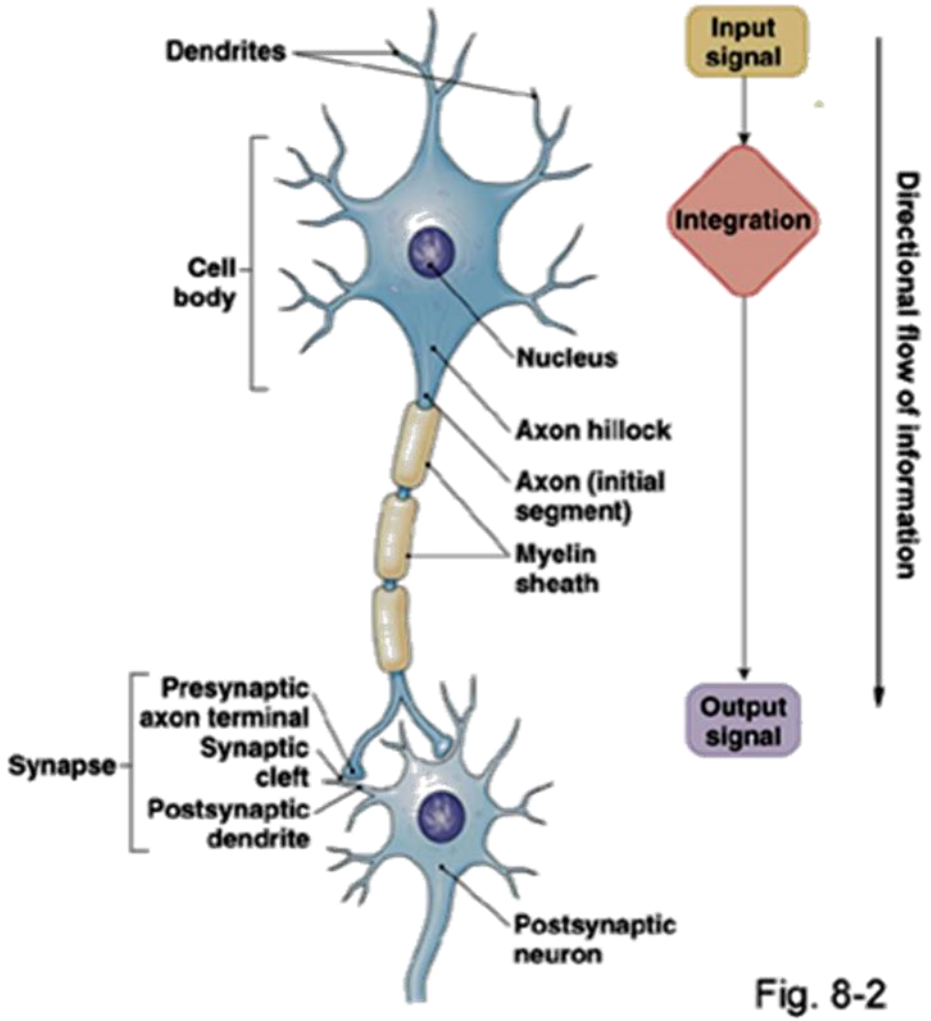
# Synapse

- Communication between neurons

- Electrical
- Chemical

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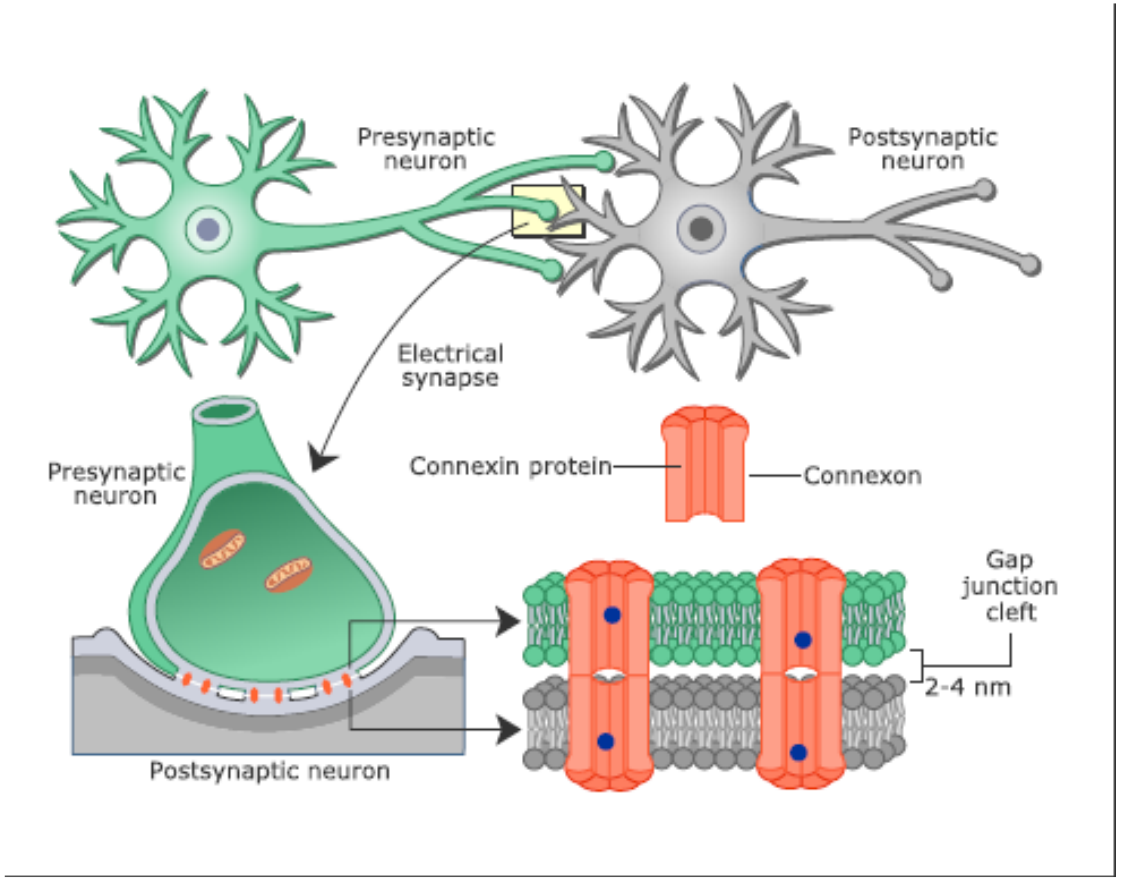
# Electrical synapse

- Evolutionary old
- Less frequent than ch.
- Ubiquitous




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



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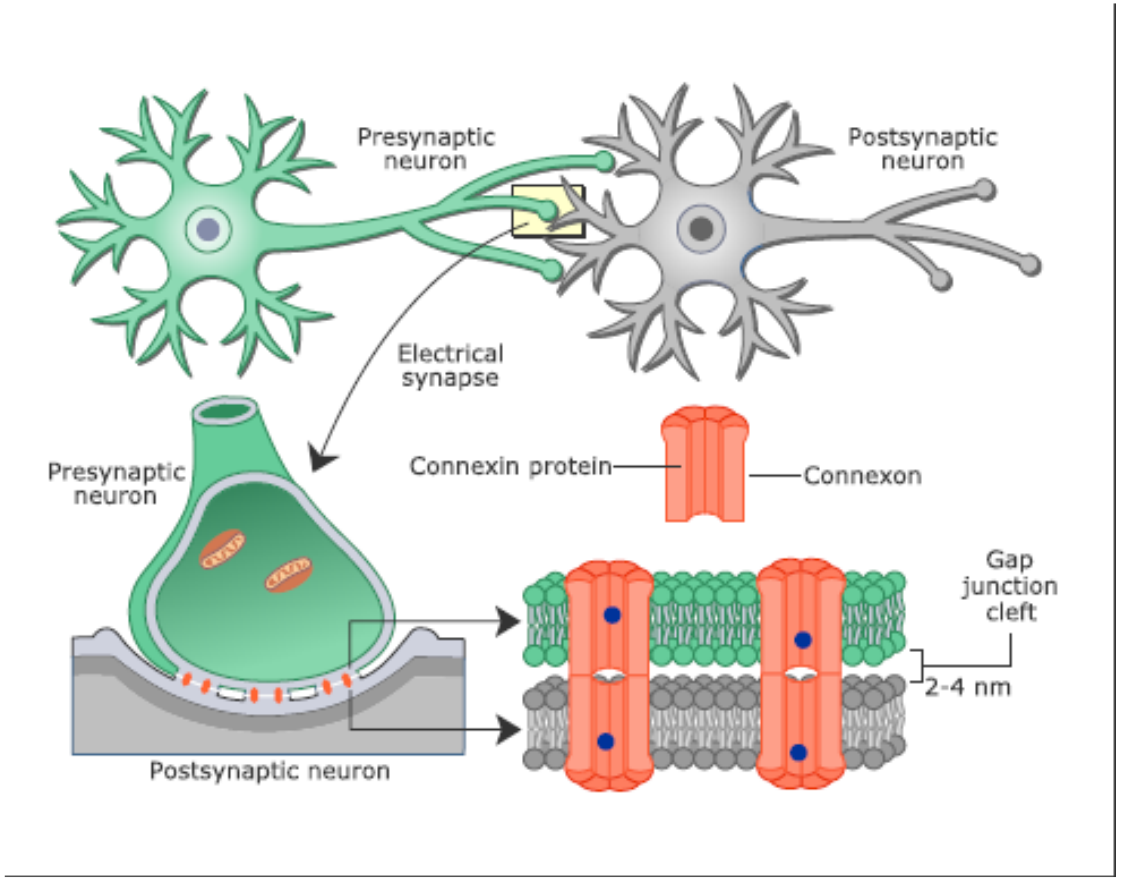
# Electrical synapse

- Evolutionary old
- Less frequent than ch.
- Ubiquitous

- Gap junctions
- Bidirectional tranmission
- Fast
- Strength of signal may decrease

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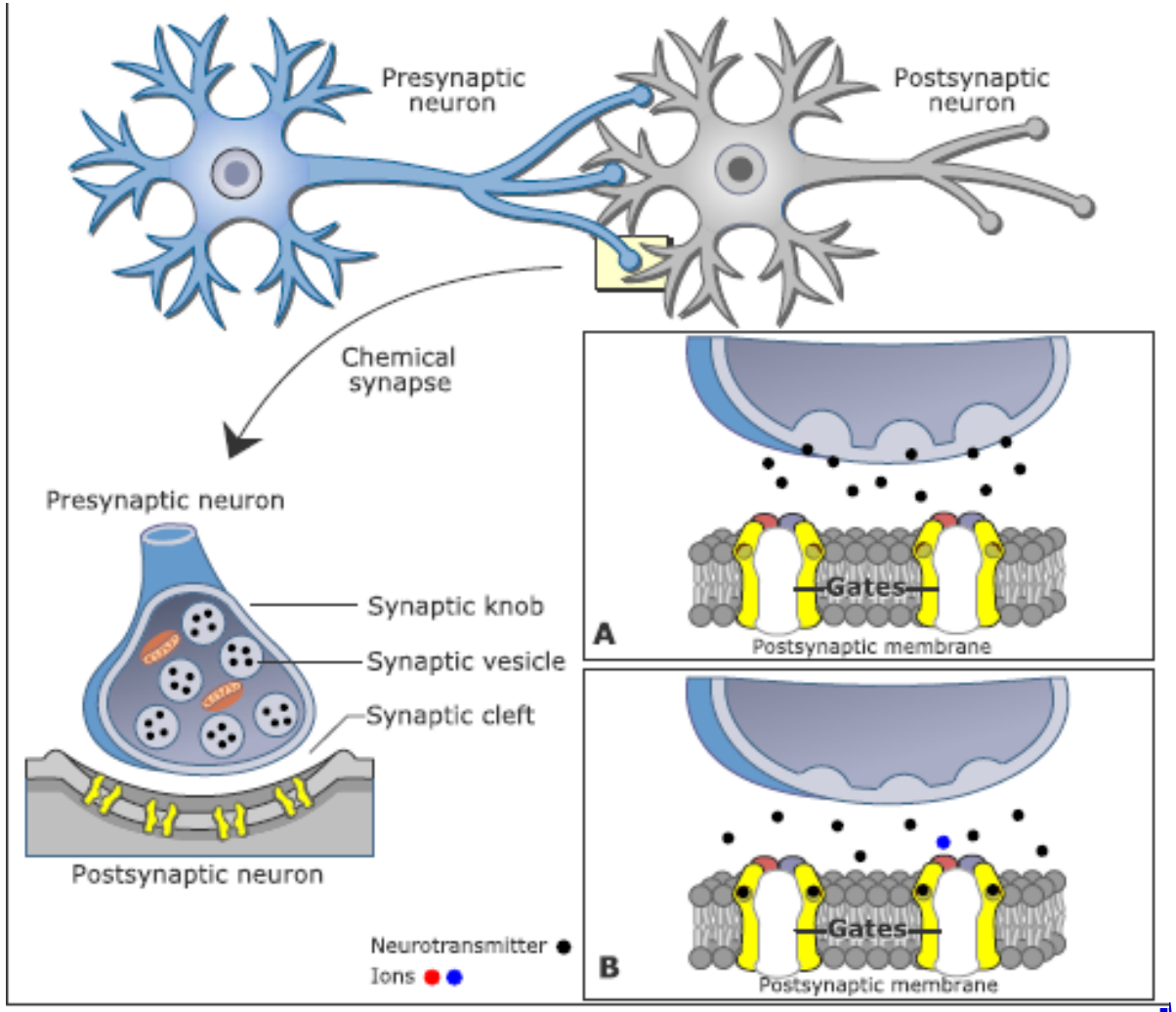
# Chemical synapse

- Evolutionary young
- Majority type of s.

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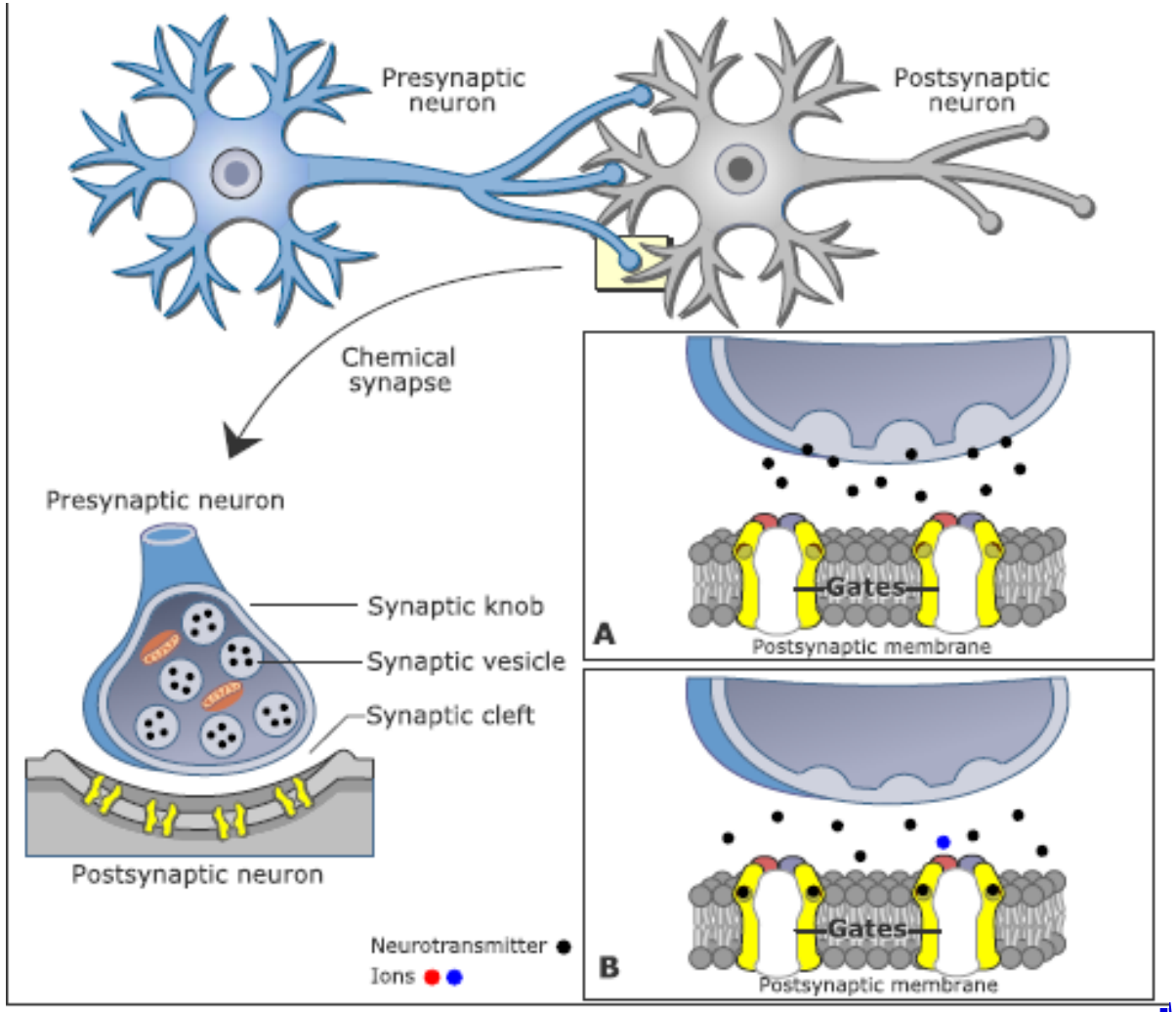
# Chemical synapse

- Evolutionary young
- Majority type of s.

- Unidirectional
- Synaptic cleft
- Neurotransmitter
- Constant signal strength




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



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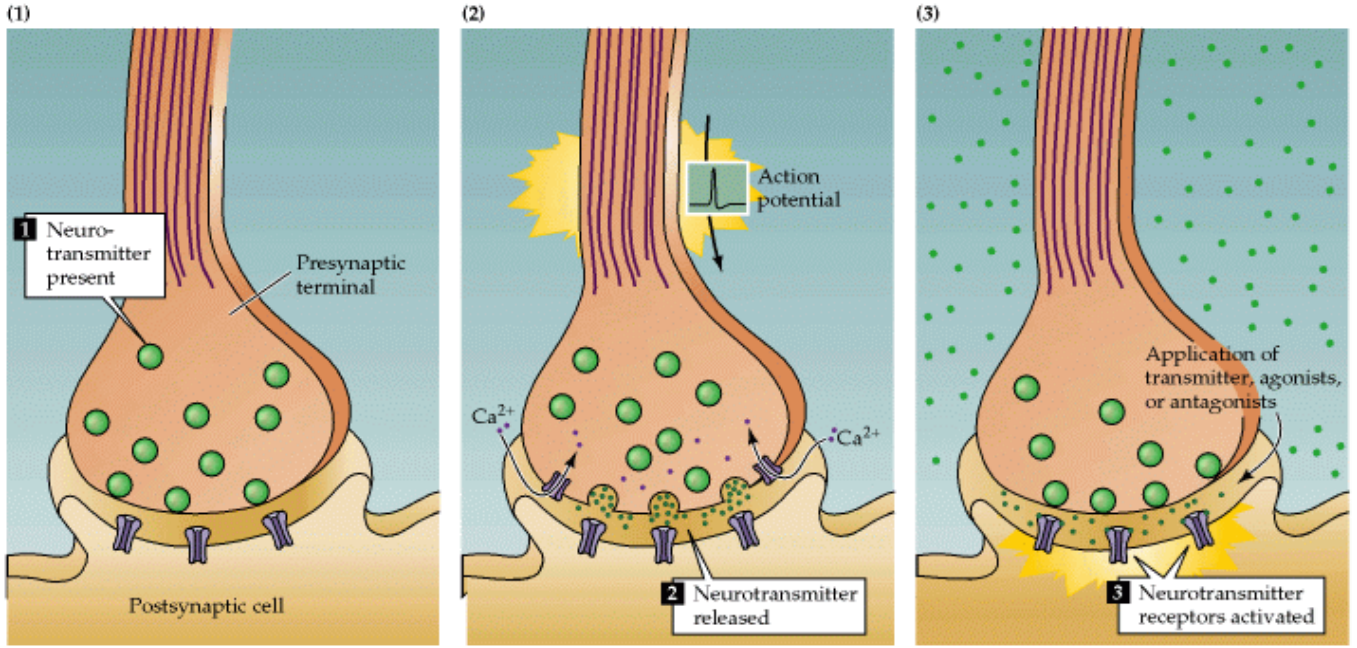
# Neurotrasnsmiter

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- Present in presinaptic neuron



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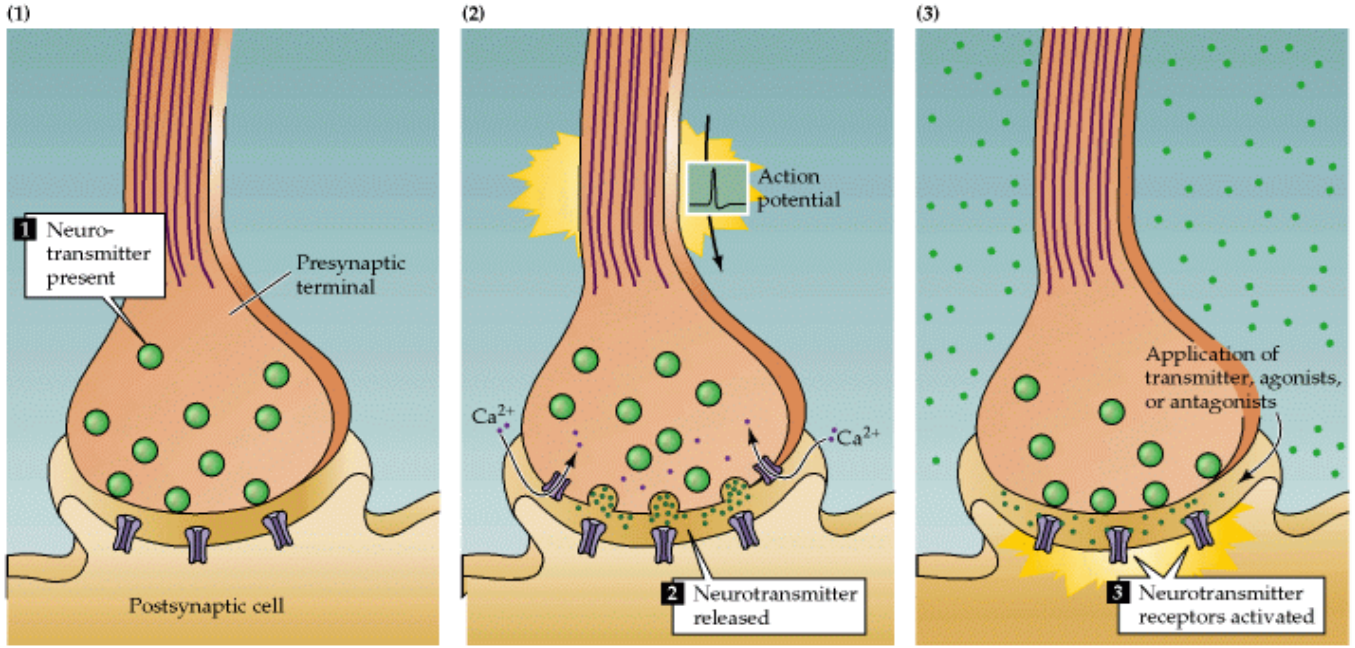
# Neurotrasnsmiter

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



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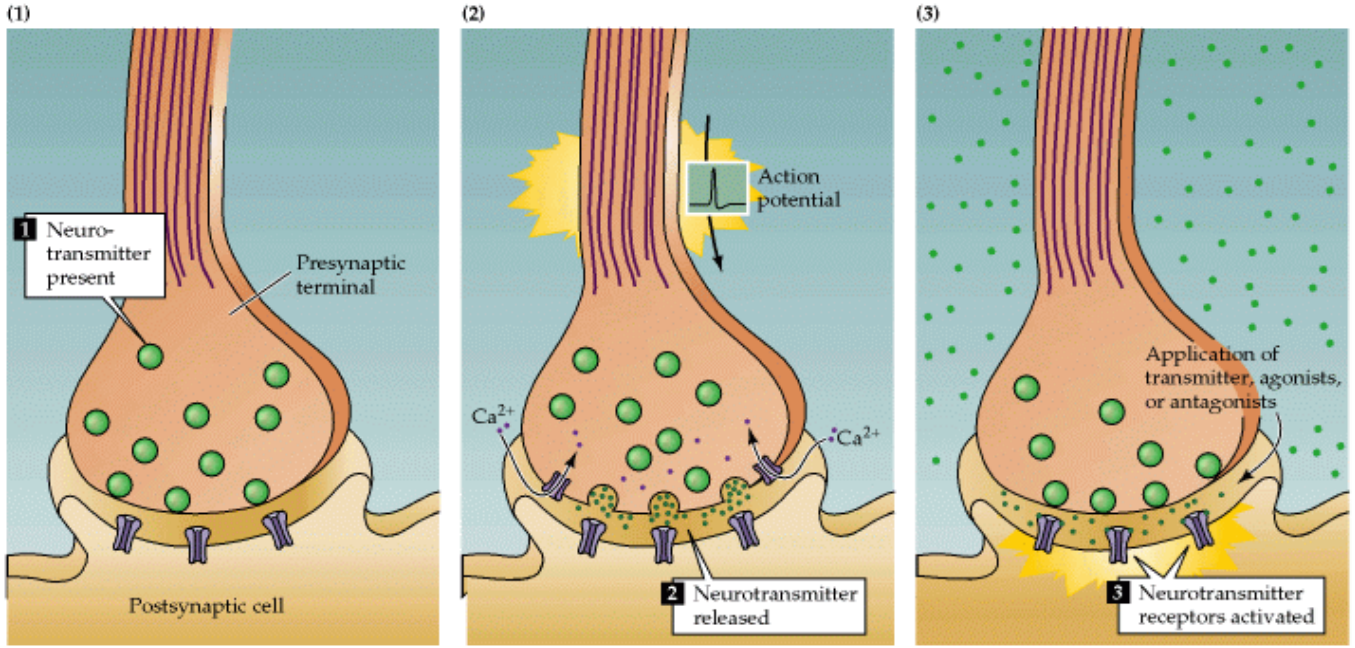
# Neurotrasnsmiter




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

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



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# Neuromuscular junction

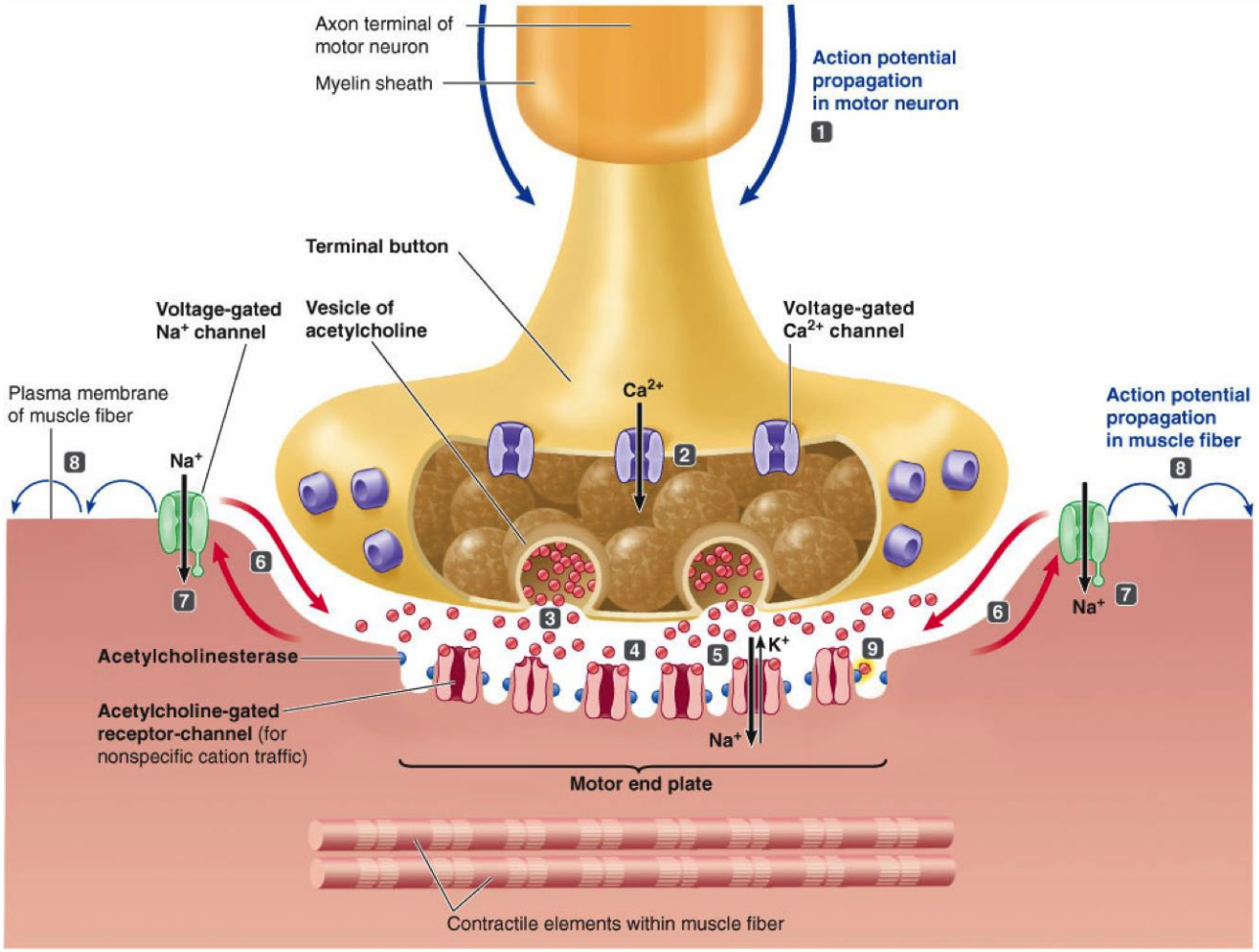


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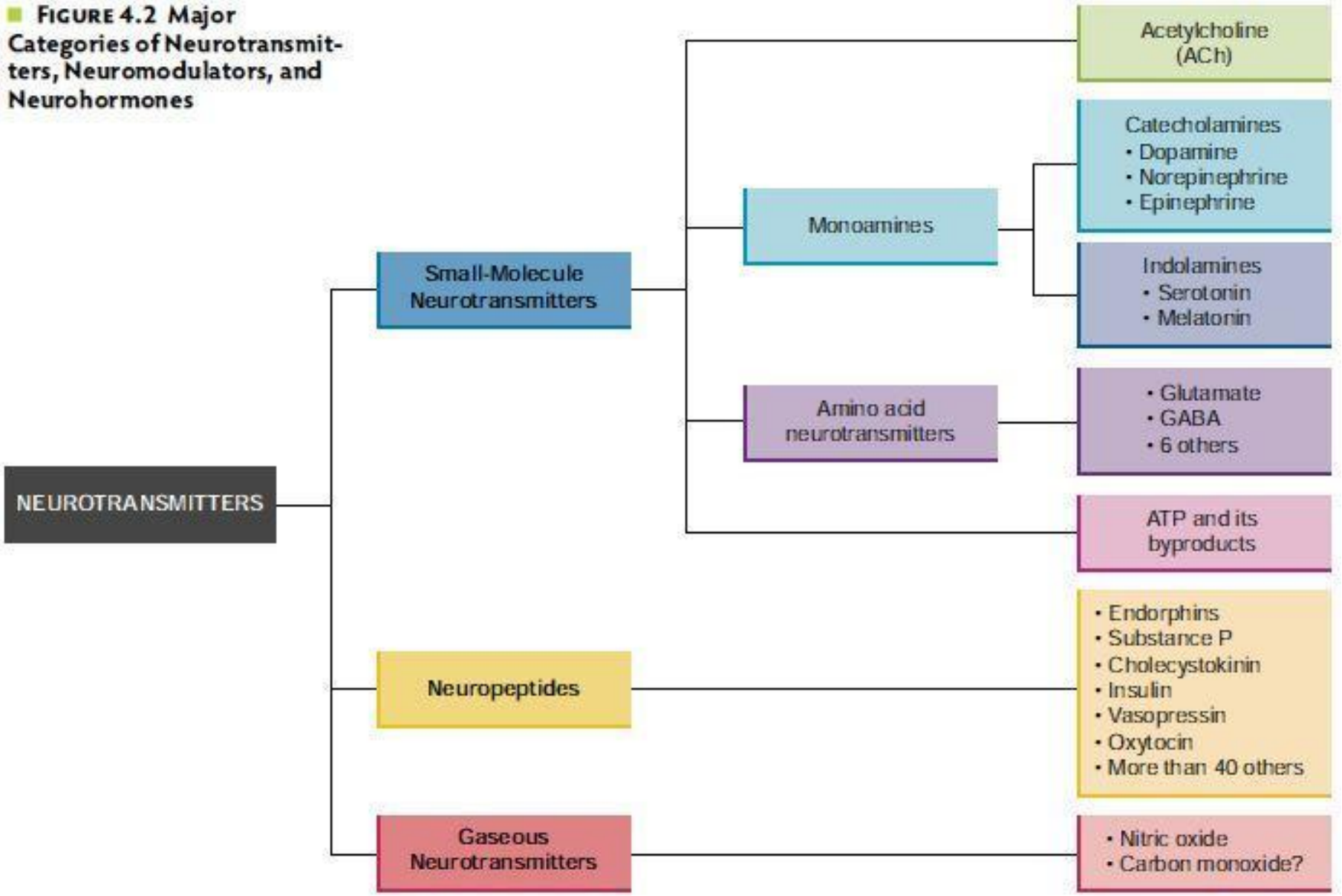
**FIGURE 4.2 Major Categories of Neurotransmitters, Neuromodulators, and Neurohormones**

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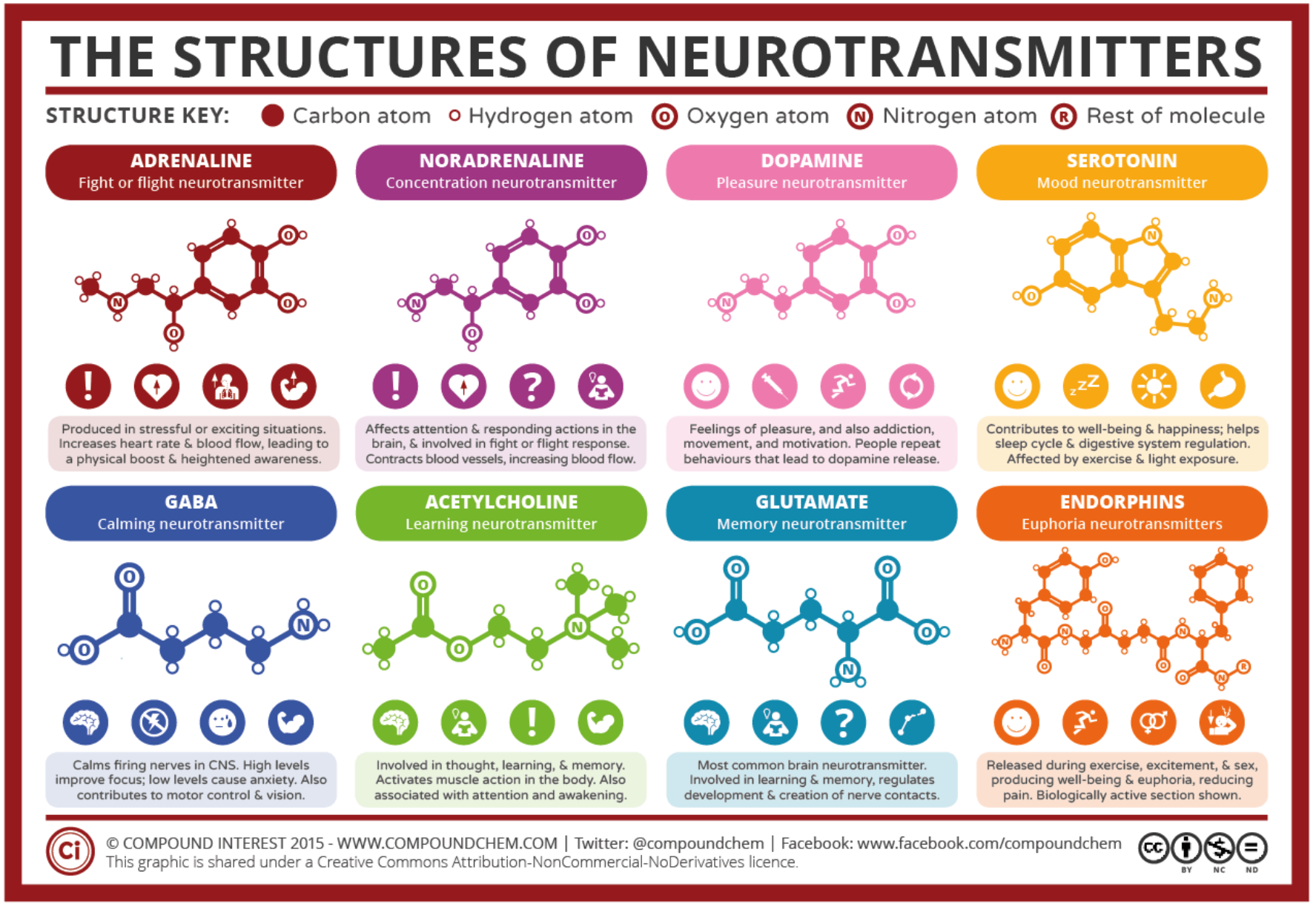


http://www.compoundchem.com/2015/07/30/neurotransmitters/



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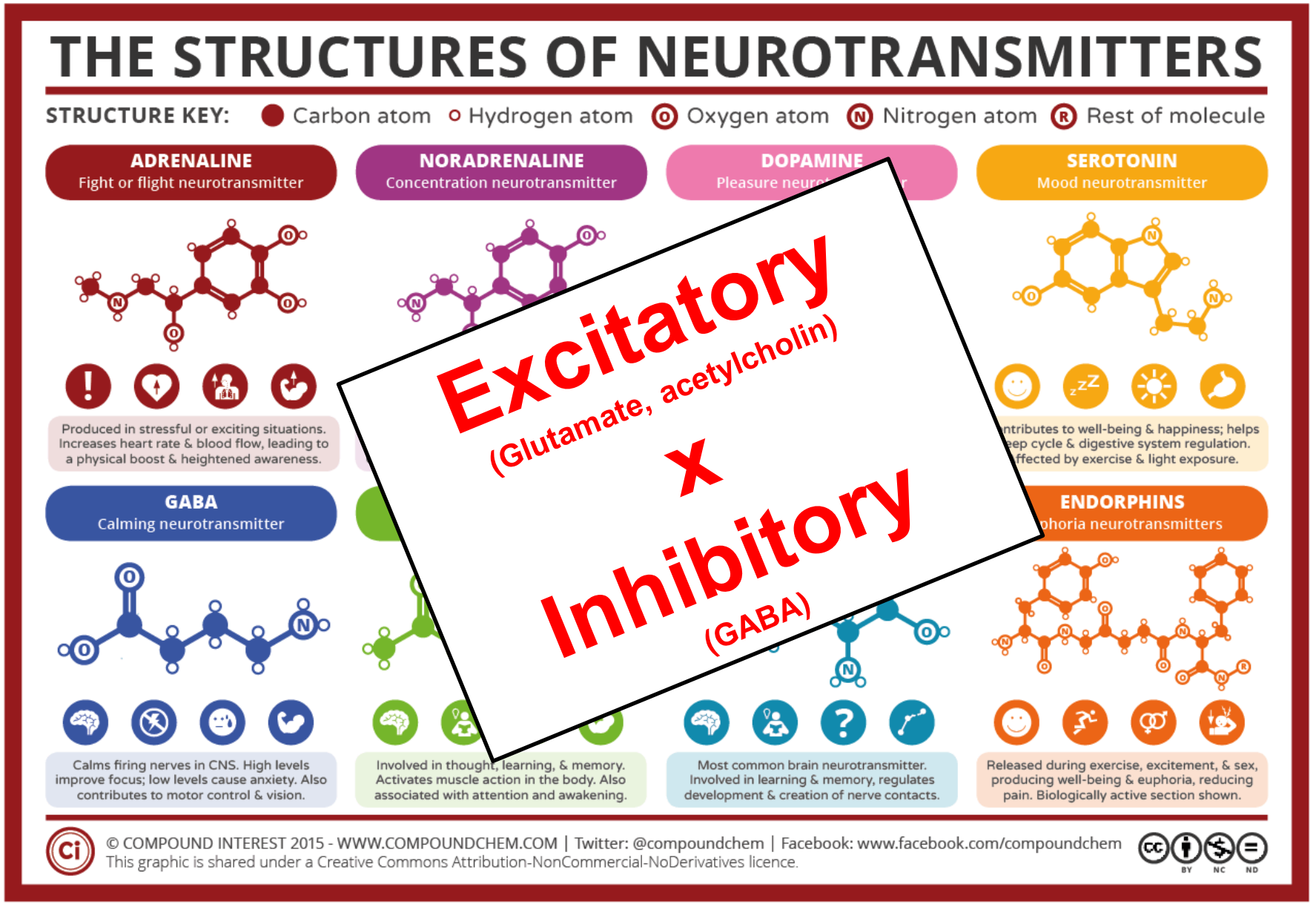


http://www.compoundchem.com/2015/07/30/neurotransmitters/



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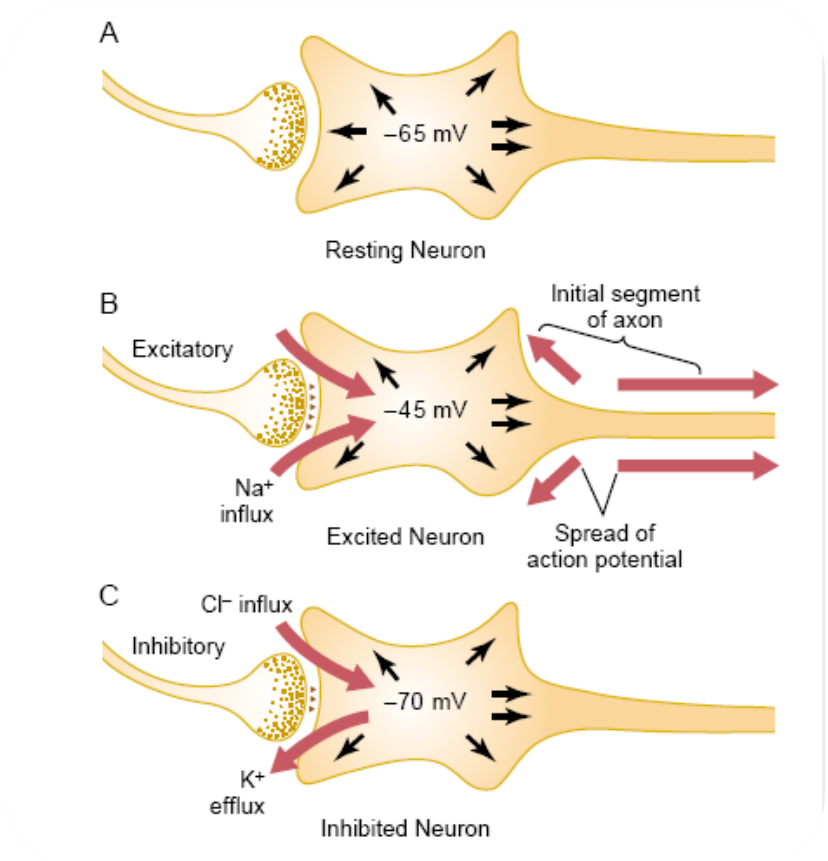
# Excitatory/inhibtory postsynaptic potencial

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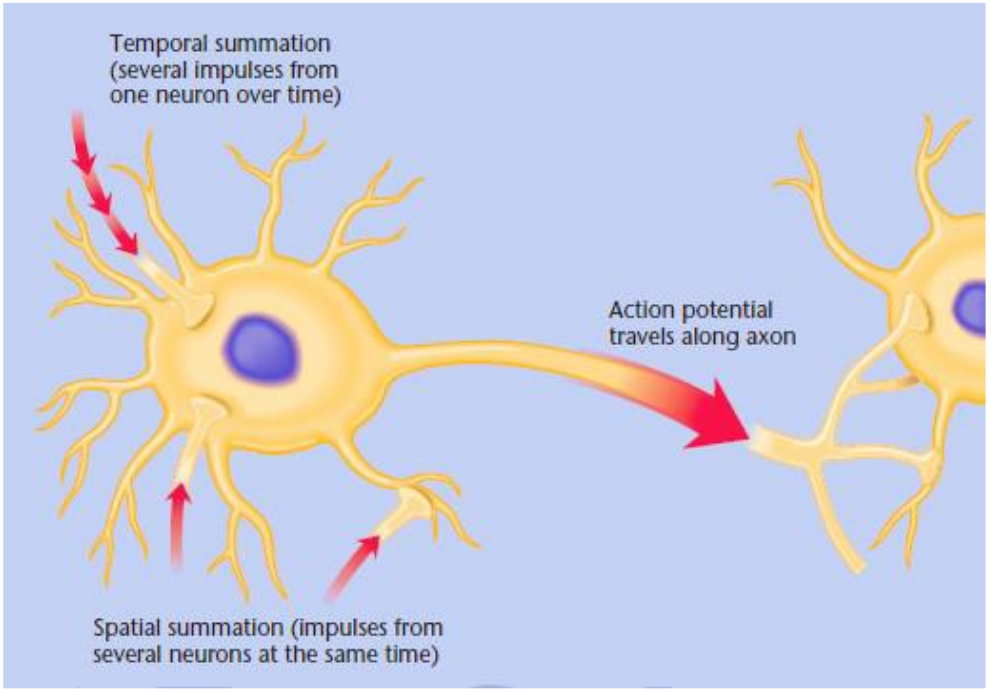
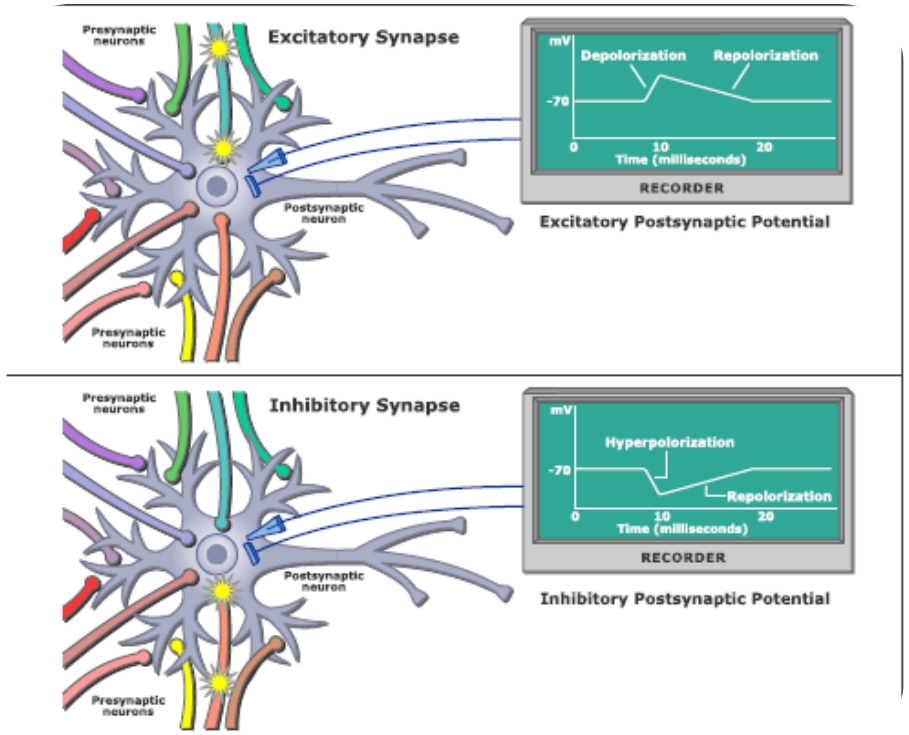
# Signal summation

- Temporal
- Spatial




https://www.slideshare.net/drgabe/biological-psychology-synapses?from_action=save

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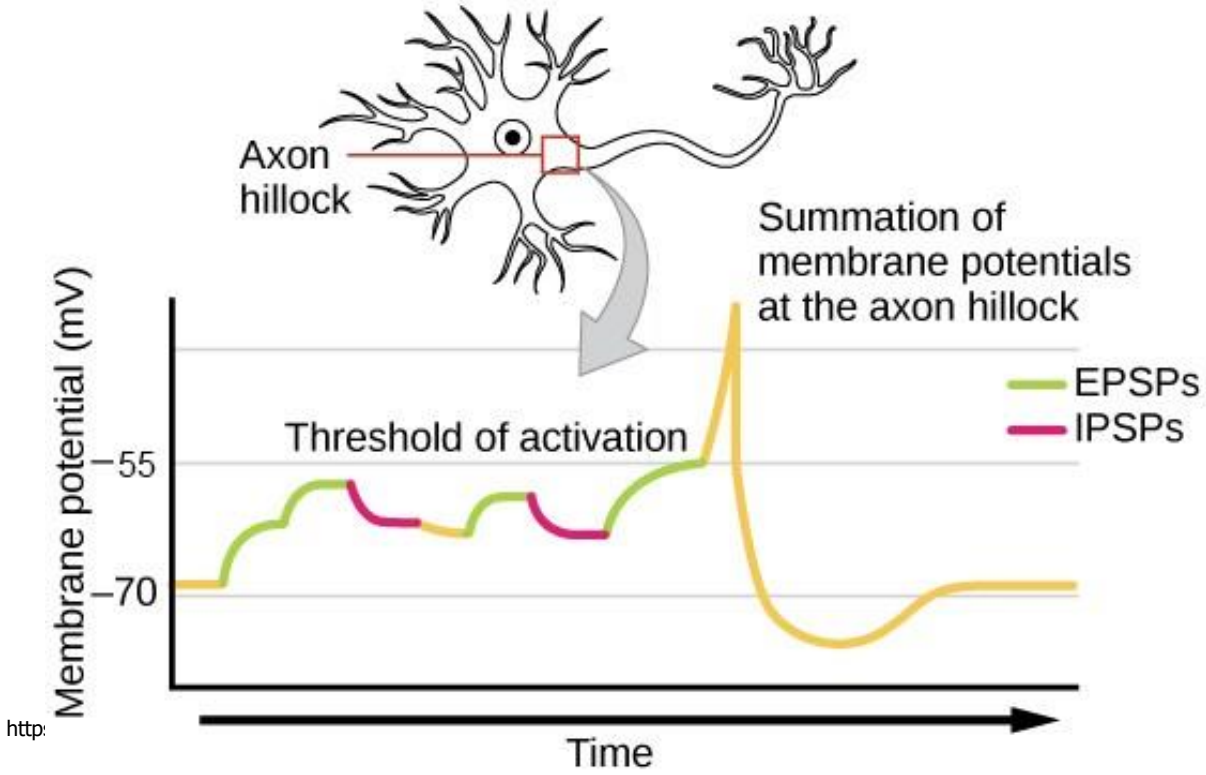
# Signal summation




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



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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

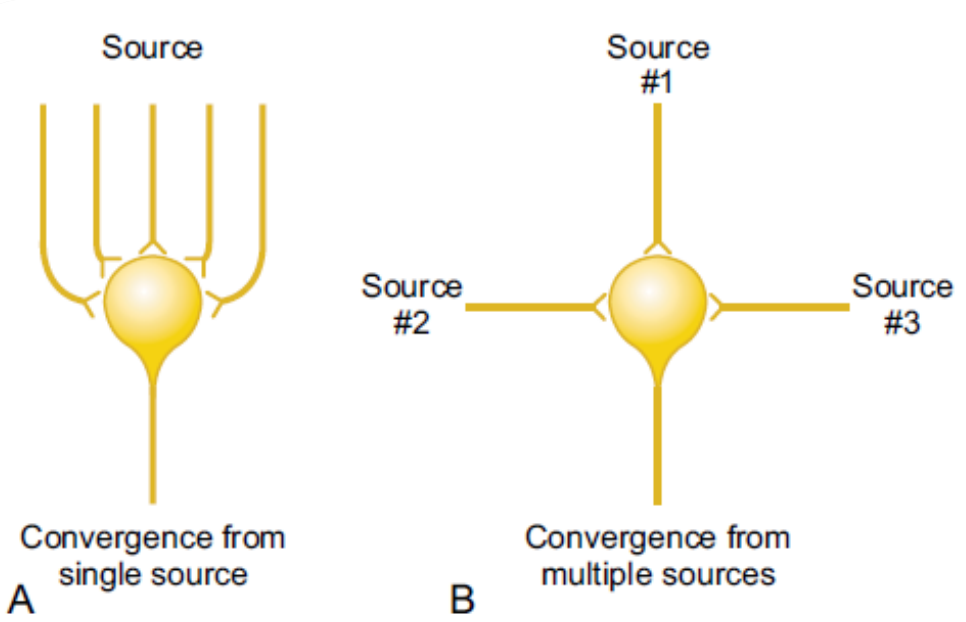


**Figure 46–12**

"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

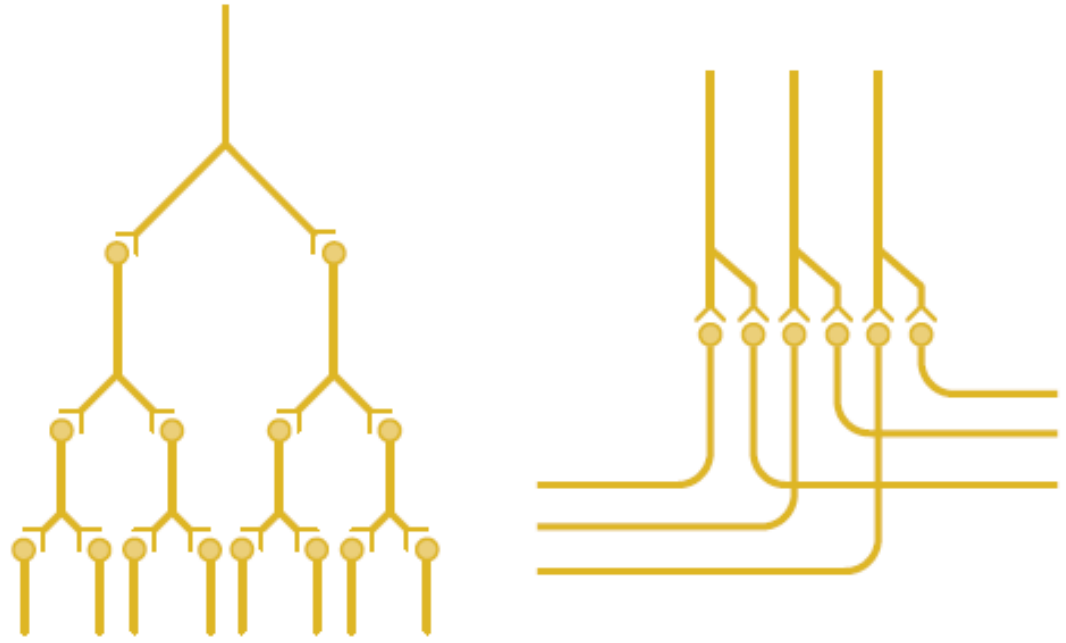


**Figure 46–11**

"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.



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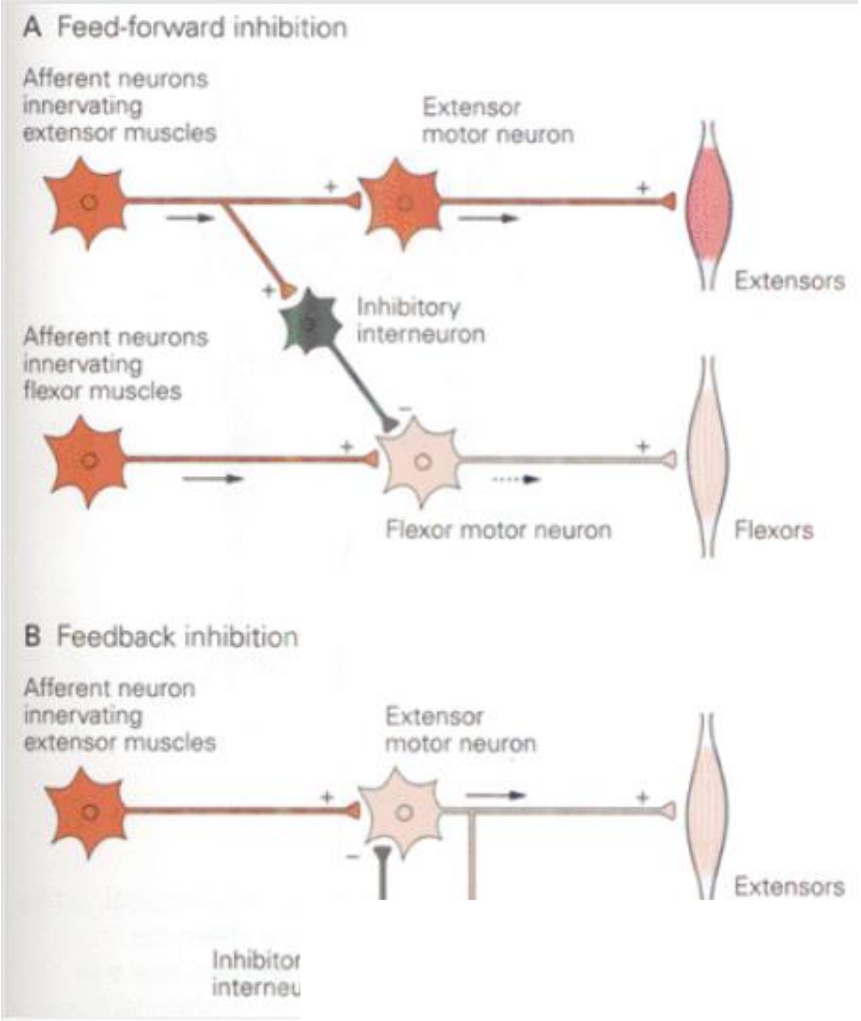
# Networking



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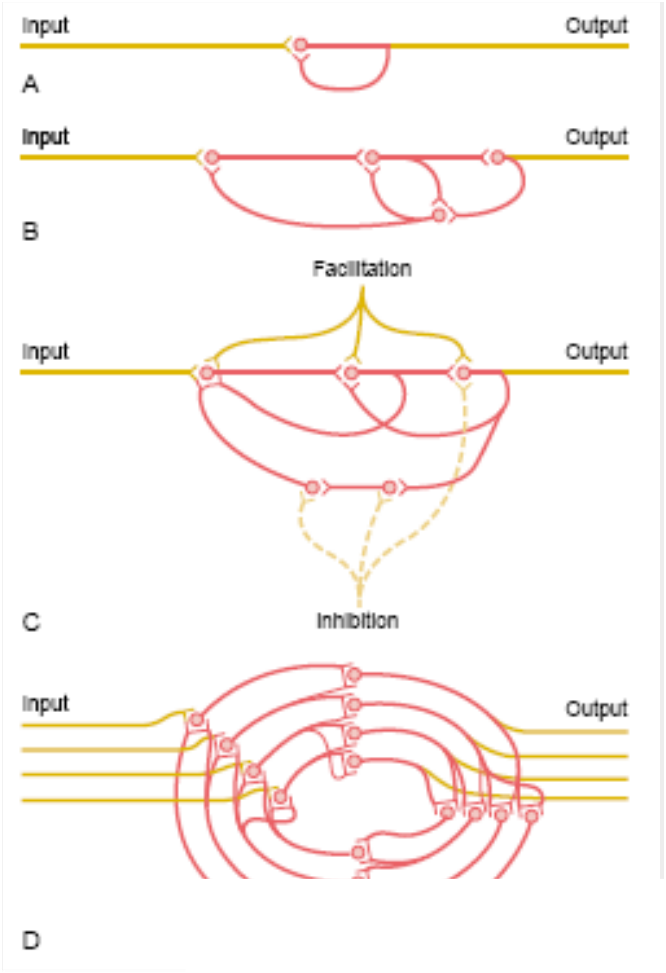
# Networking



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# Neurotransmission vs. Neuromodulation

- Information transmission

- Regulation of NS activity



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# Neurotransmission vs. Neuromodulation

- Information transmission
- Specific

- Regulation of NS activity
- Diffuse (volume transmission)



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# Neurotransmission vs. Neuromodulation

- Information transmission
- Specific
- Receptors – ion channels

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



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# 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



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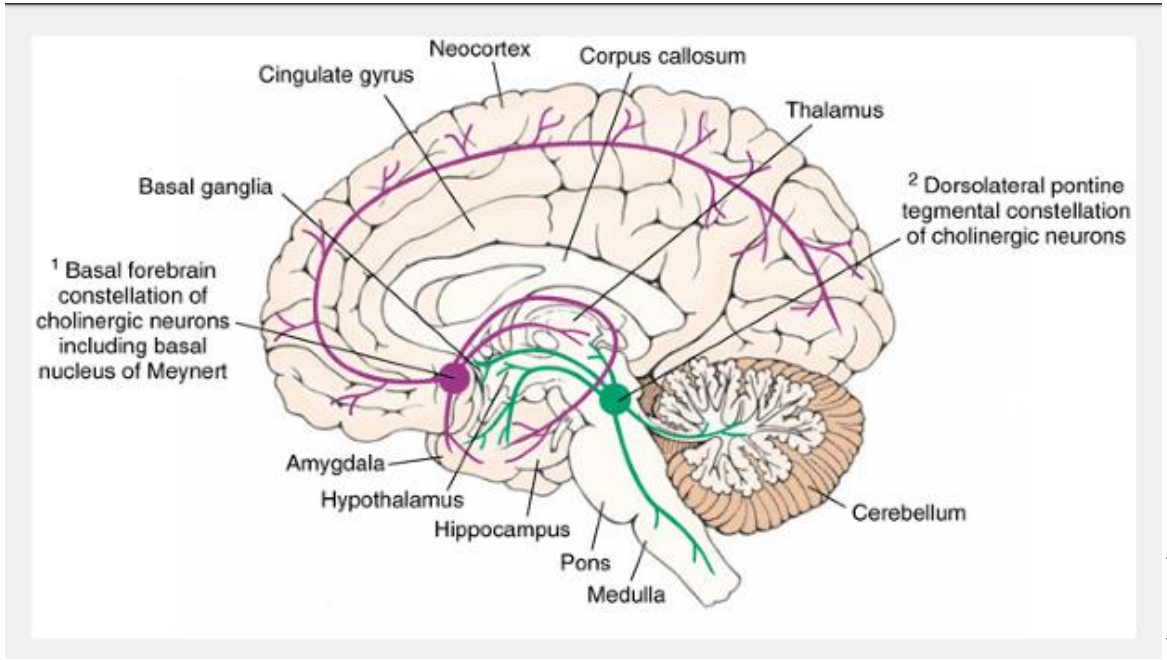
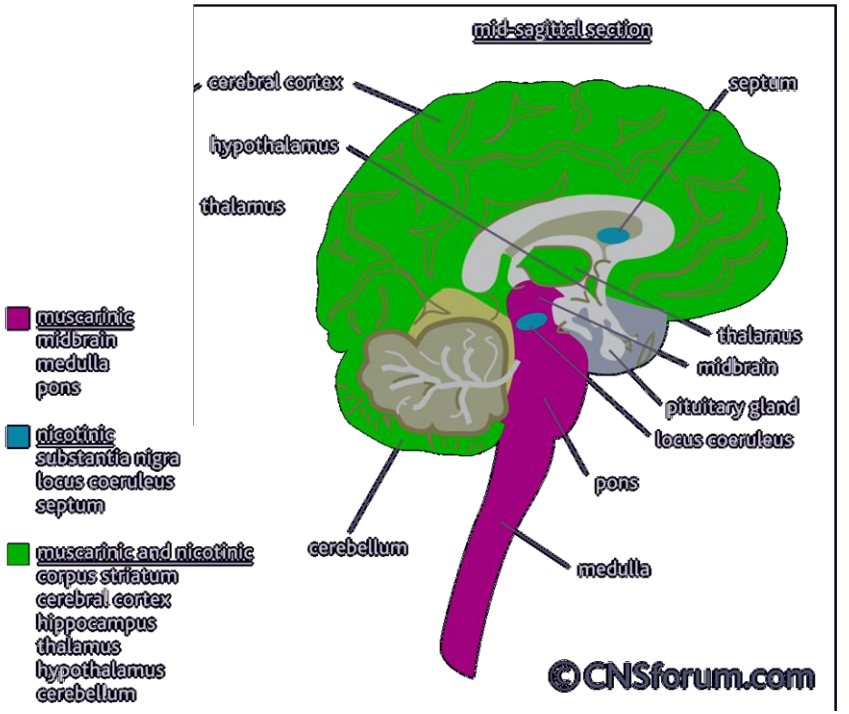
# Acetylcholine

- Nucleus basalis (Meynerti) abd other nuclei
- Nicotin receptors
- Muscarin receptors

- Sleep/wake regulation
- Cognitive functions
- Behavior
- Emotions

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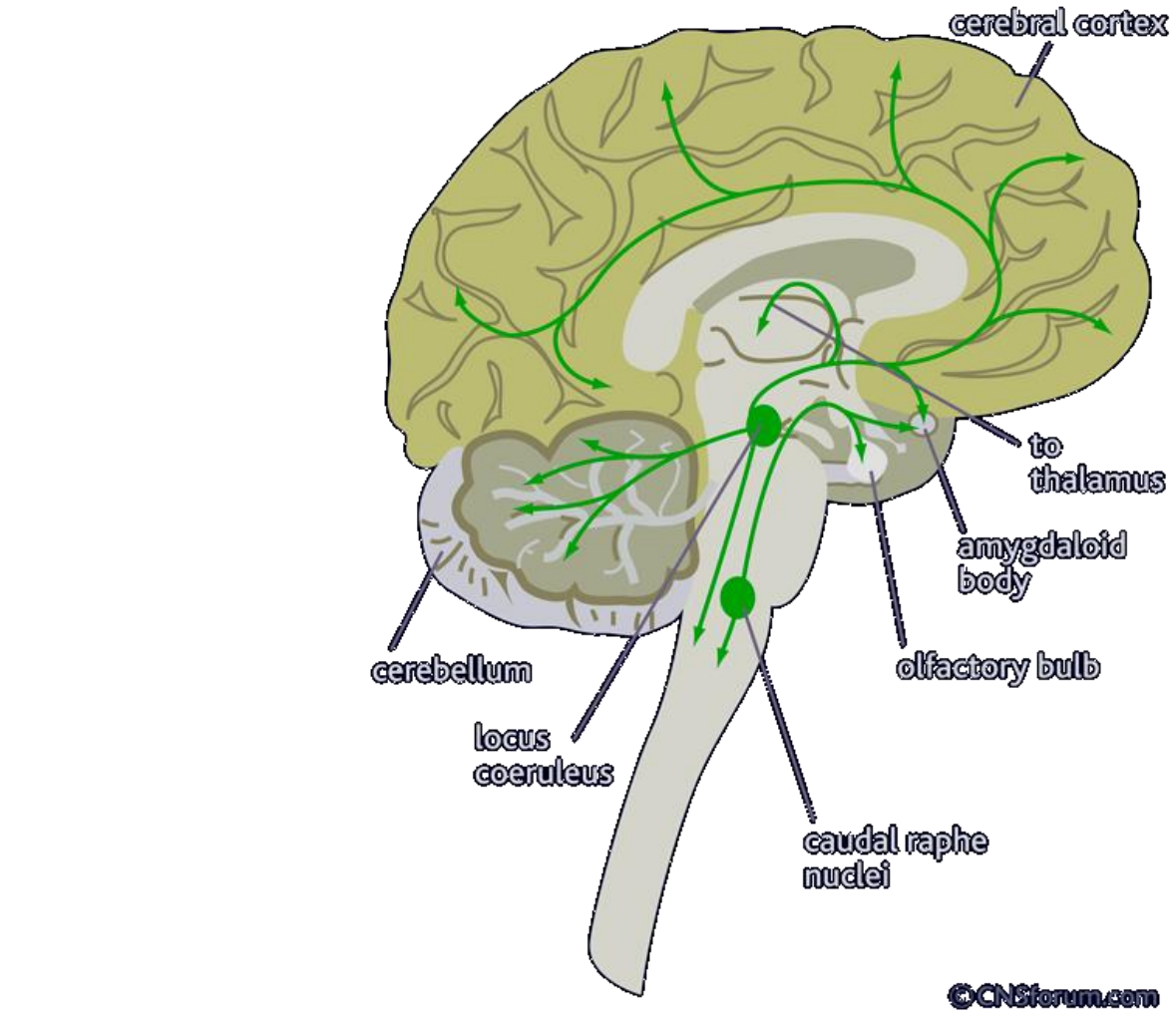
# Noradrenalin

- Locus coeruleus
- Nuclei raphe caudalis

- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning

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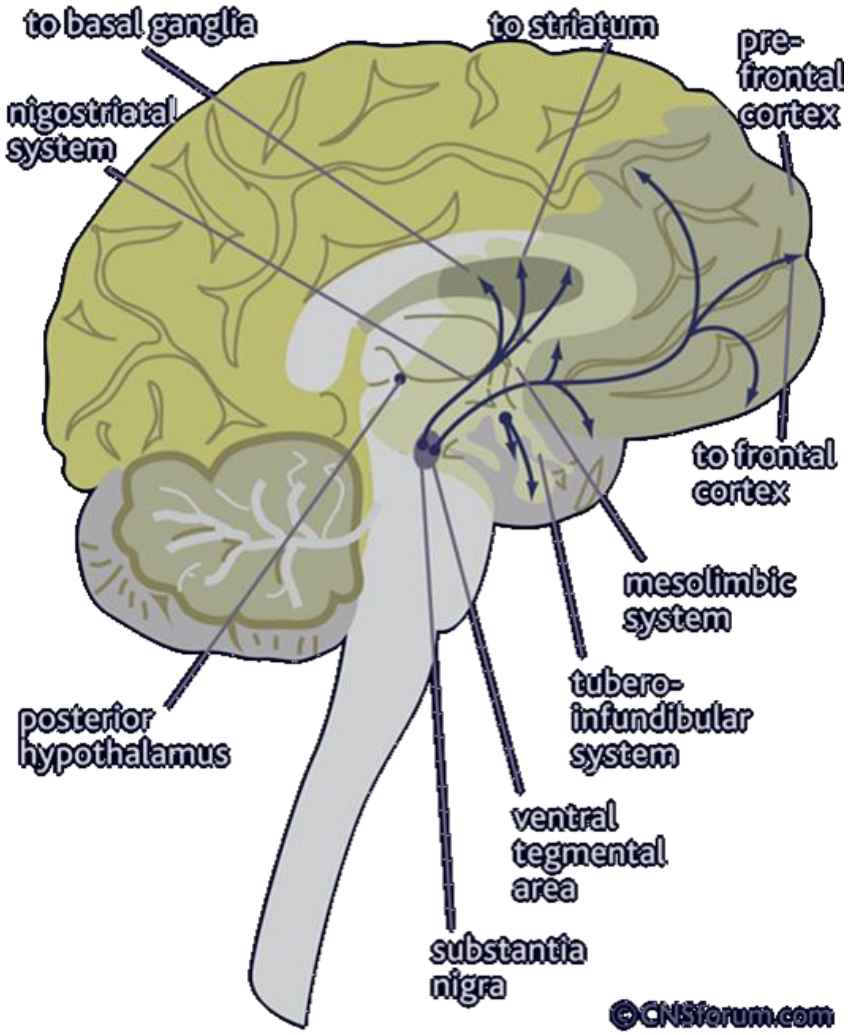
# Dopamin

- Nigrostriatal system
  - Movement
  - Sensory stimuli
- Ventrotegmentno-mesolimbic-frontal system
  - Reward
  - Cognitive function
  - Emotional behavior
- Tubero-infundibular system
  - Hypotalamic-pituatory regulation
- D1 receptors – excitatory
- D2 receptors - inhibitory

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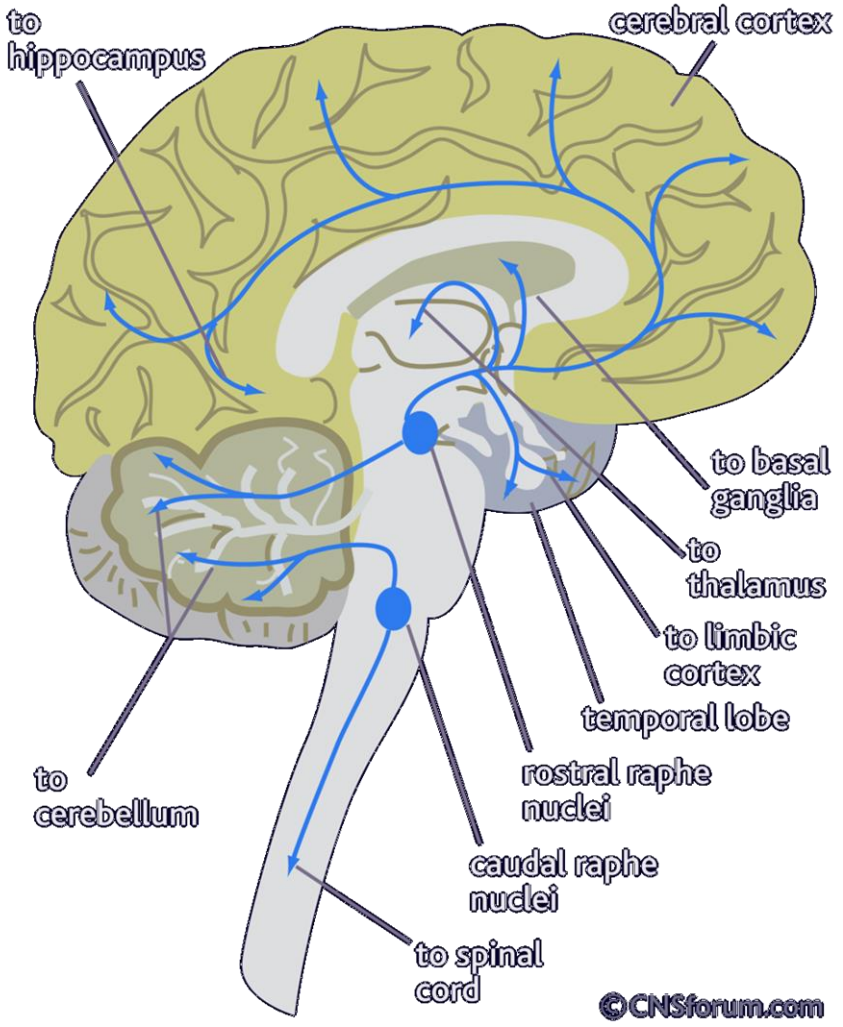
# Serotonin

- Nuclei raphe rostralis
- Nuclei raphe caudalis

- Anxiety/relaxation
- Impulsive behavior
- Sleep

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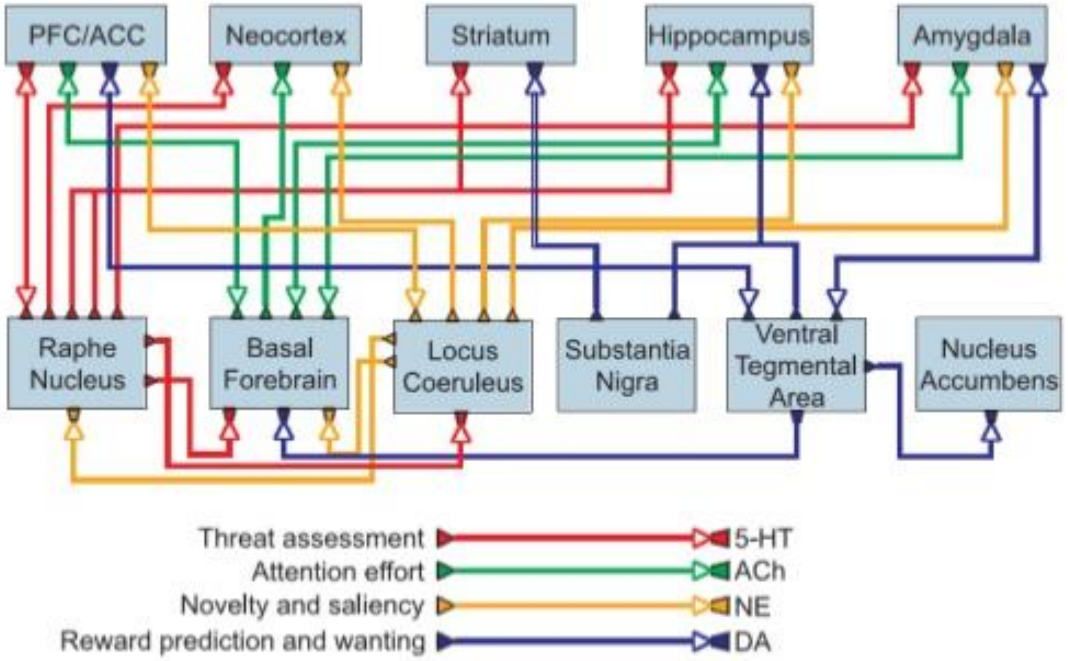
# Neuromodulatory systems




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

http://image.slidesharecdn.com/neuromodulationincognition-140119031056-phpapp02/95/neuromodulation-in-cognition-5-638.jpg?cb=1419657931



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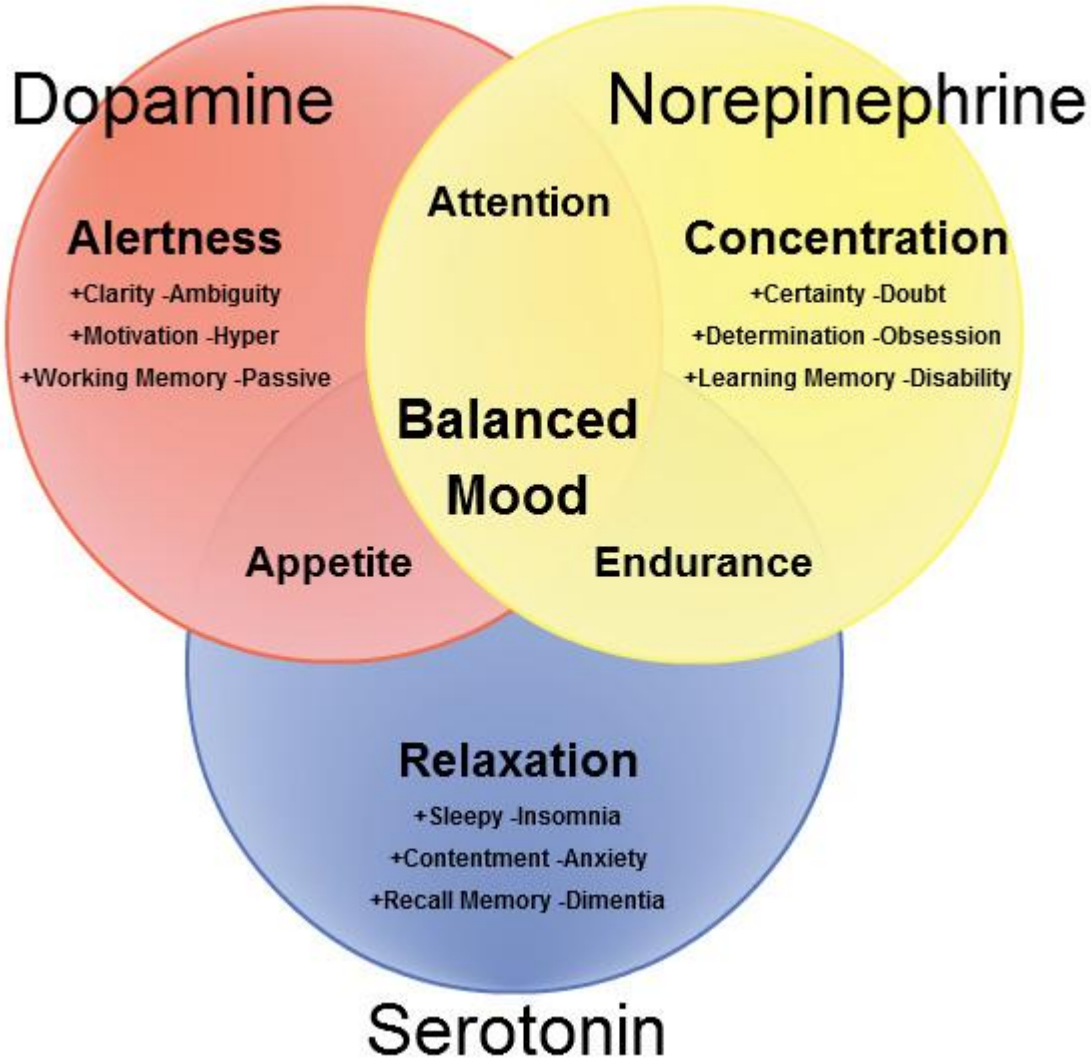
# Neuromodulatory systems




http://ausm.org.uk/wp-content/uploads/2015/02/Dopamine_Norepinephrine_Serotonin.jpg



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