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Introduction to neurophysiology
Cellular base of nervous system
Synapse

Contact

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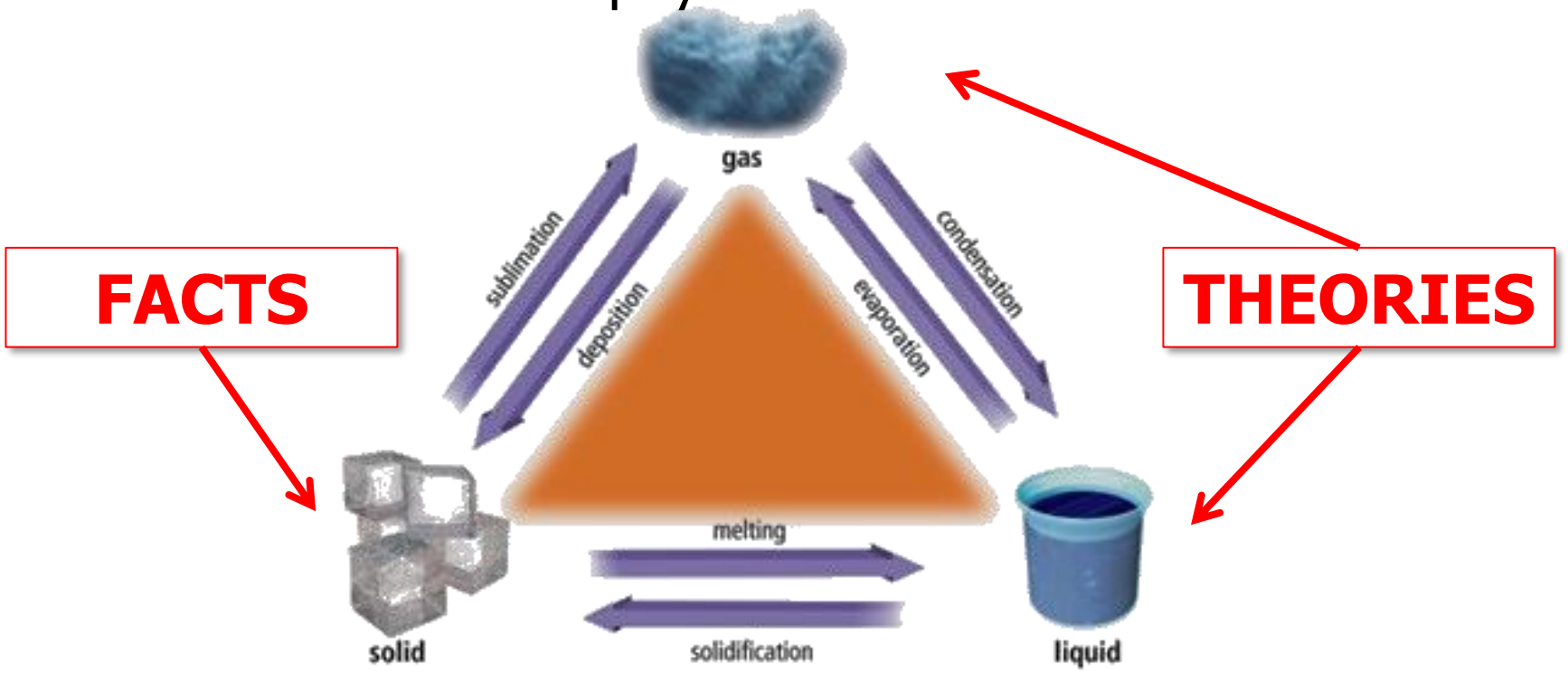
Why and how to STUDY neuroscience

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?

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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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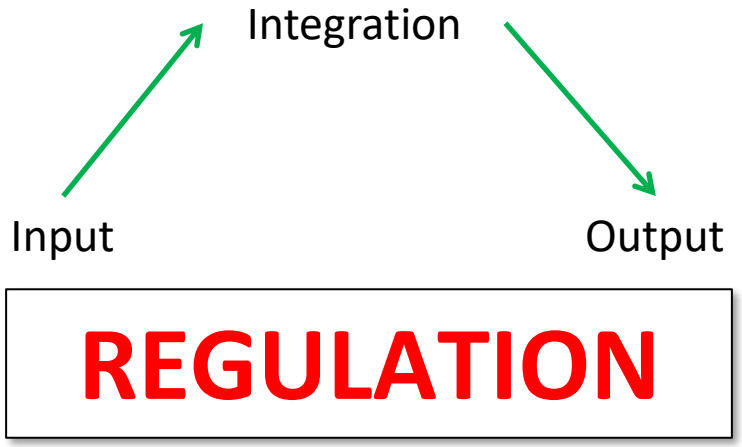
The role of nervous system

- 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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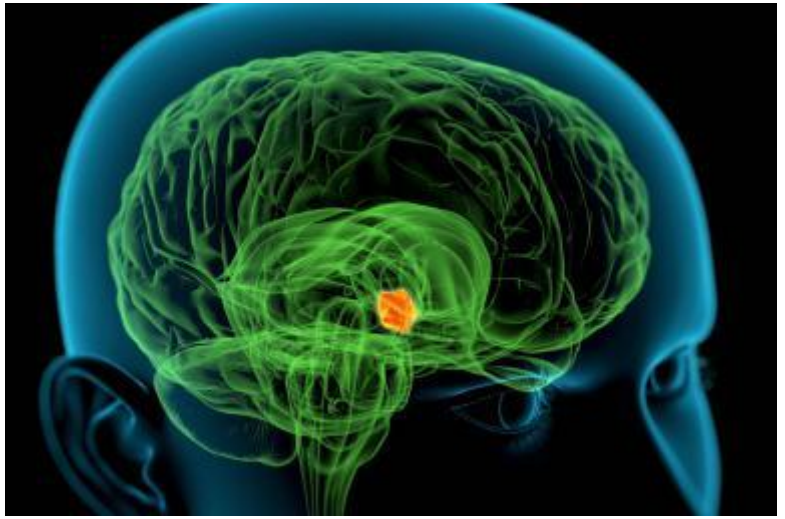
The role of nervous system

- 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

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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
- 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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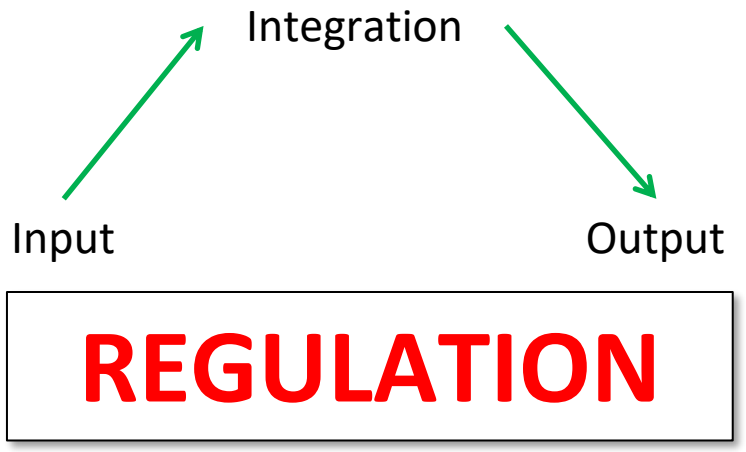
The role of nervous system



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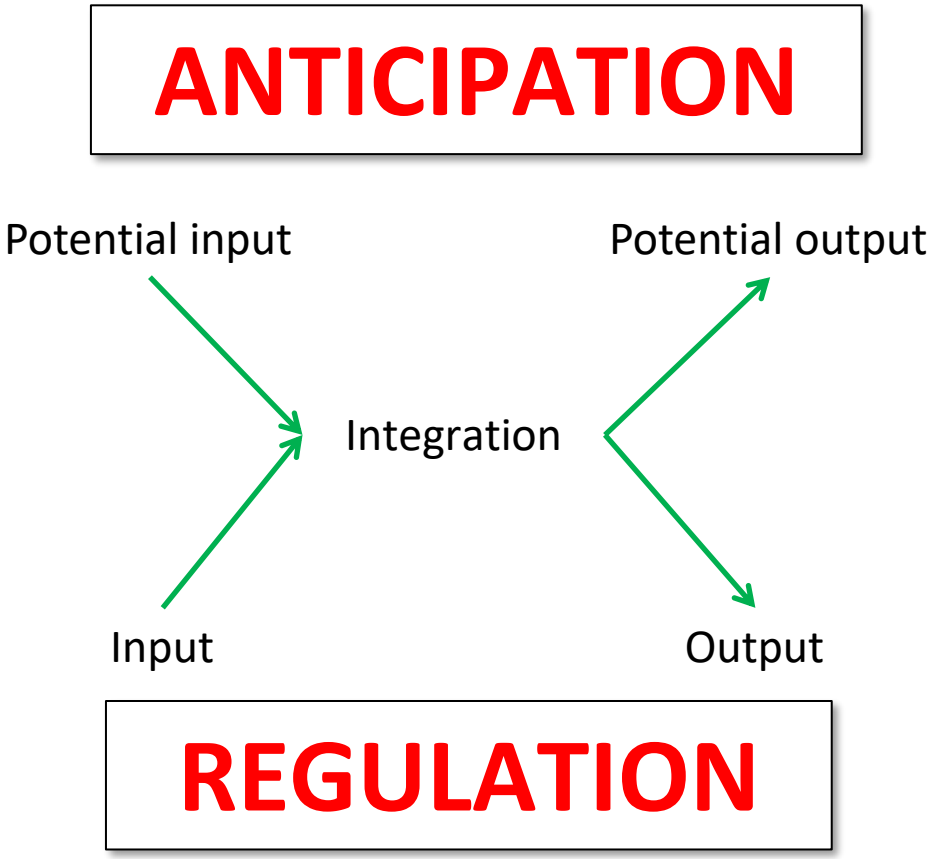
The role of nervous system



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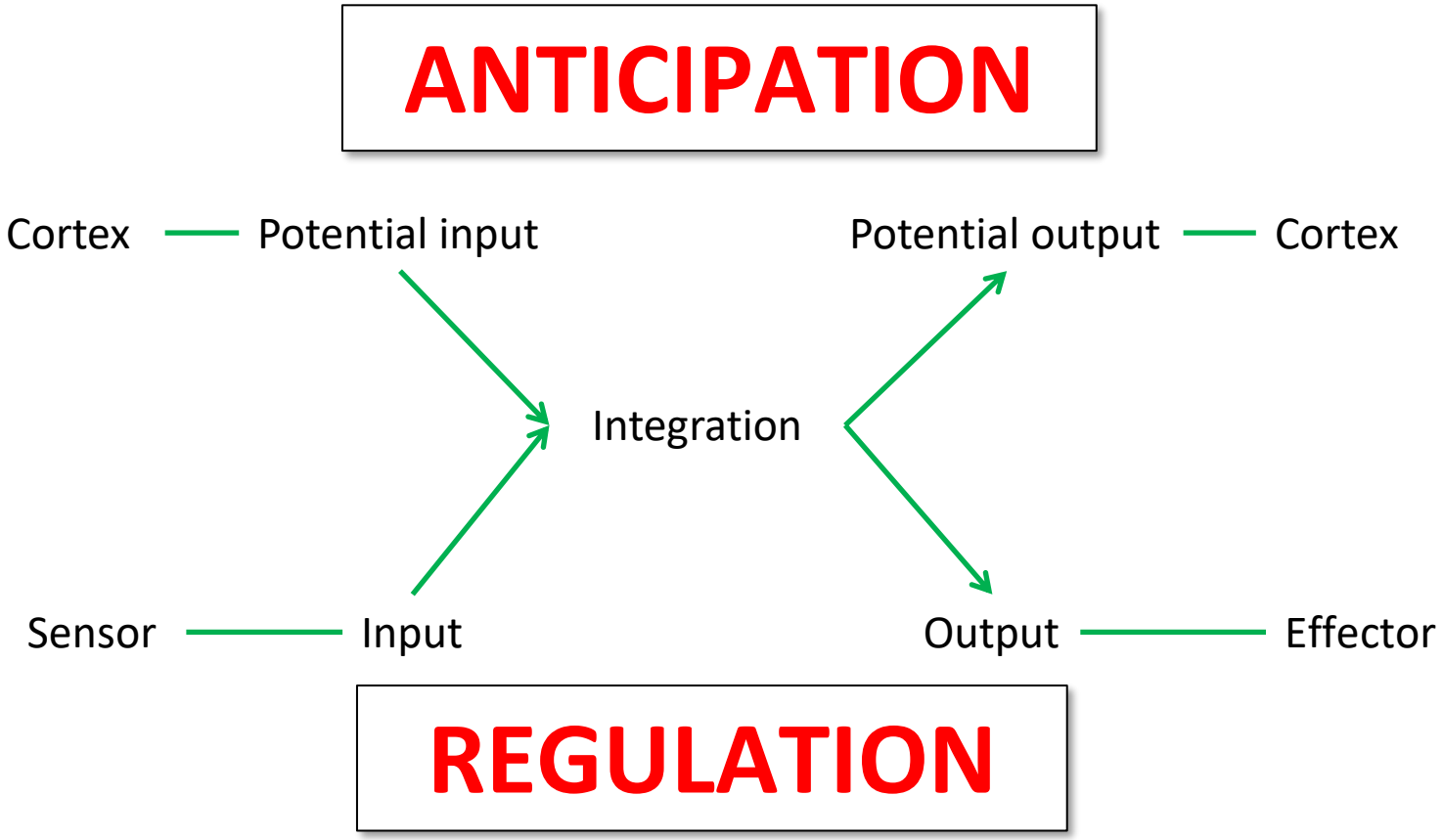
The role of nervous system



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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

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

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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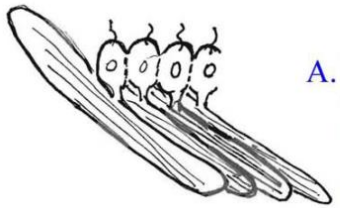
Evolution of the nervous system

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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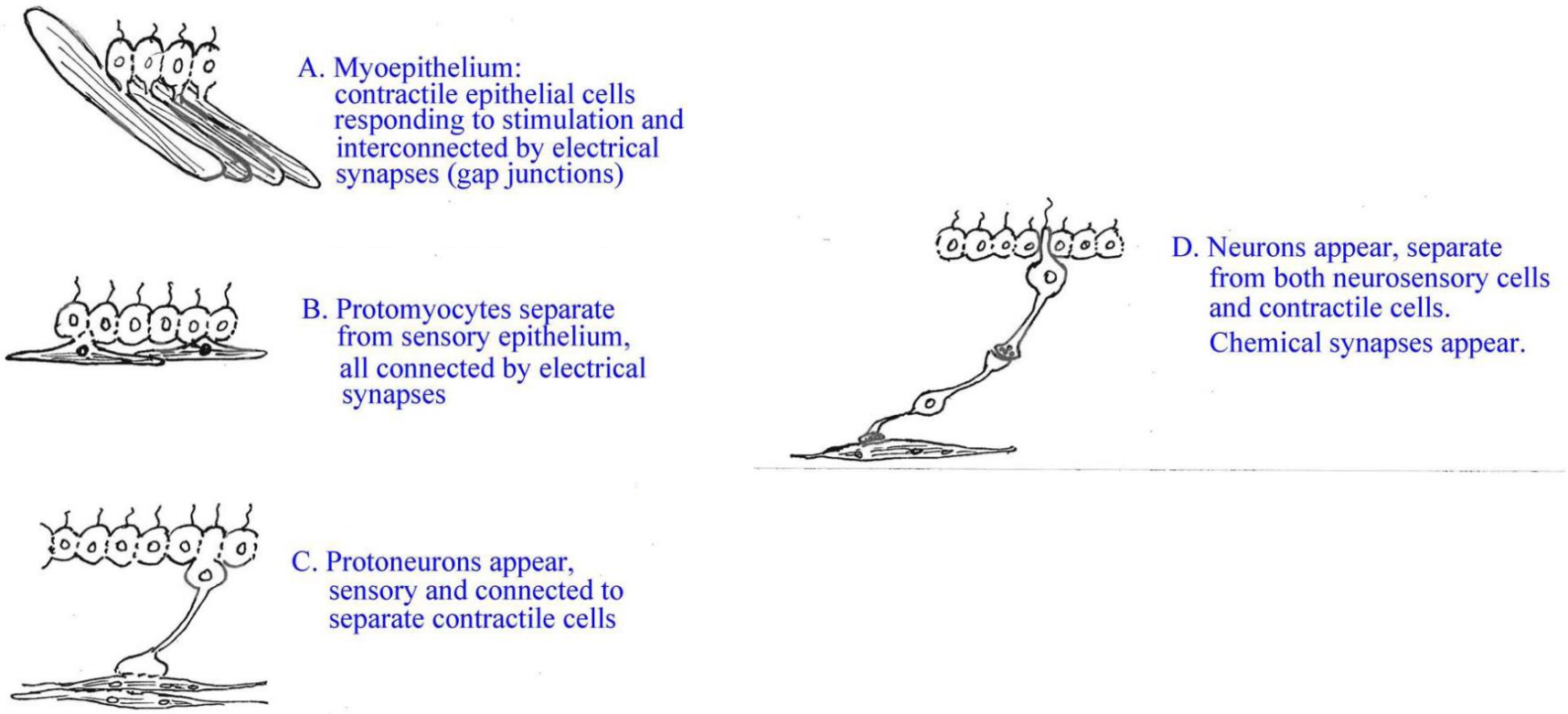
Evolution of the nervous system

Input → Integration → Output



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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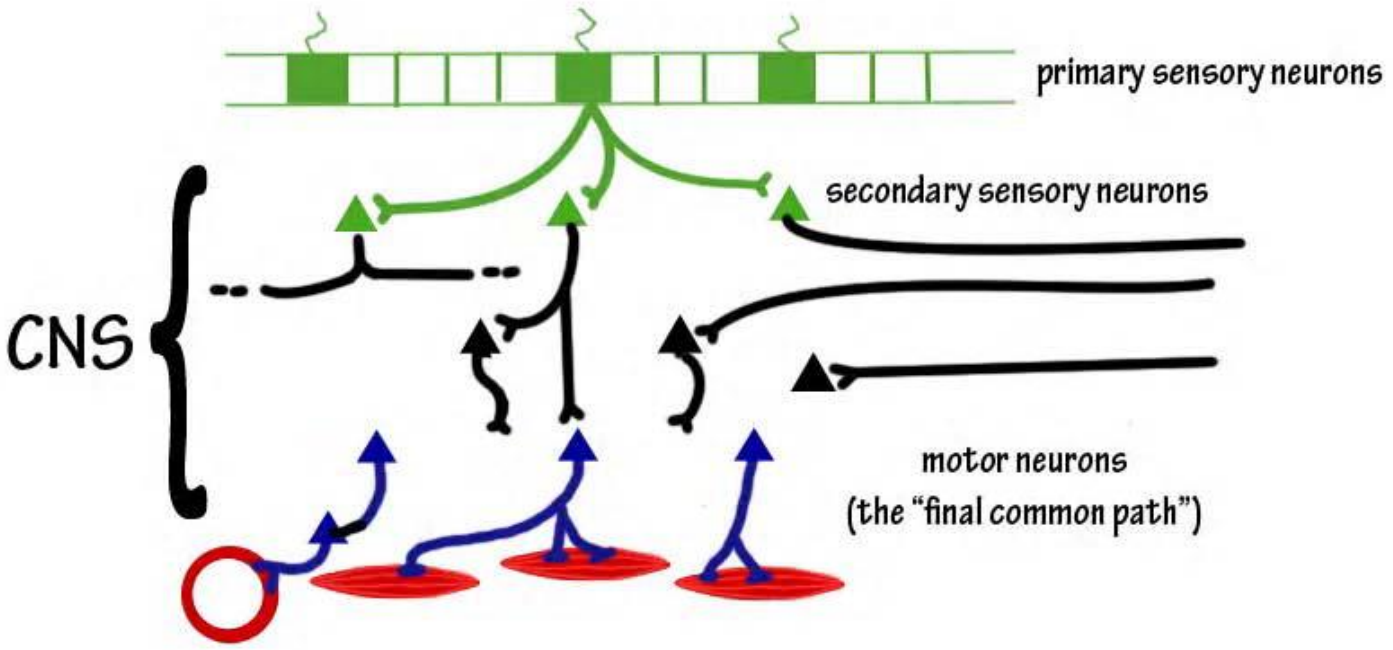
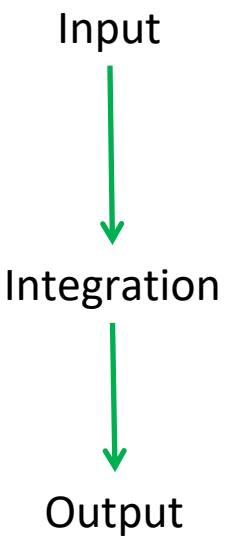
Evolution of the nervous system





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 compartmentalizatio…vels
  - 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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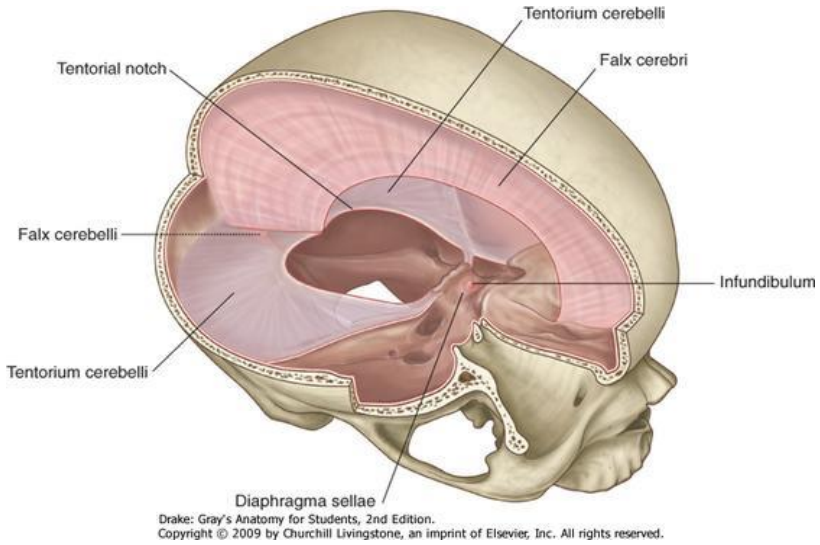
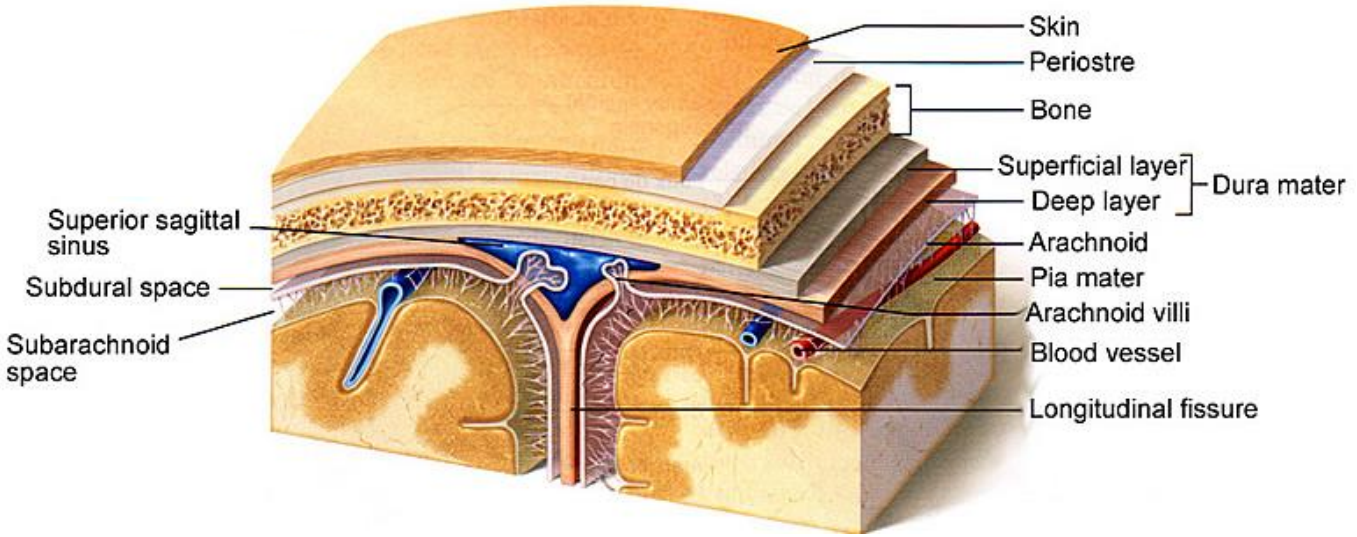
Intracranial compartment

- ✓ „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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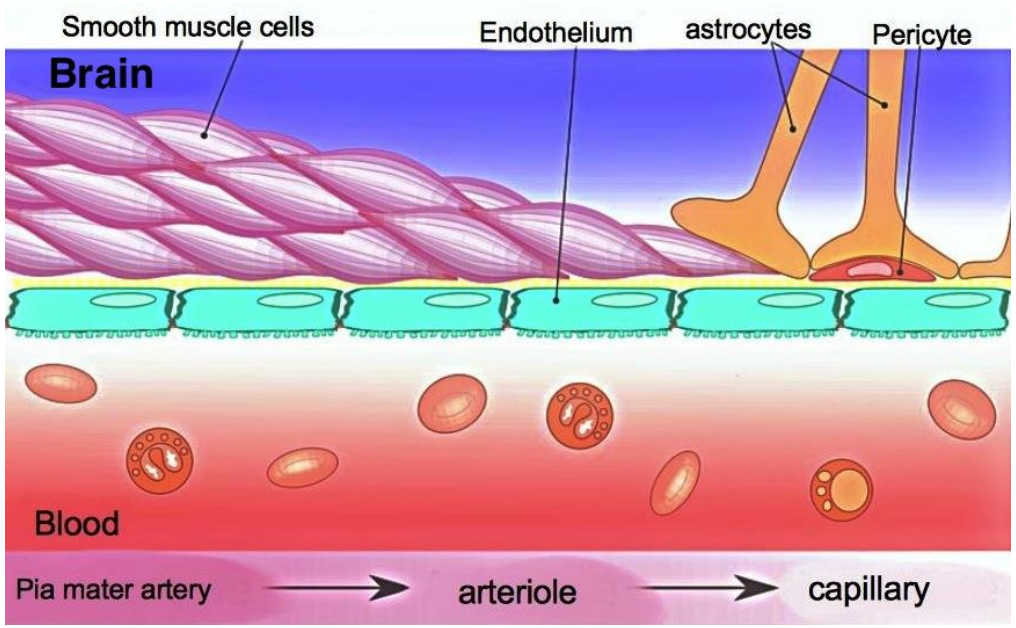
Hematoencephalic barrier

- 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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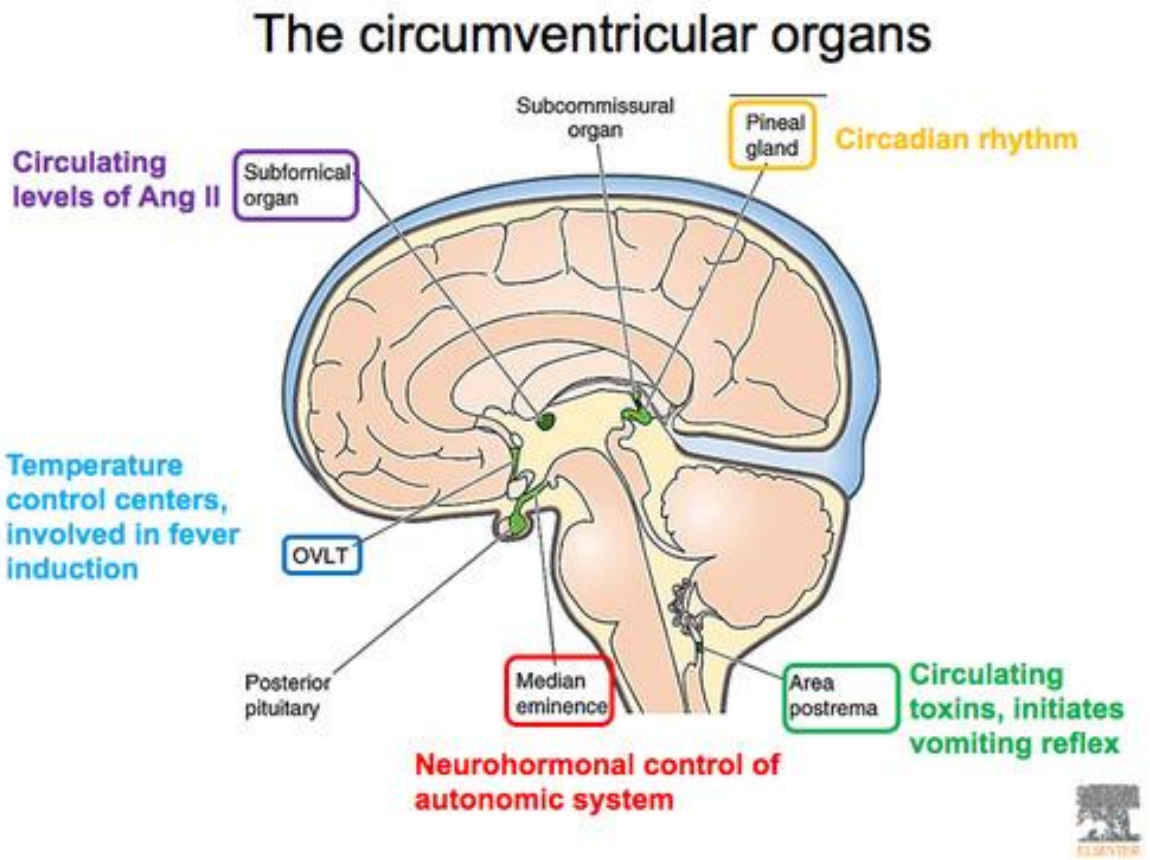
Circumventricular organs

- Rich vascularisation
- Modified hematoencephalic barrier
- Sensors
- Secretion



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

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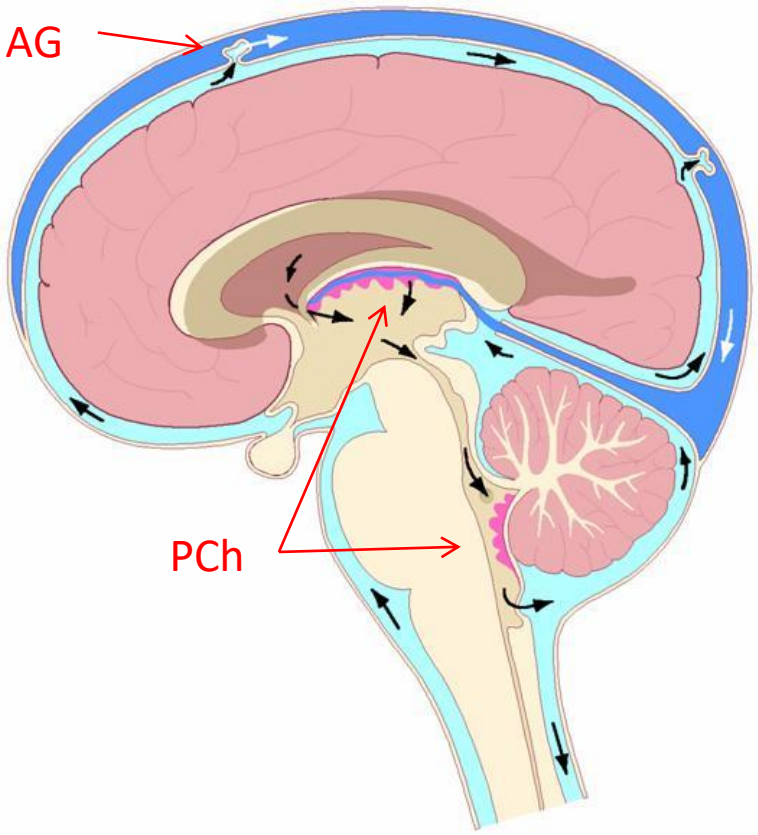
Cerebrospinal fluid

- 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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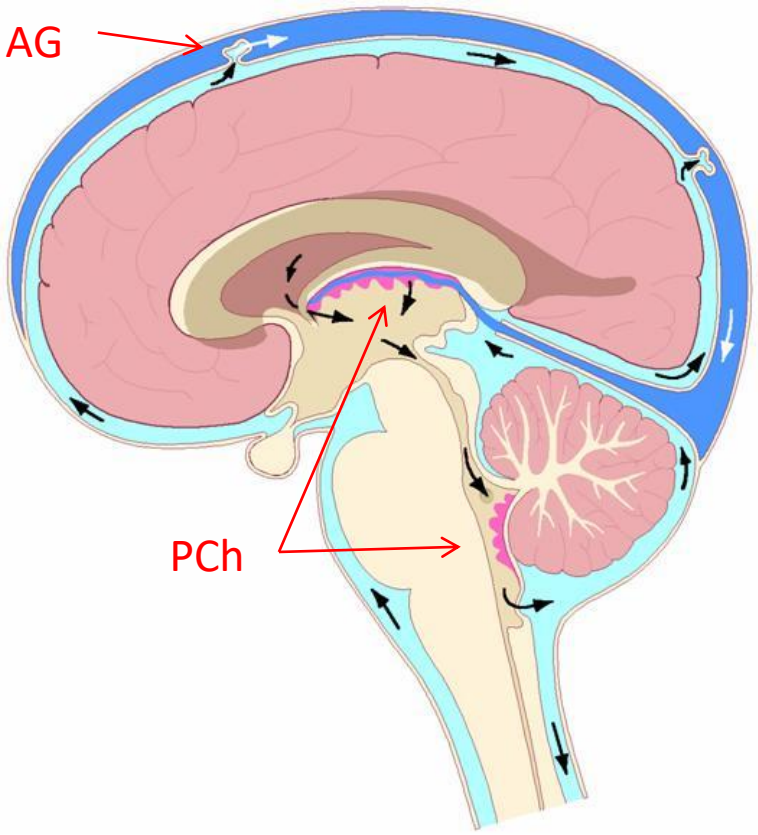
Cerebrospinal fluid

- 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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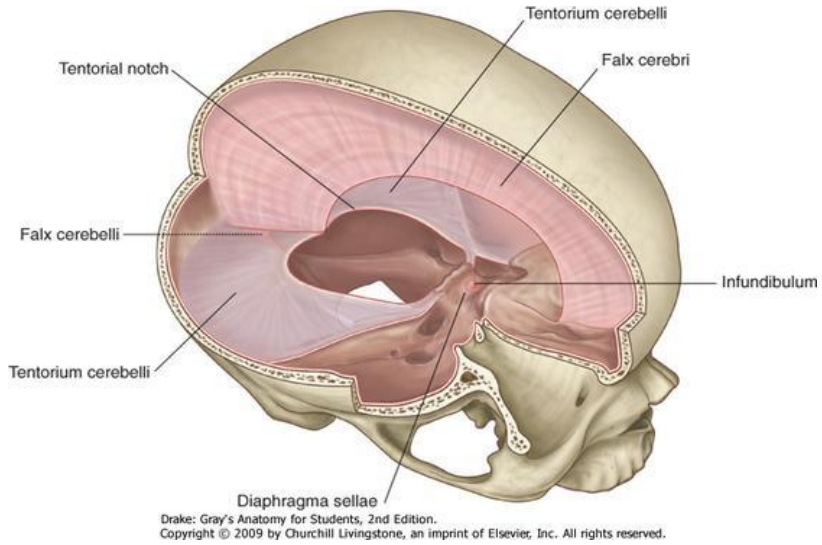
Intracranial compartment

- 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)

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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
- ✓ …

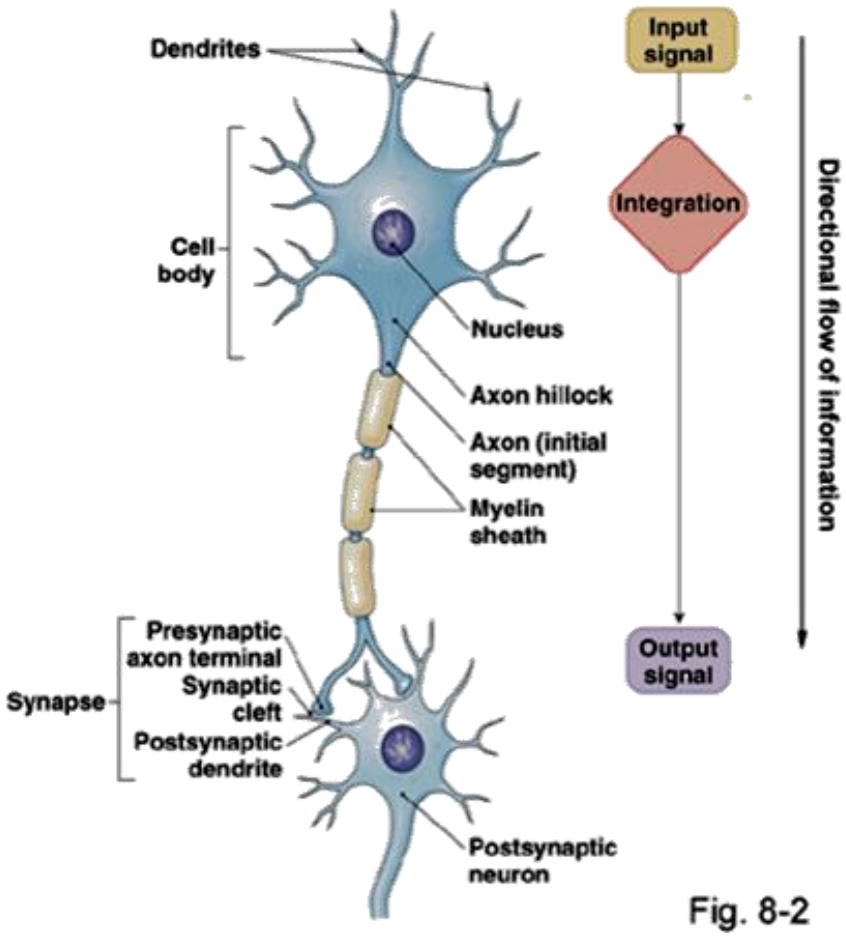

Fig. 8-2

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Information processing and transmission

The membrane

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

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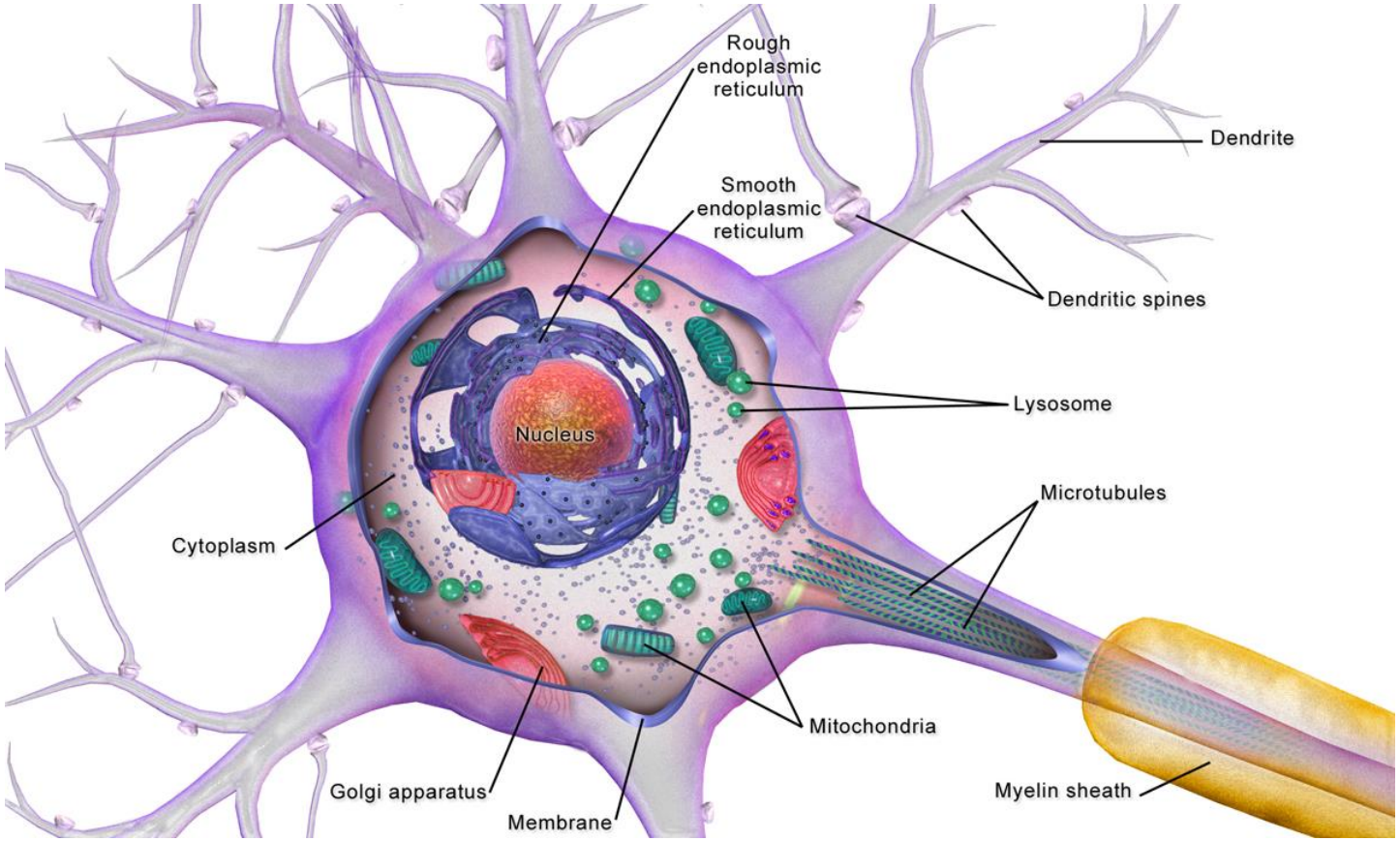
Background Activity



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

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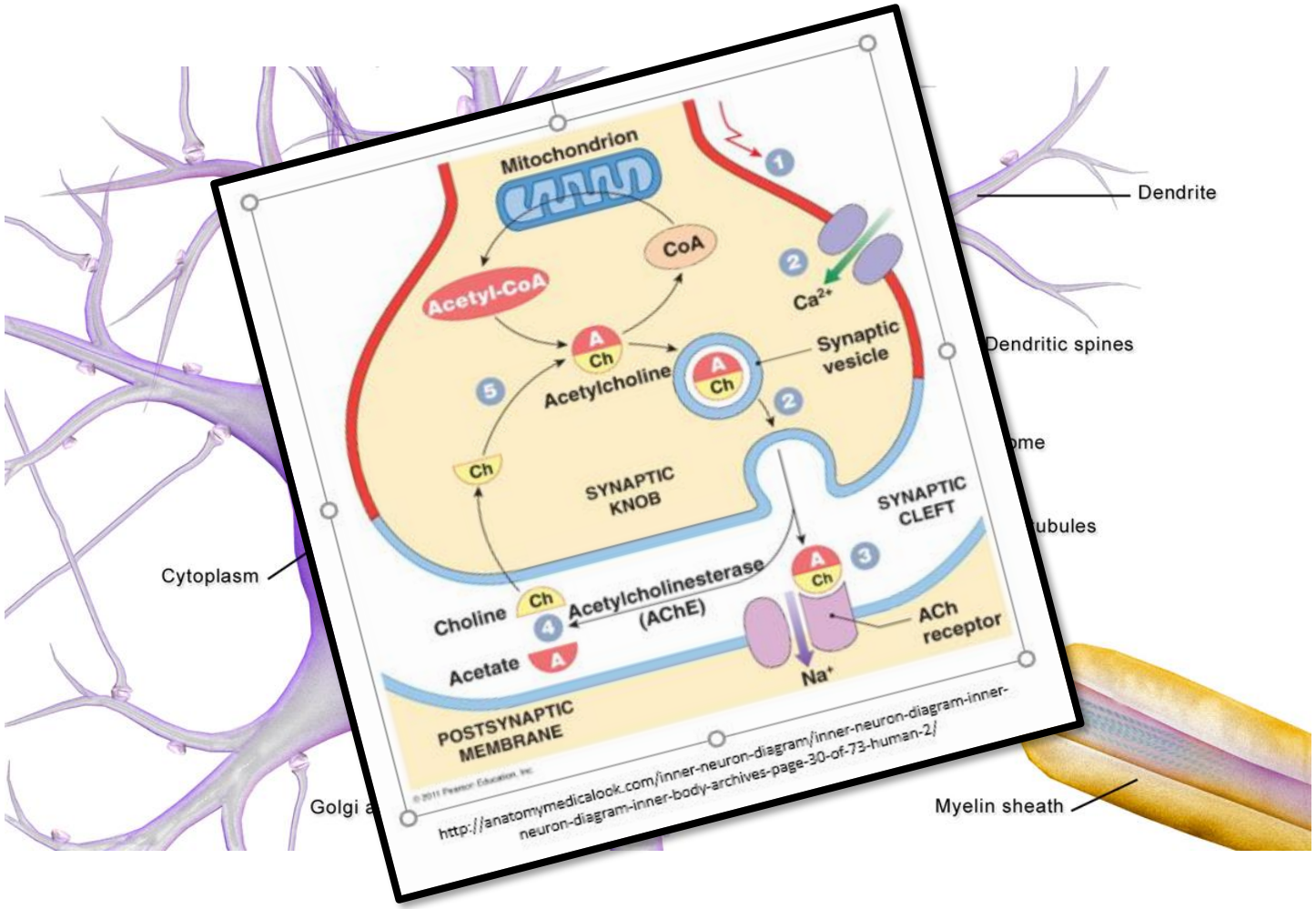
Background Activity



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

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Background Activity

Fast axonal transport

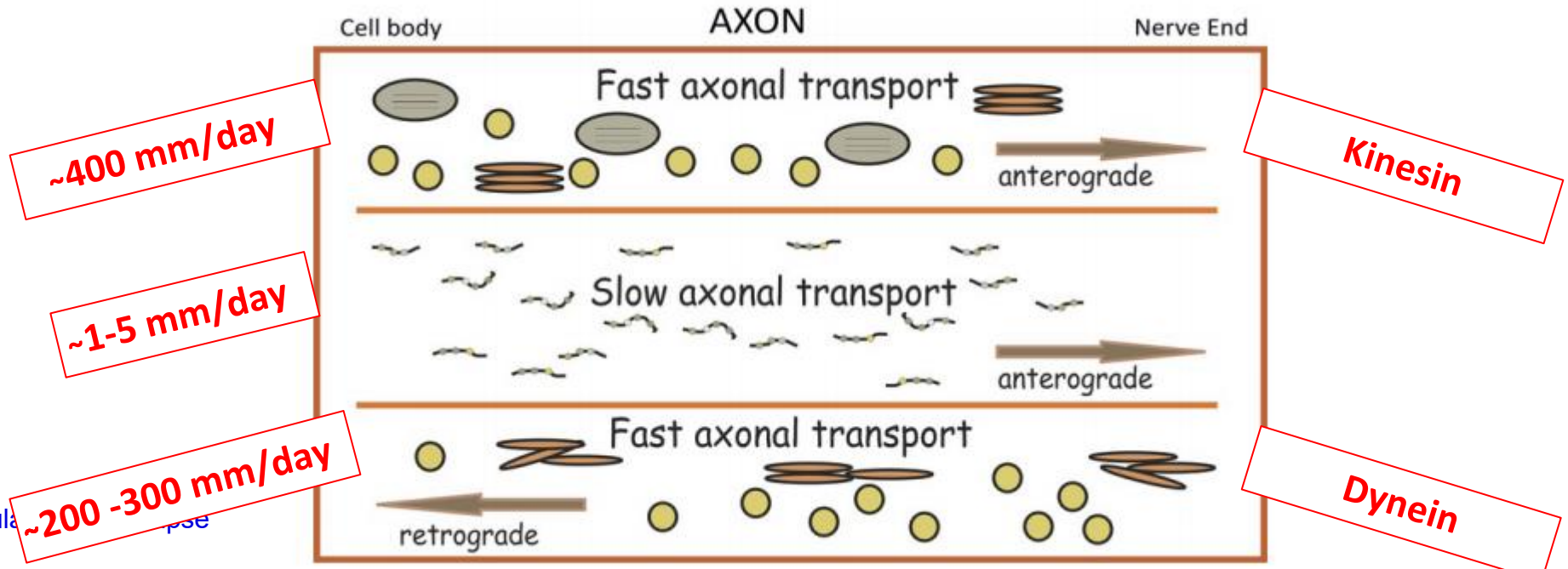
- bidirectional
- ATP dependant
- associated with microtubules: dynein and kinesin

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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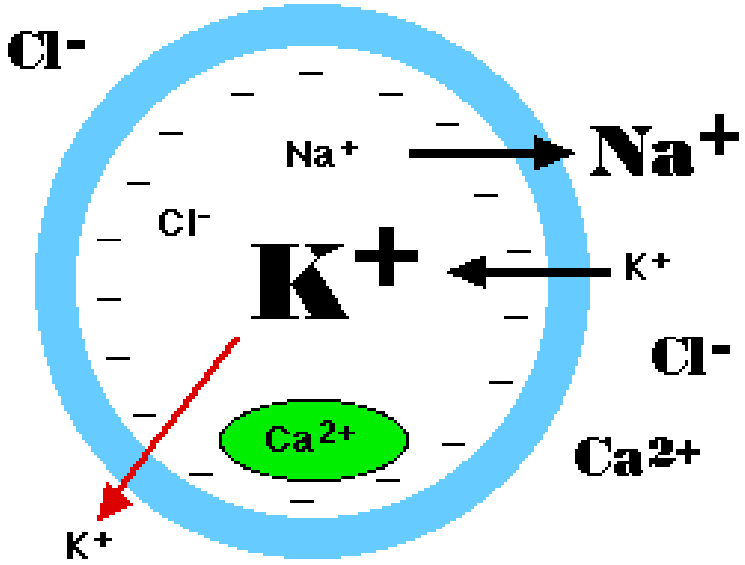
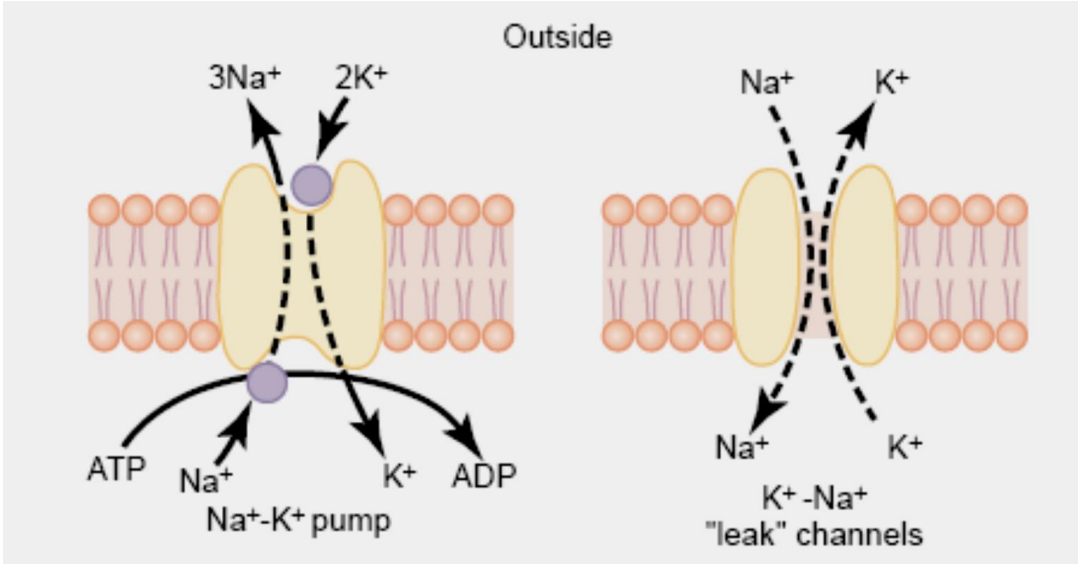
Membrane potential

- 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

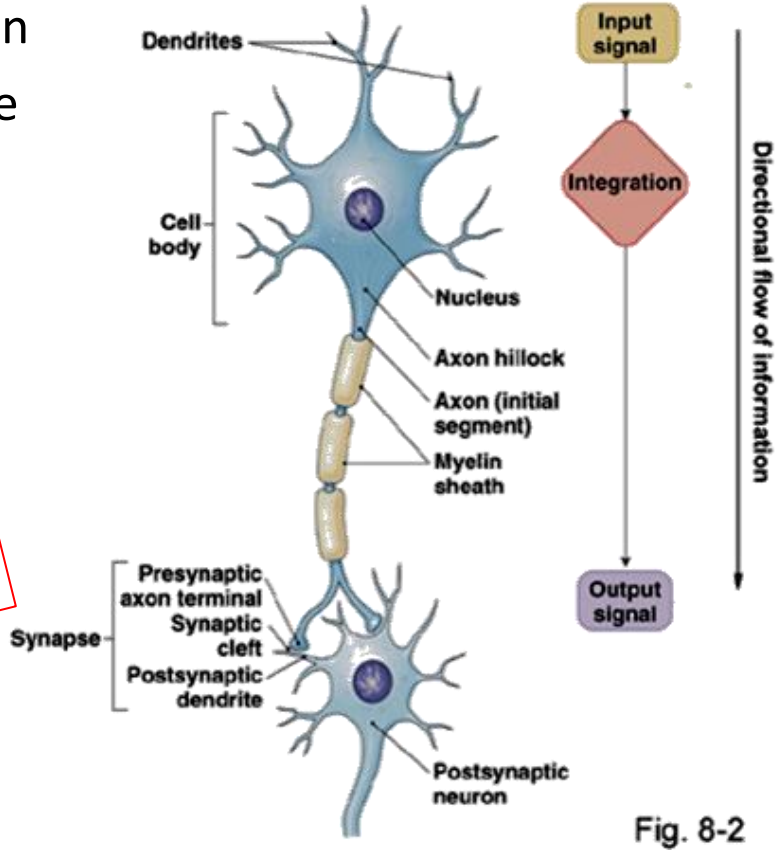
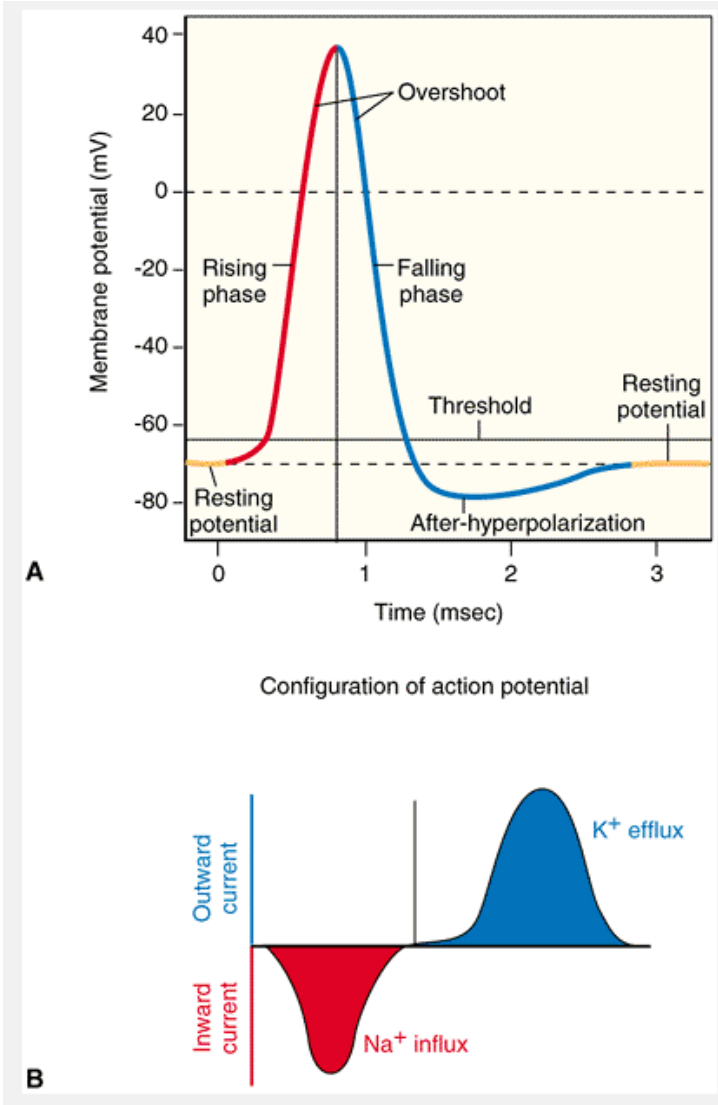


Fig. 8-2



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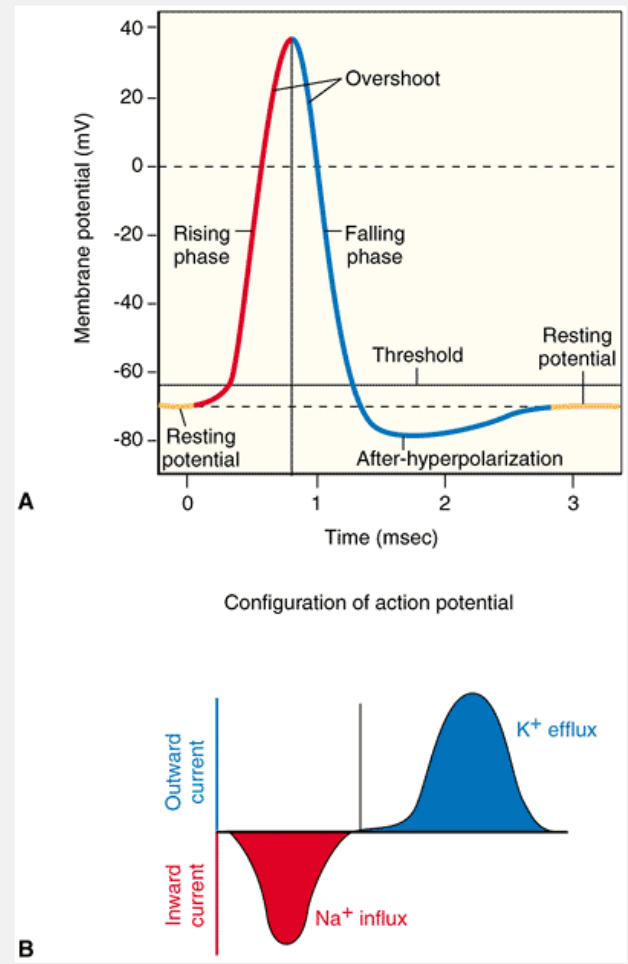
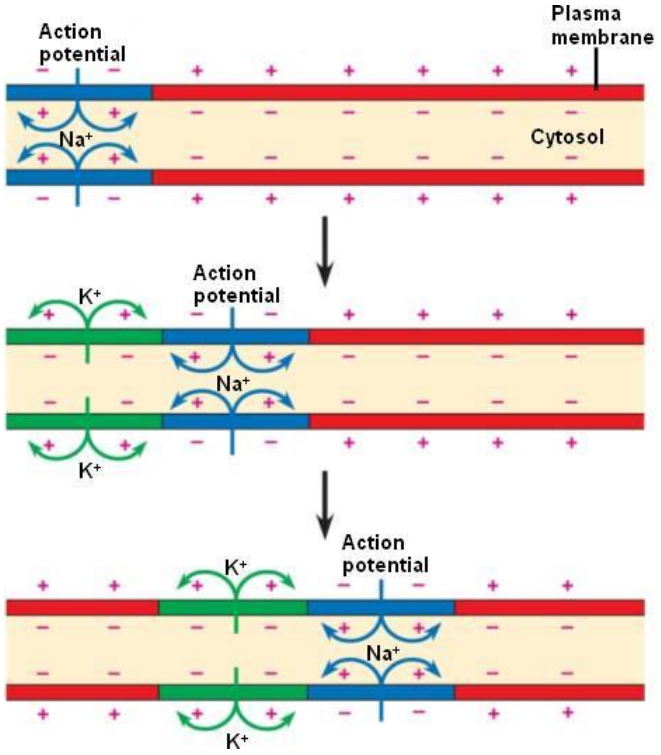
Action potential spreading





- Local currents
- Anterograde

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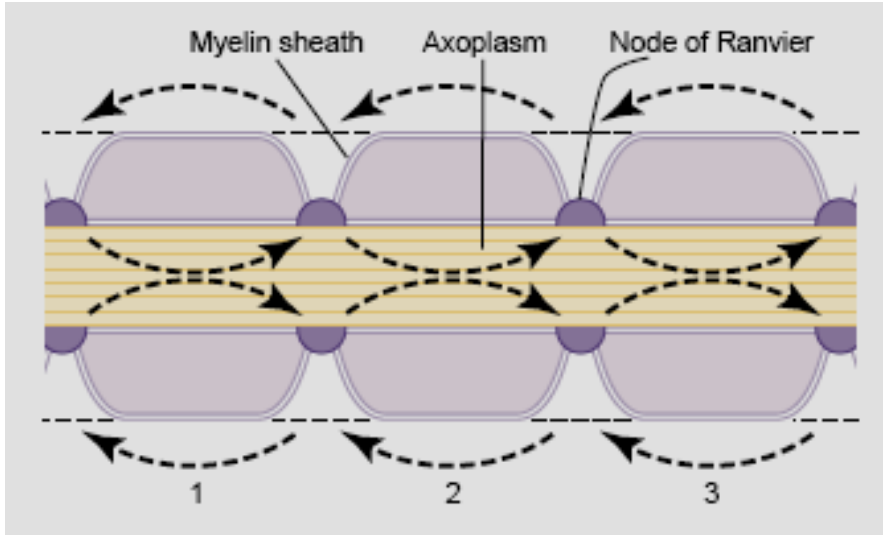
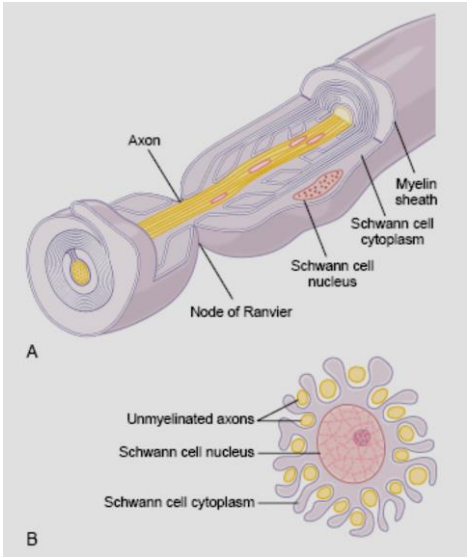
Saltatory conduction

- 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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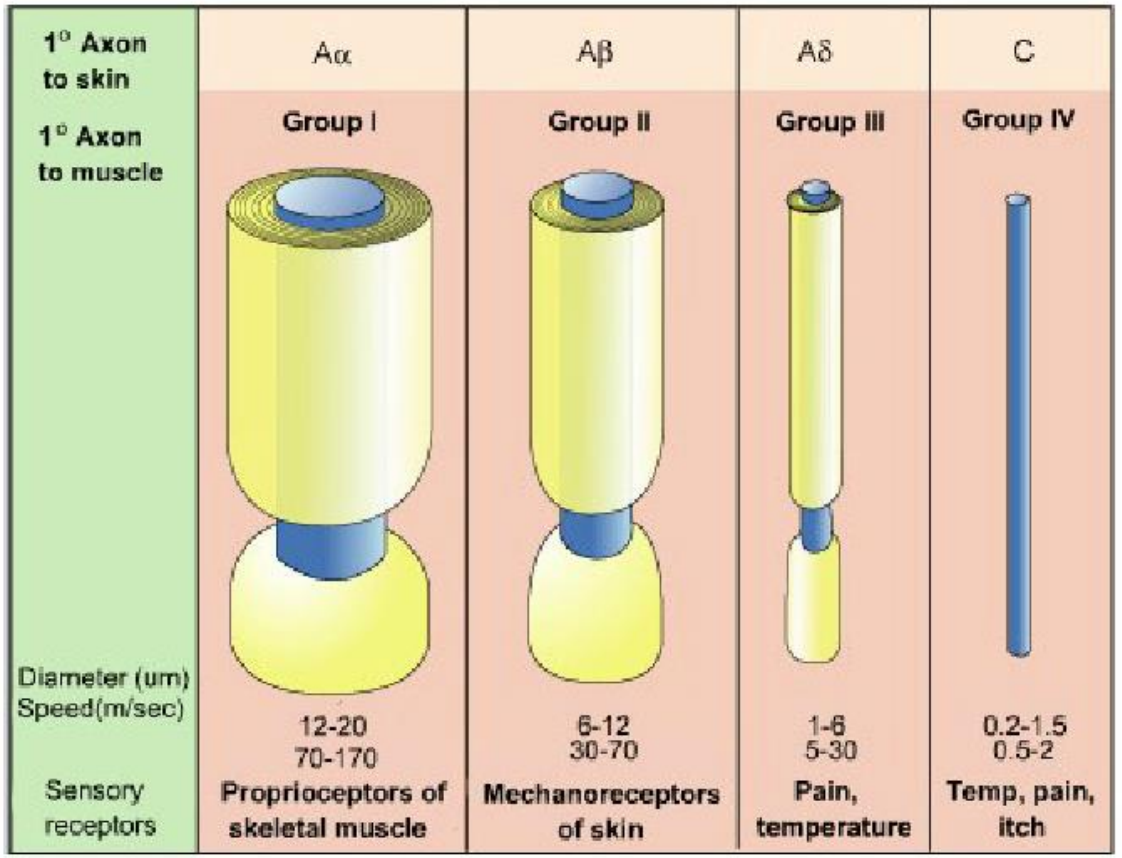
Classification of nerve fibers

- 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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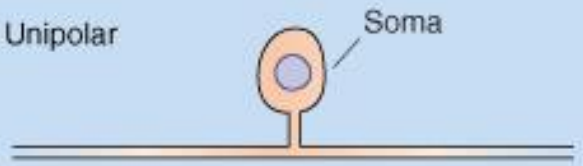
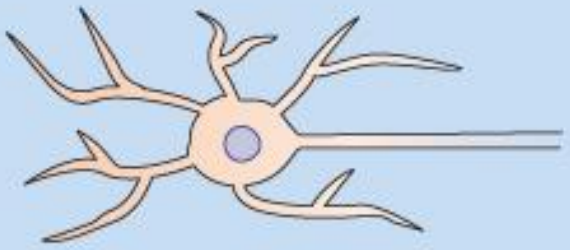
Neuronal classification

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 

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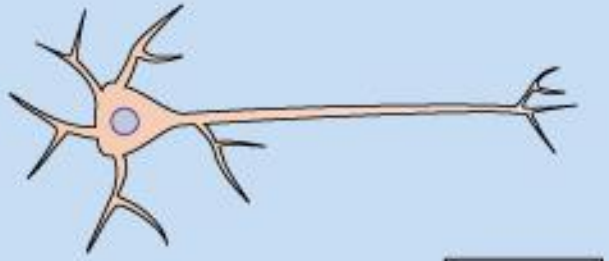
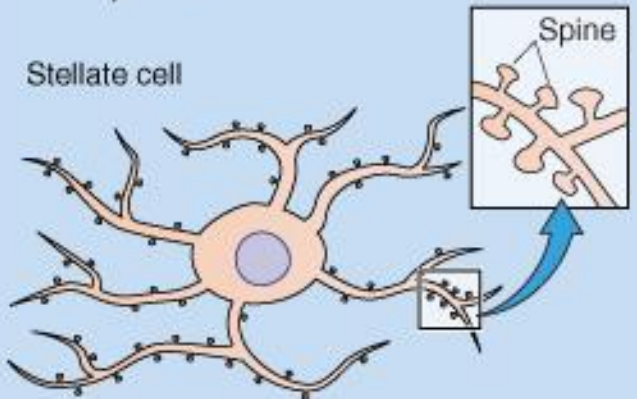
Neuronal classification

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 

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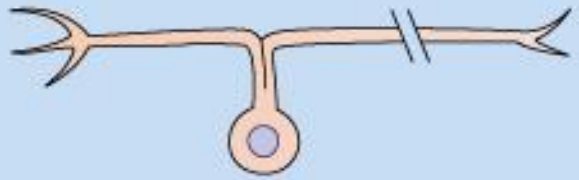
Neuronal classification

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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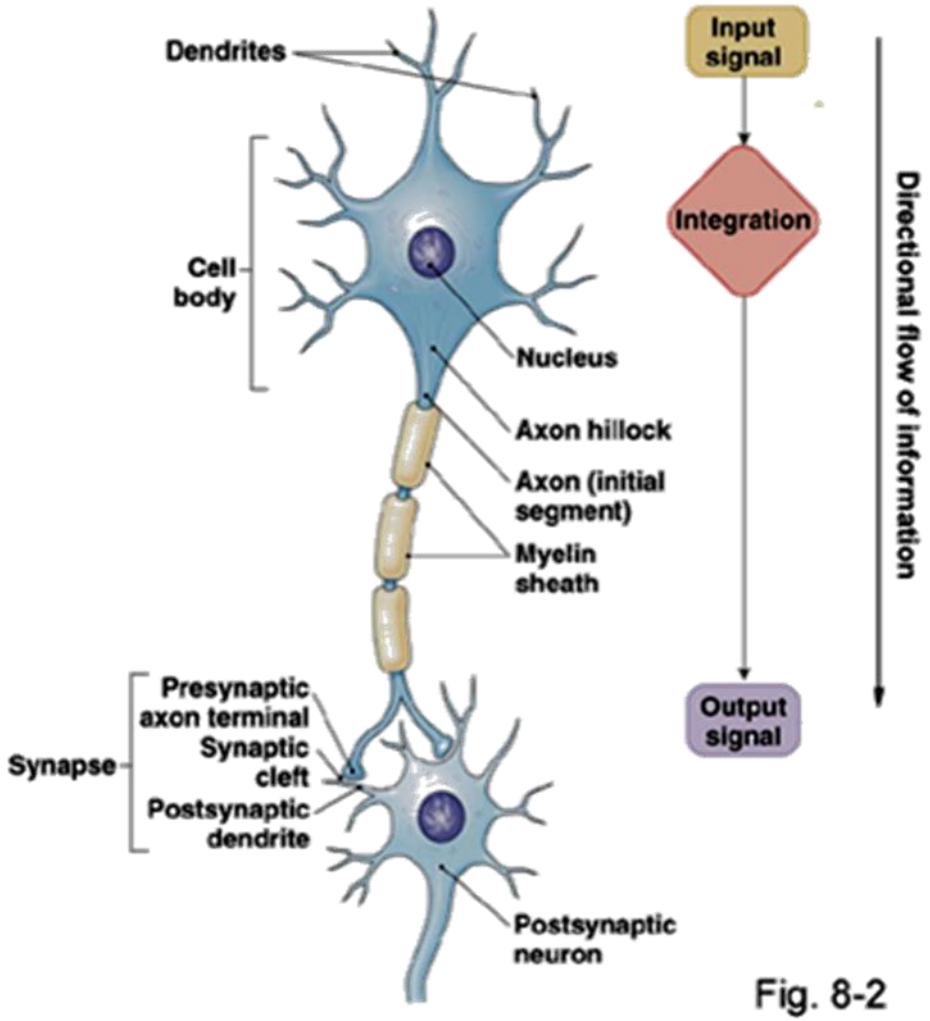
Synapse

- Communication between neurons

- Electrical
- Chemical



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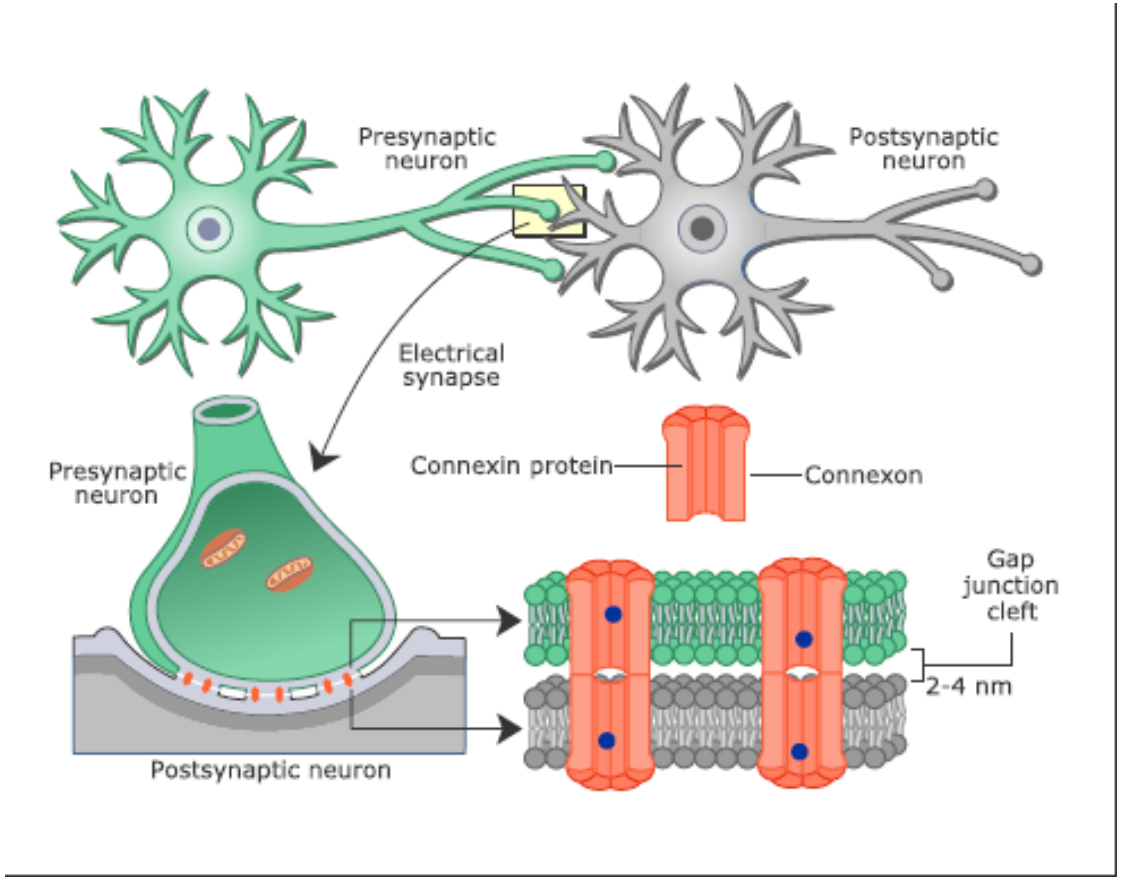
Electrical synapse

- Evolutionary old
- Less frequent than ch.
- Ubiquitous



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

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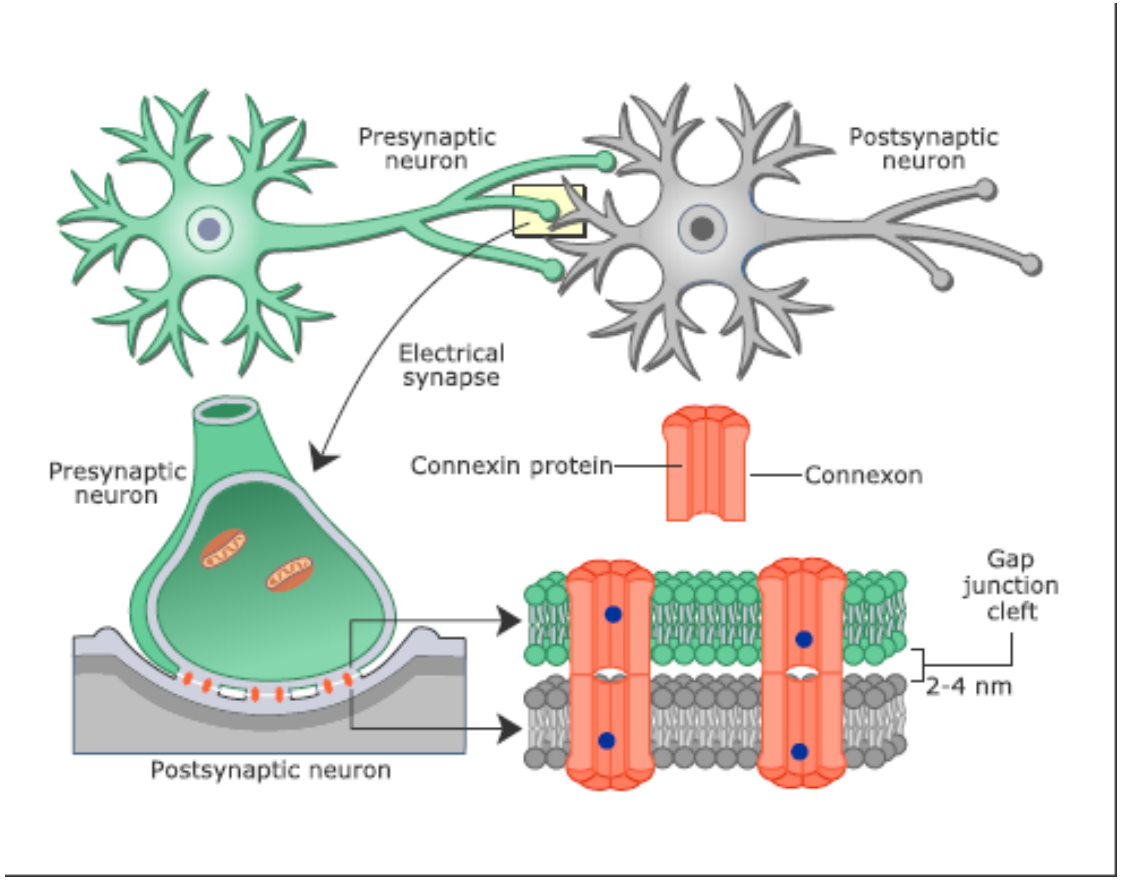
Electrical synapse

- Evolutionary old
- Less frequent than ch.
- Ubiquitous

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



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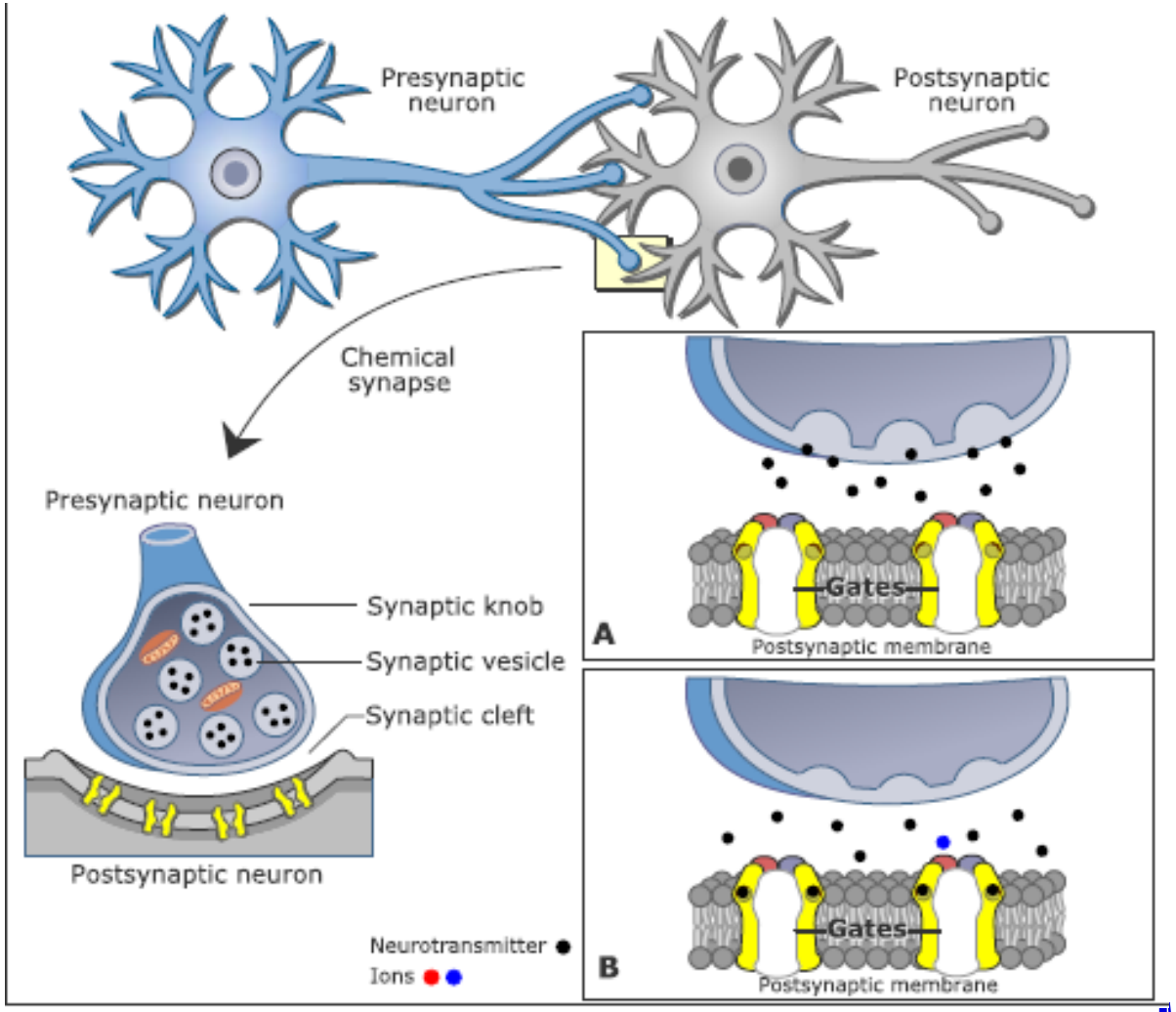
Chemical synapse

- Evolutionary young
- Majority type of s.



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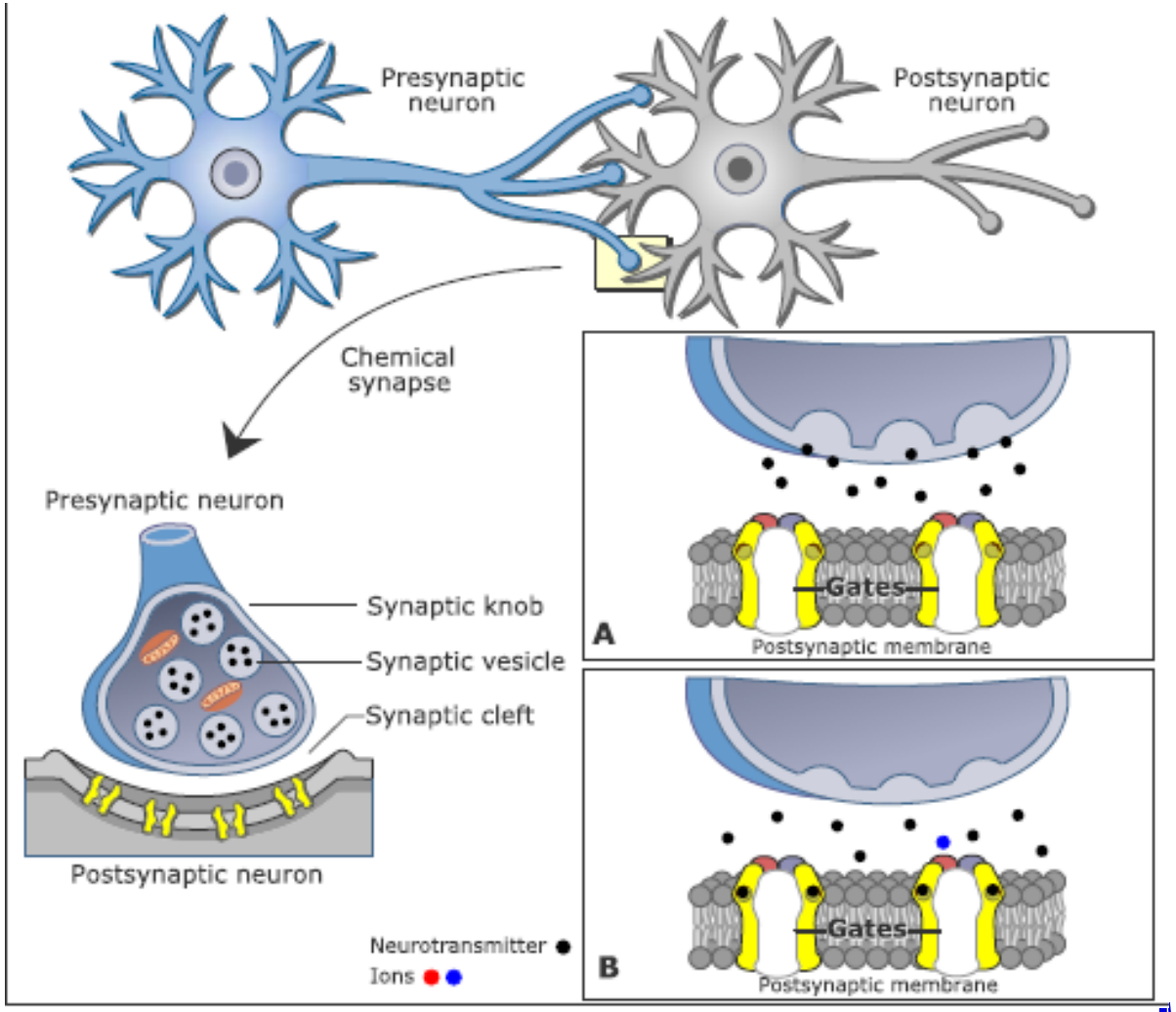
Chemical synapse

- Evolutionary young
- Majority type of s.

- Unidirectional
- Synaptic cleft
- Neurotransmitter
- Constant signal strength



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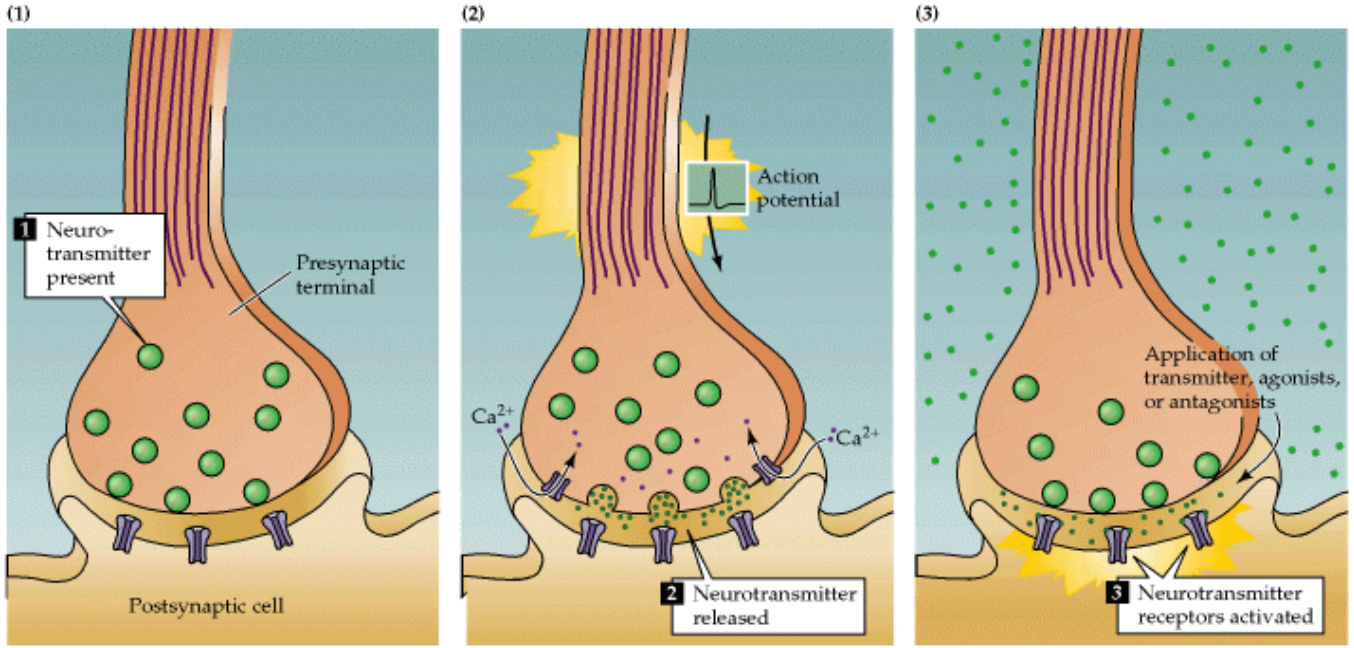
Neurotrasnsmiter



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- Present in presinaptic neuron

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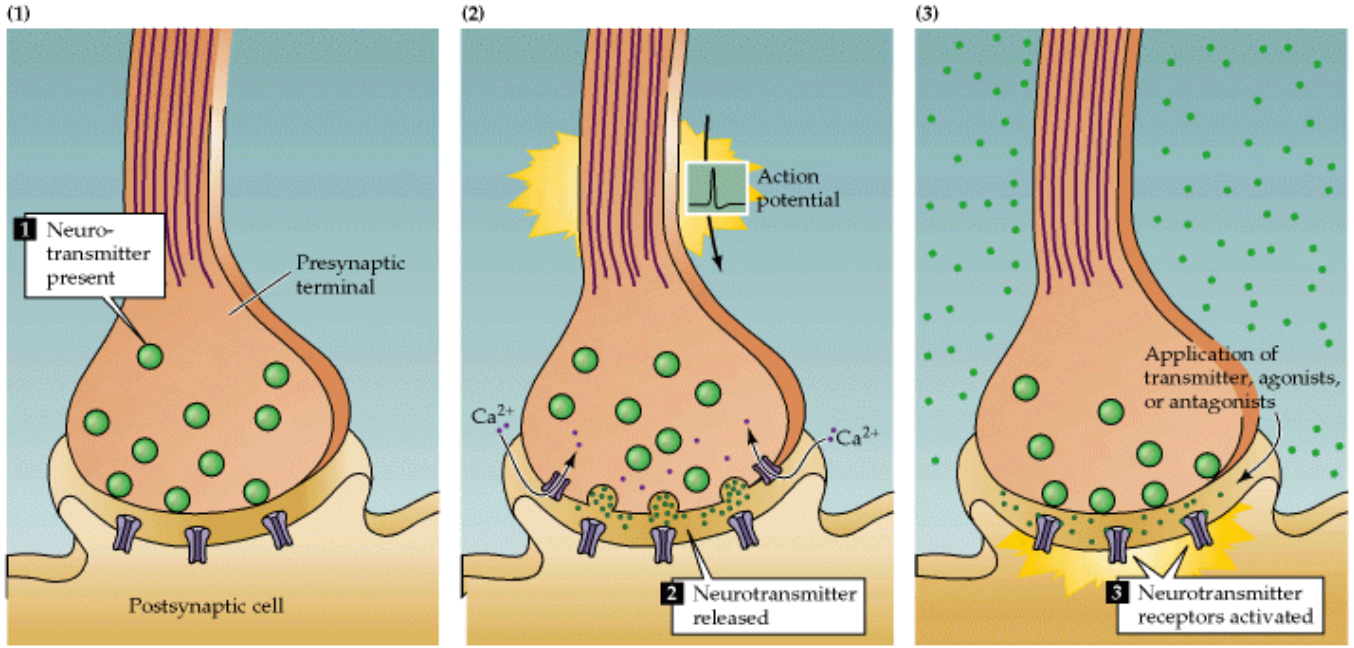
Neurotrasnsmiter



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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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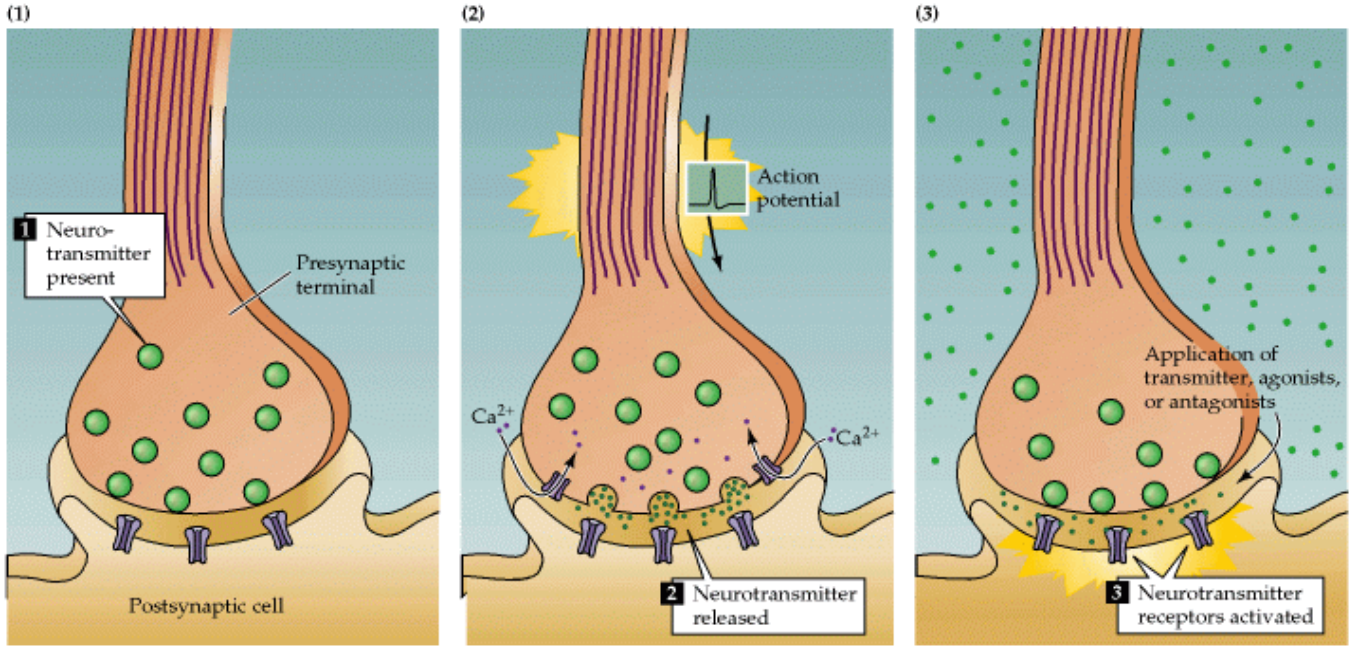
Neurotrasnsmiter



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

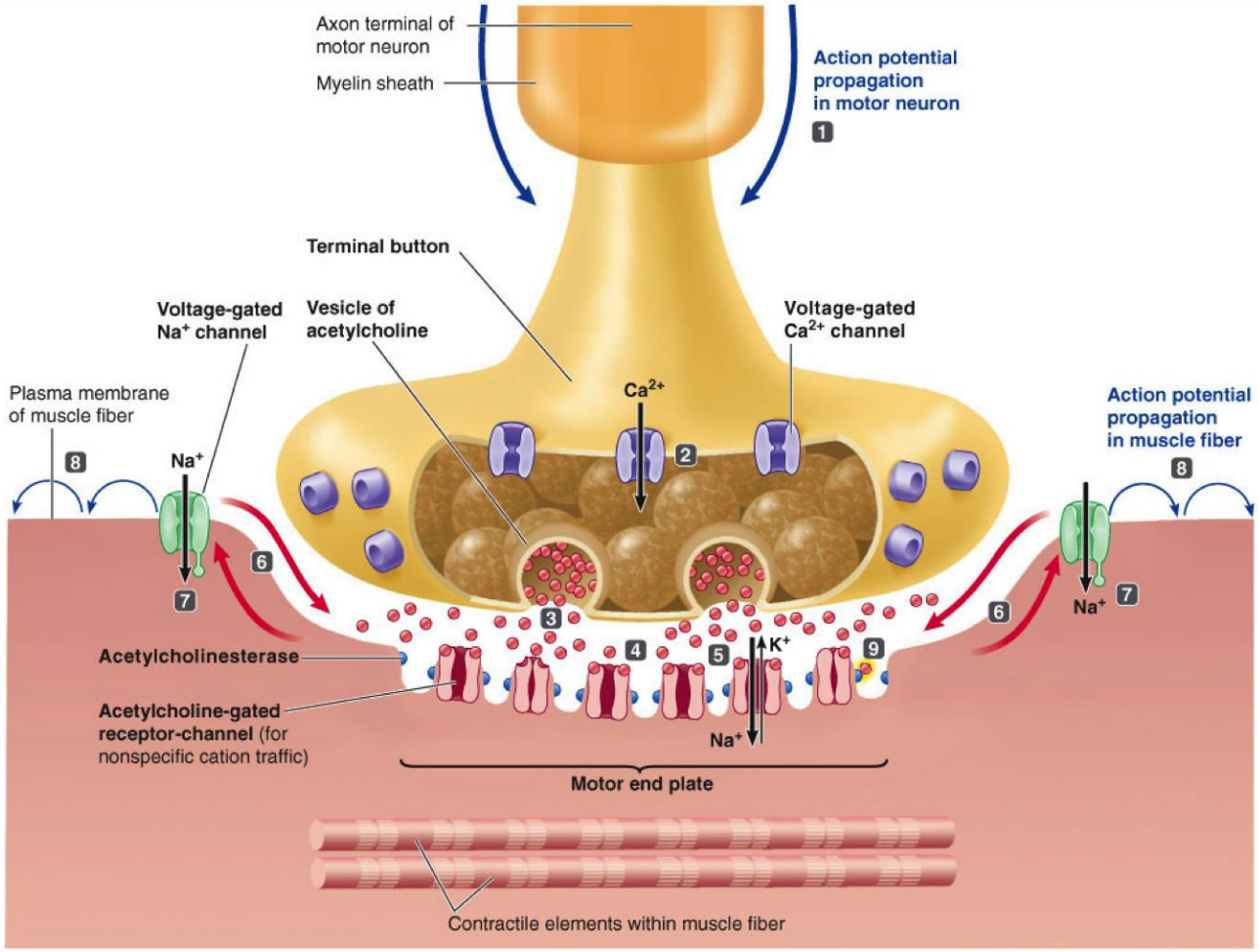

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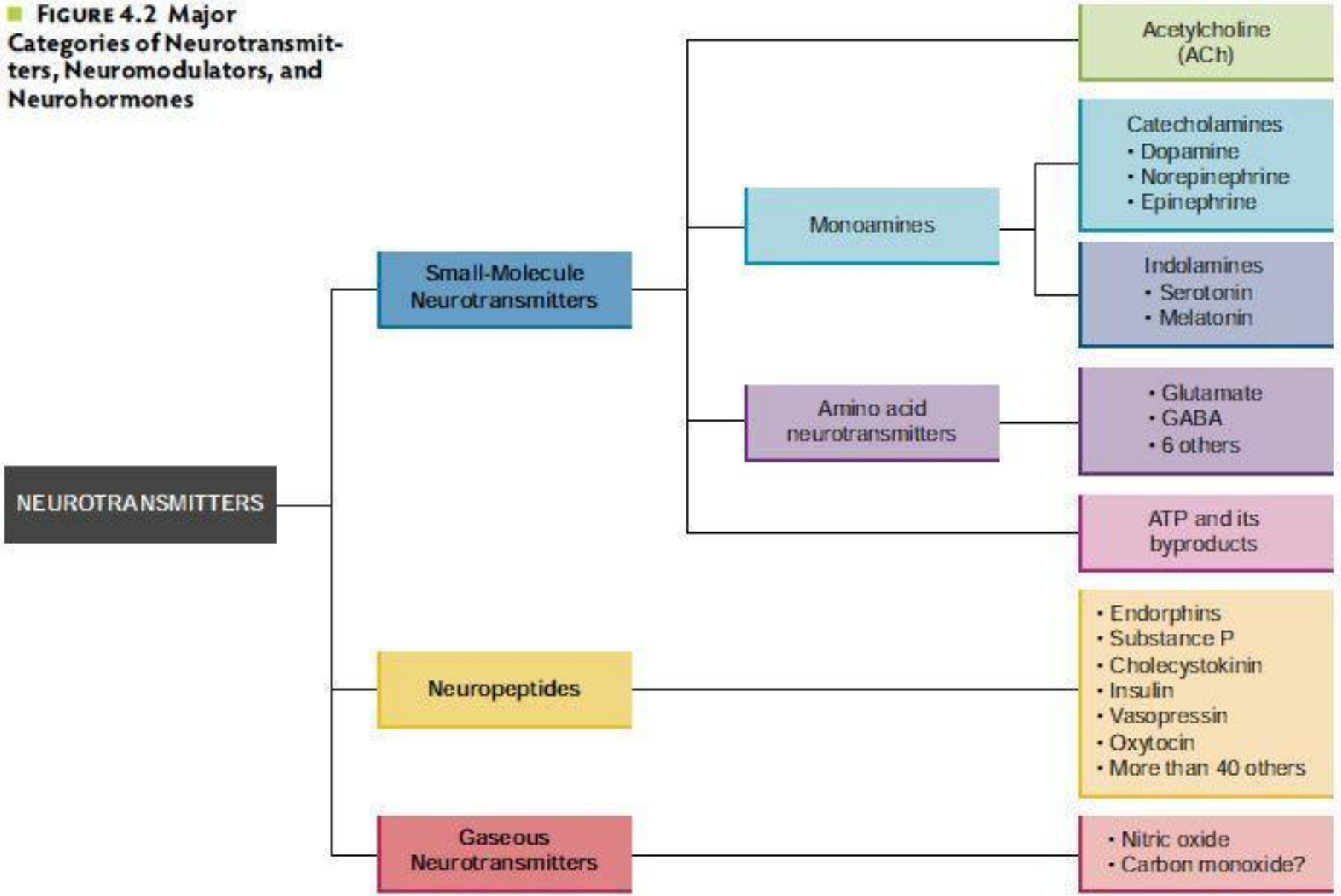
FIGURE 4.2 Major Categories of Neurotransmitters, Neuromodulators, and Neurohormones



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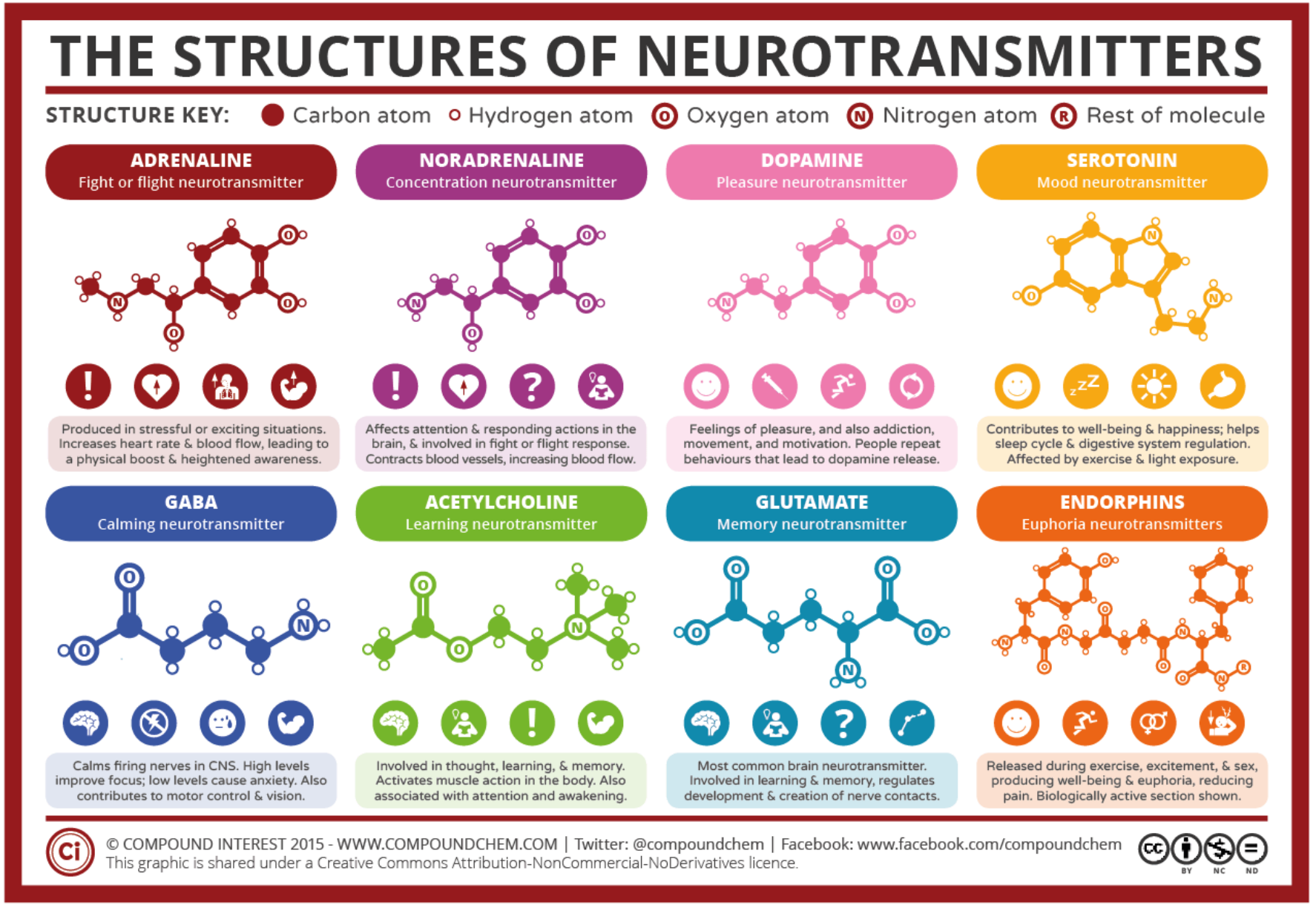

http://www.compoundchem.com/2015/07/30/neurotransmitters/

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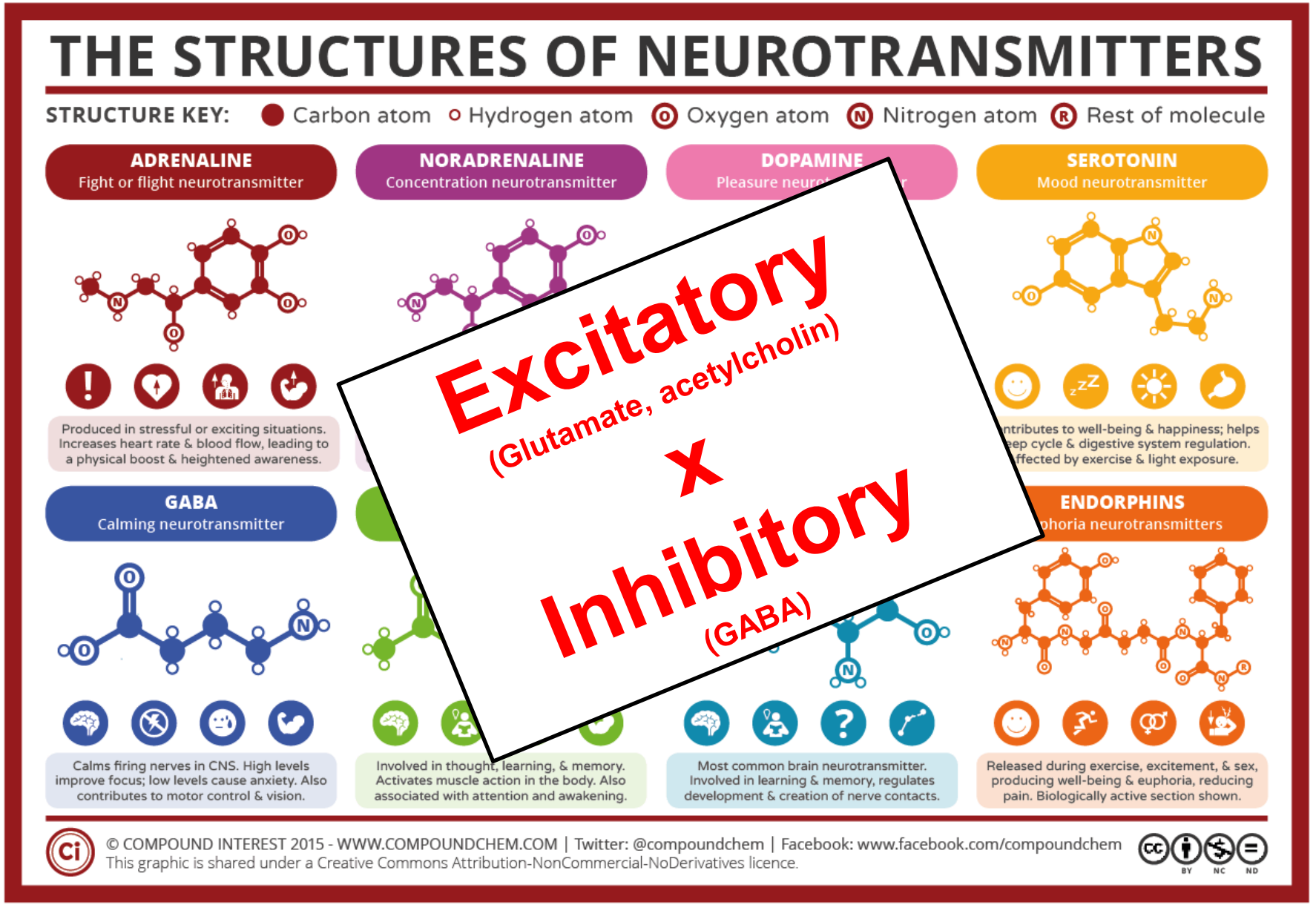

http://www.compoundchem.com/2015/07/30/neurotransmitters/

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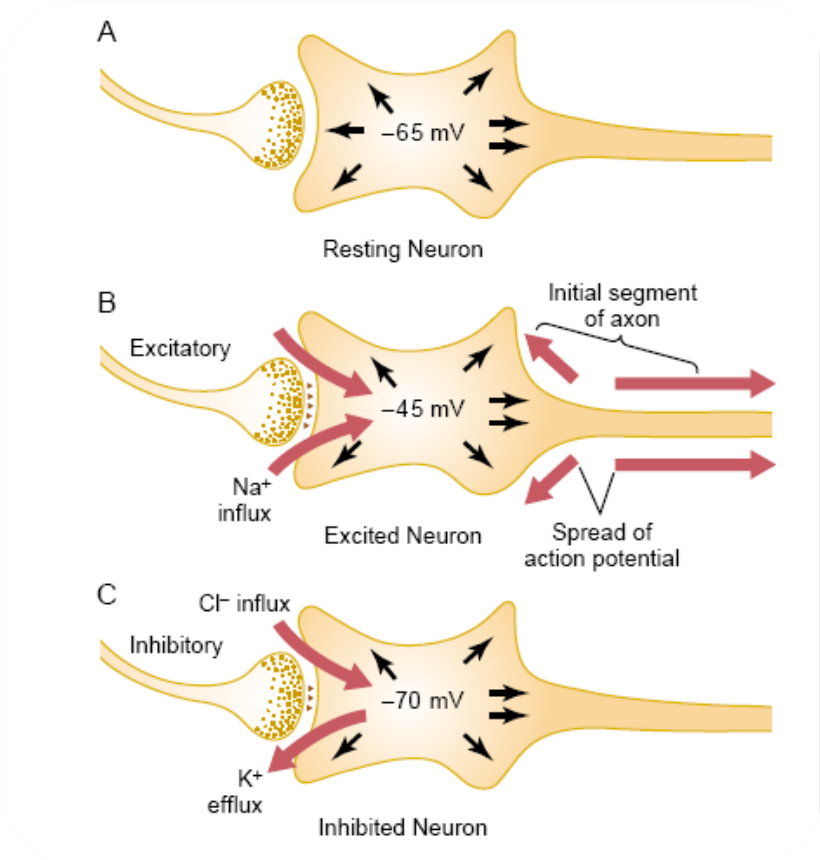
Excitatory/inhibtory postsynaptic potencial



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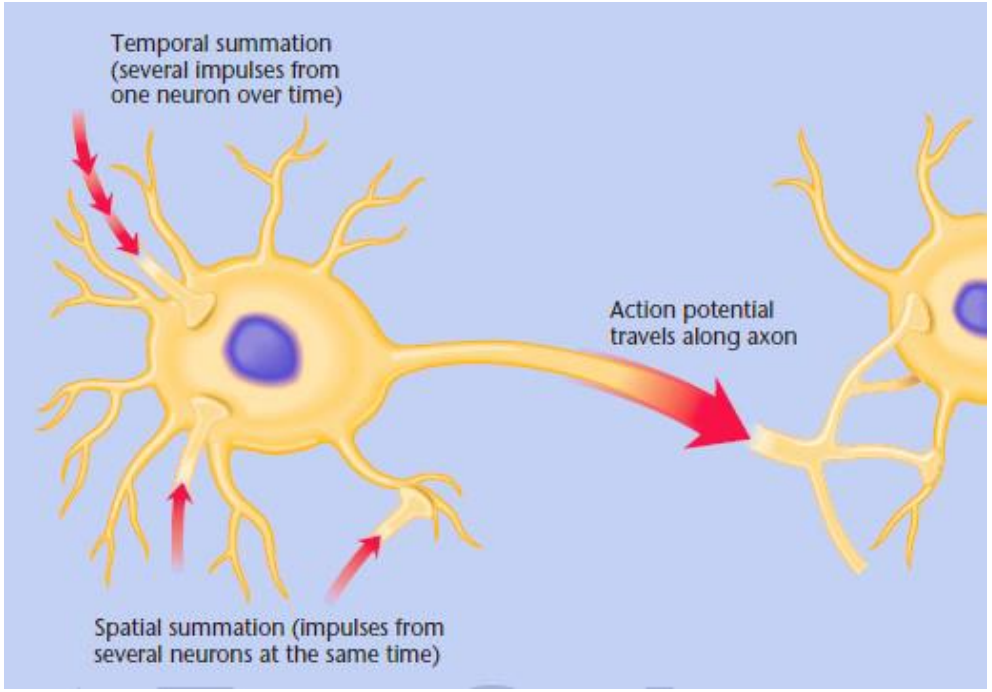
Signal summation

- Temporal
- Spatial



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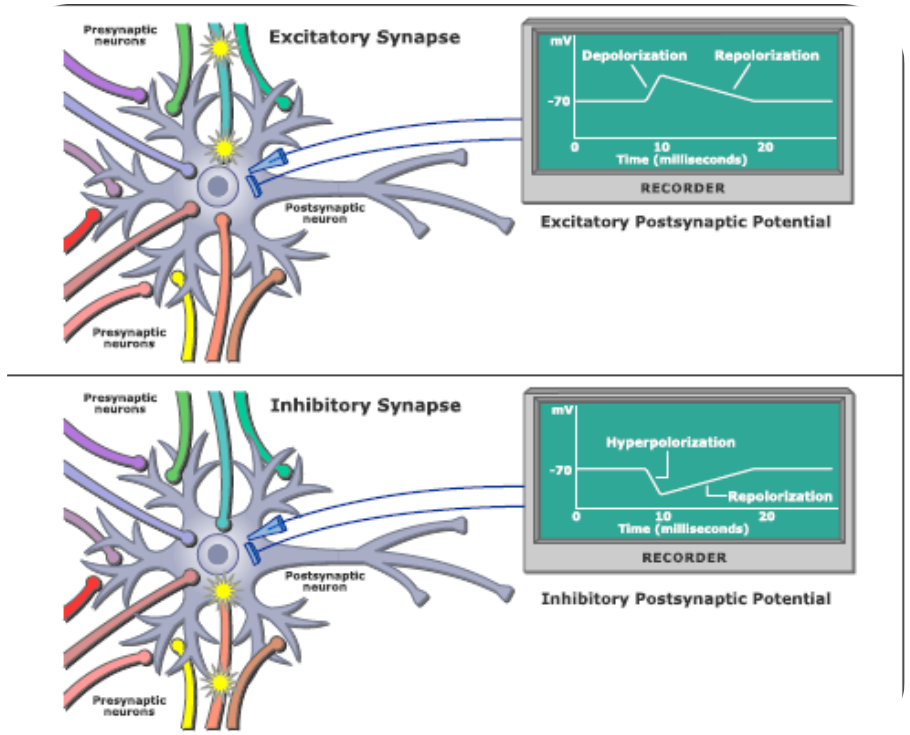

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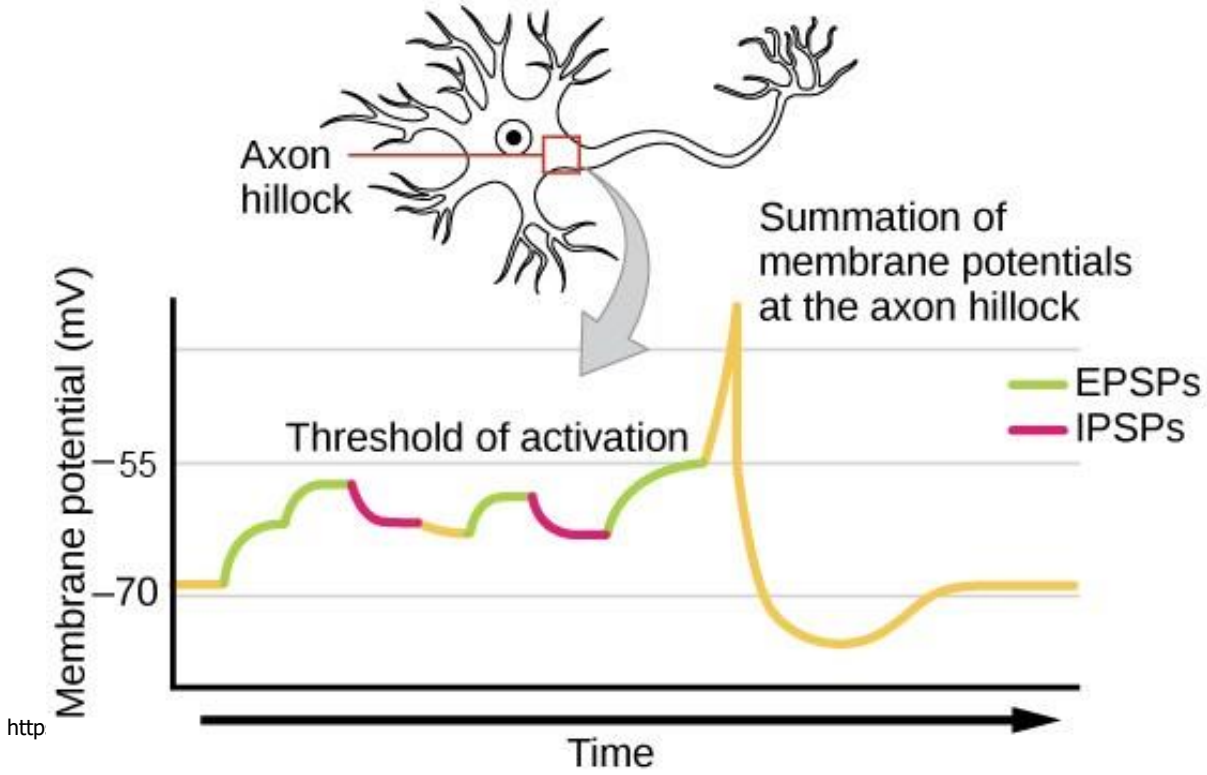
Signal summation



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

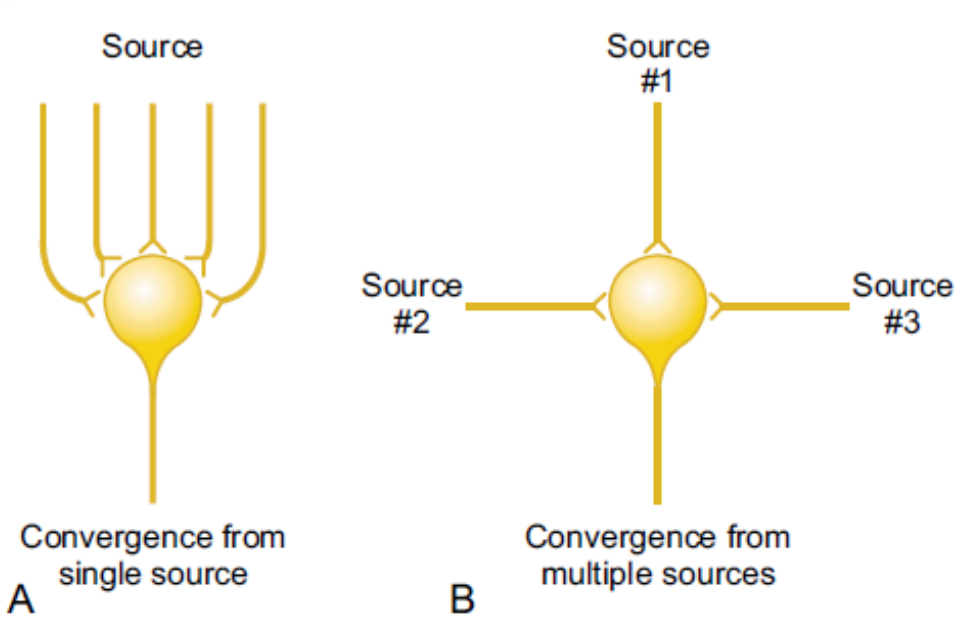

Figure 46–12

"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

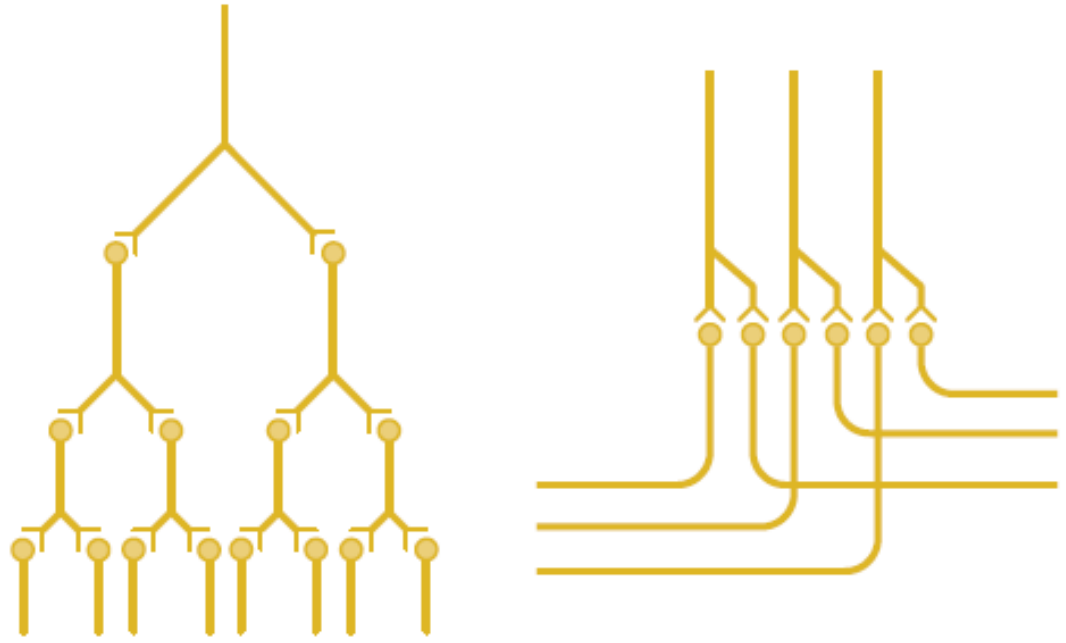

Figure 46–11

"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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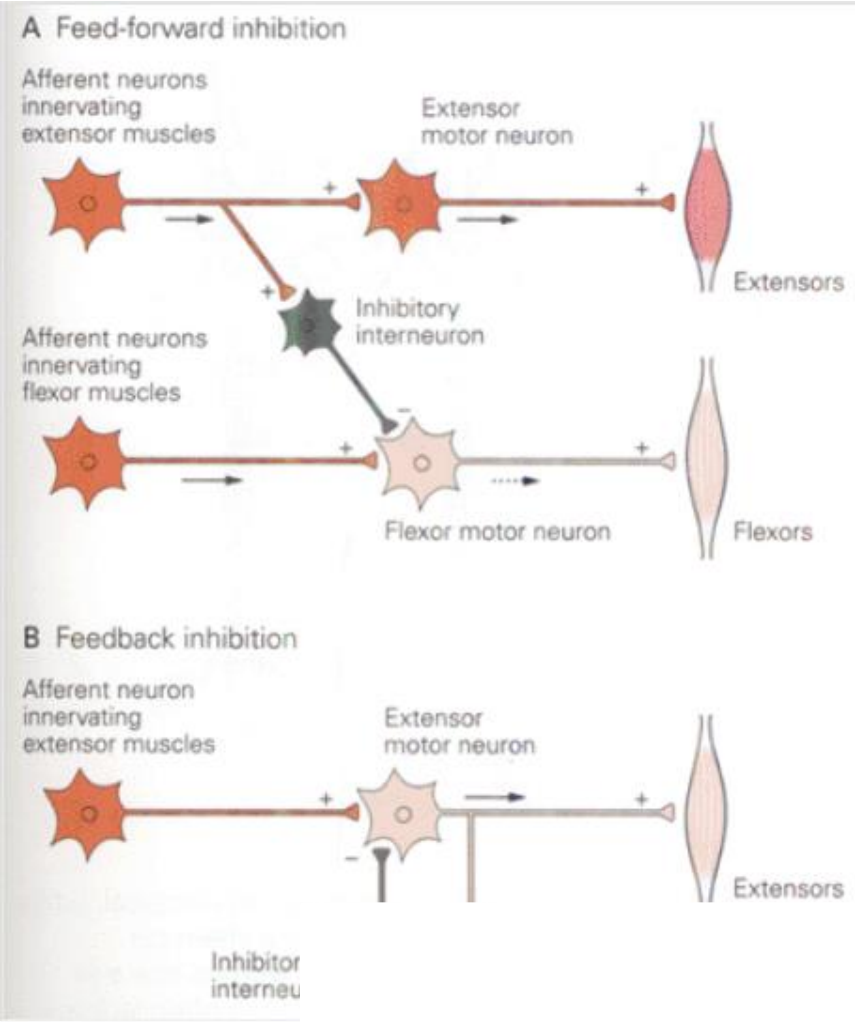
Networking



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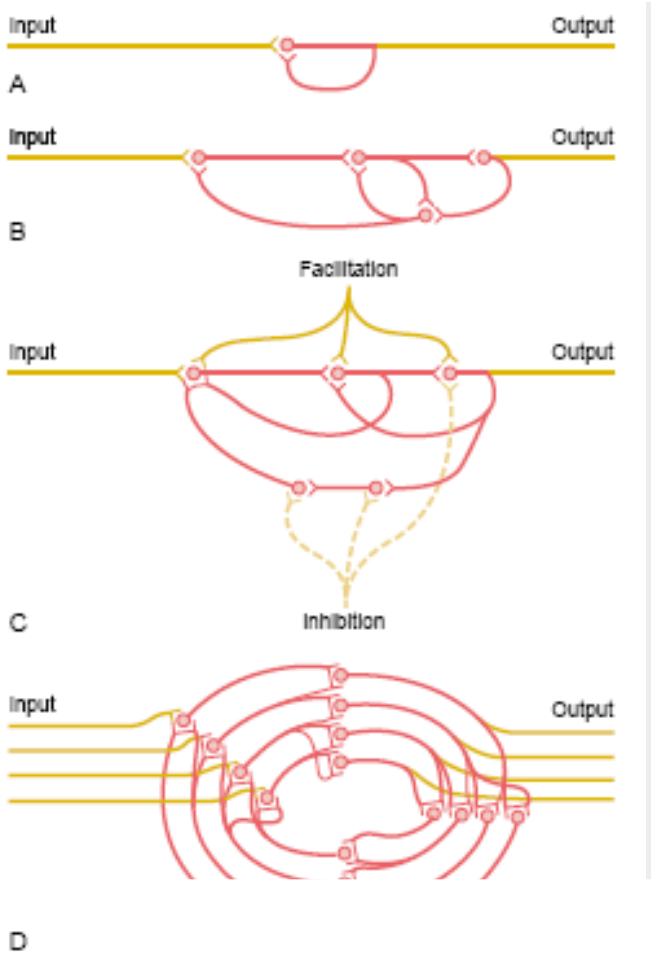
Networking



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Neurotransmission vs. Neuromodulation

- Information transmission

- Regulation of NS activity

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

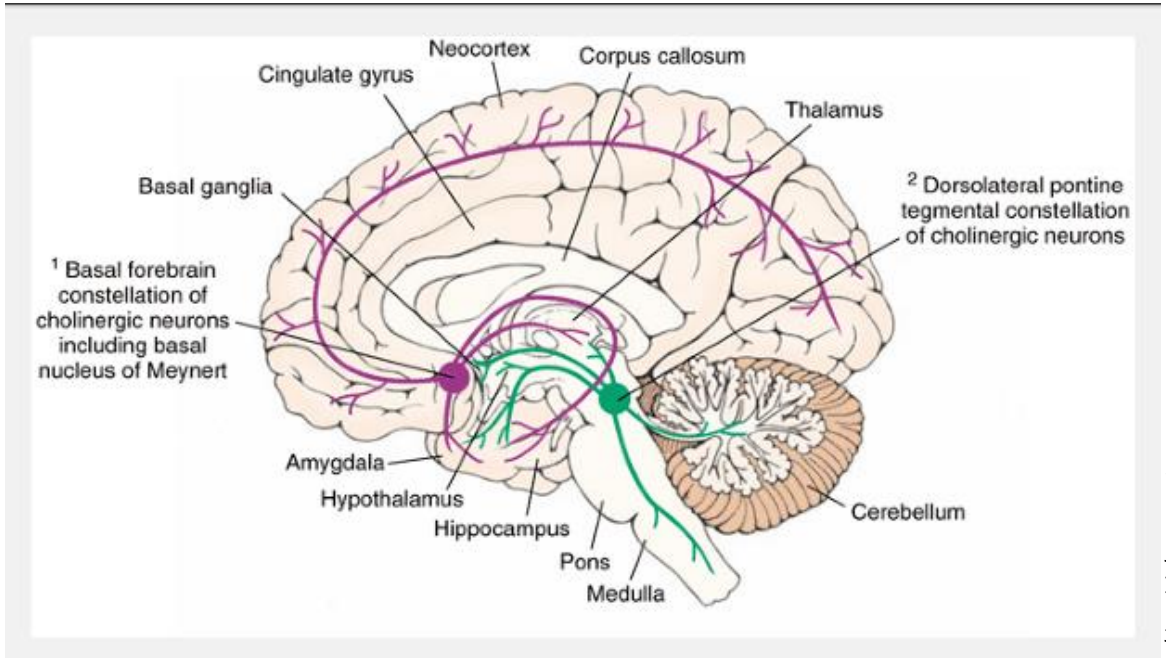
- Information transmission
- Specific
- Receptors – ion channels
- Short duration
  - membrane potential changes

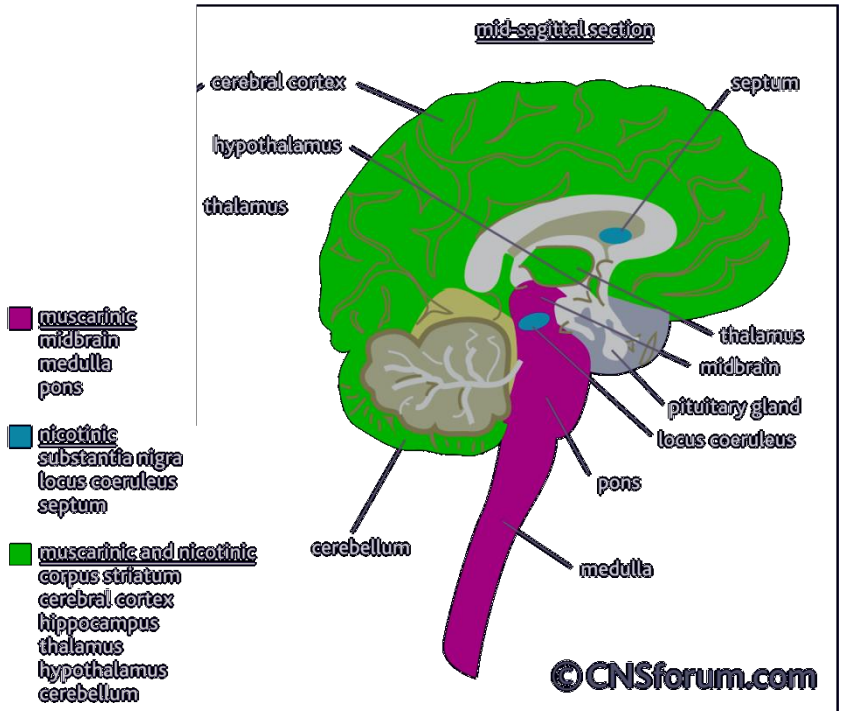
- Regulation of NS activity
- Diffuse (volume transmission)
- Receptors – G-proteins
- Longer duration
  - changes in synaptic properties

Acetylcholine

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

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





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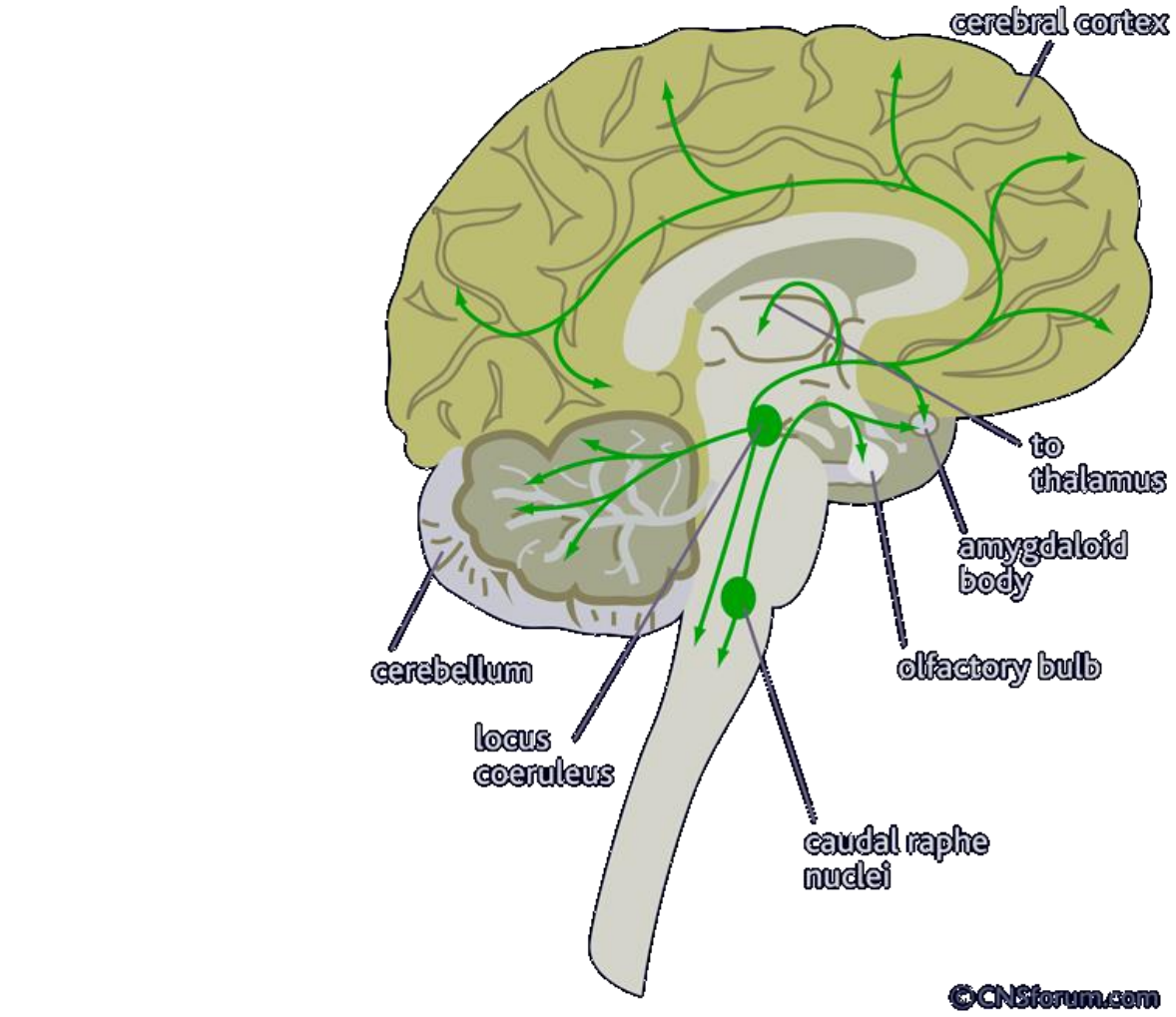
Noradrenalin

- Locus coeruleus
- Nuclei raphe caudalis

- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning



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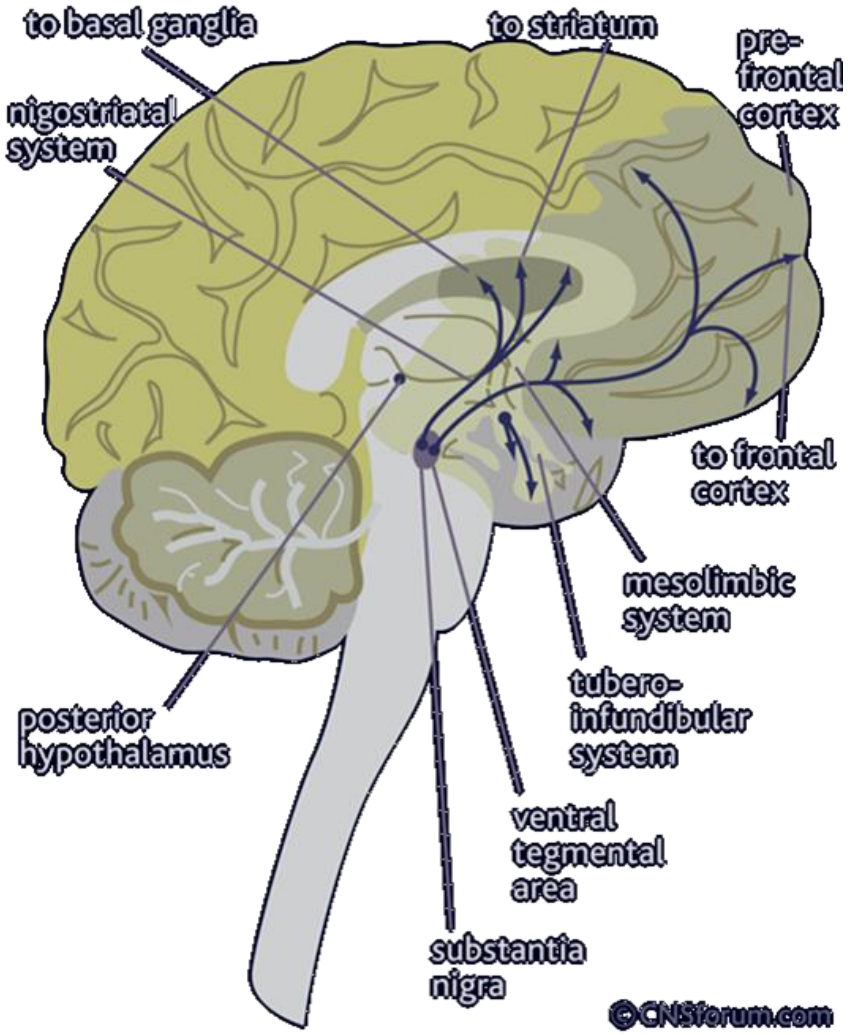
Dopamin

- 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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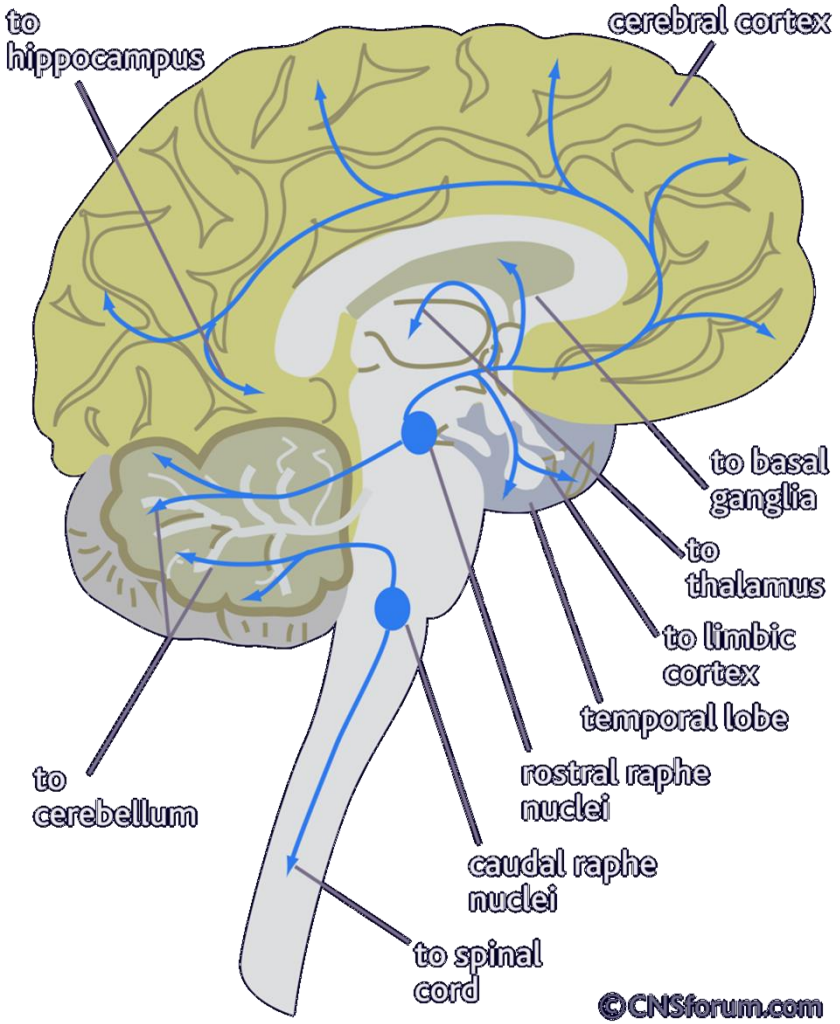
Serotonin

- Nuclei raphe rostralis
- Nuclei raphe caudalis

- Anxiety/relaxation
- Impulsive behavior
- Sleep



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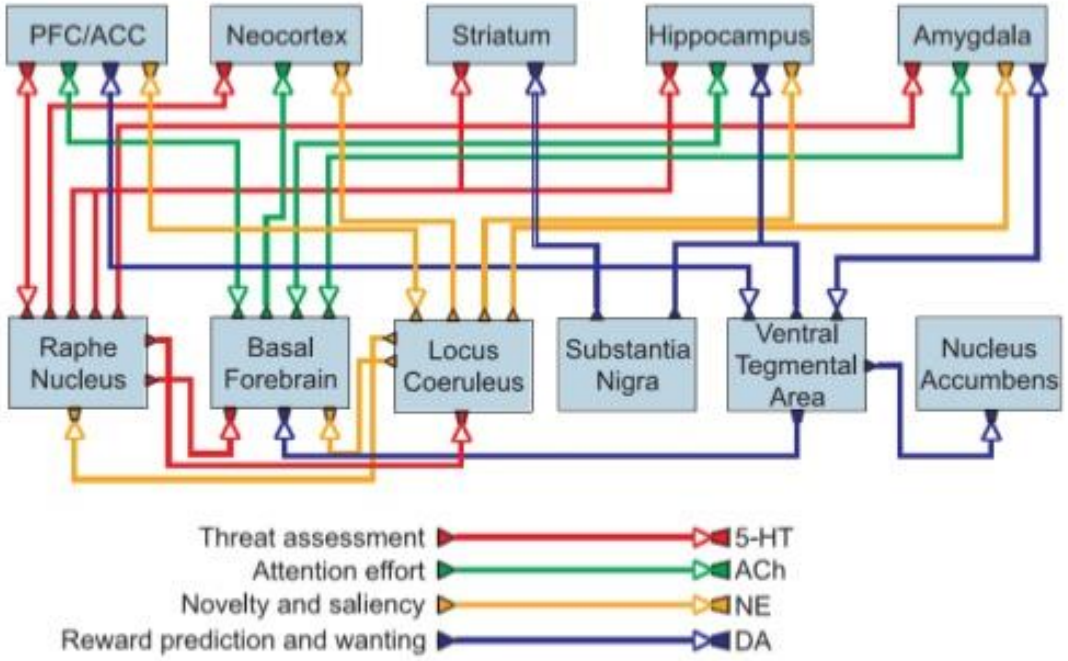
Neuromodulatory systems



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

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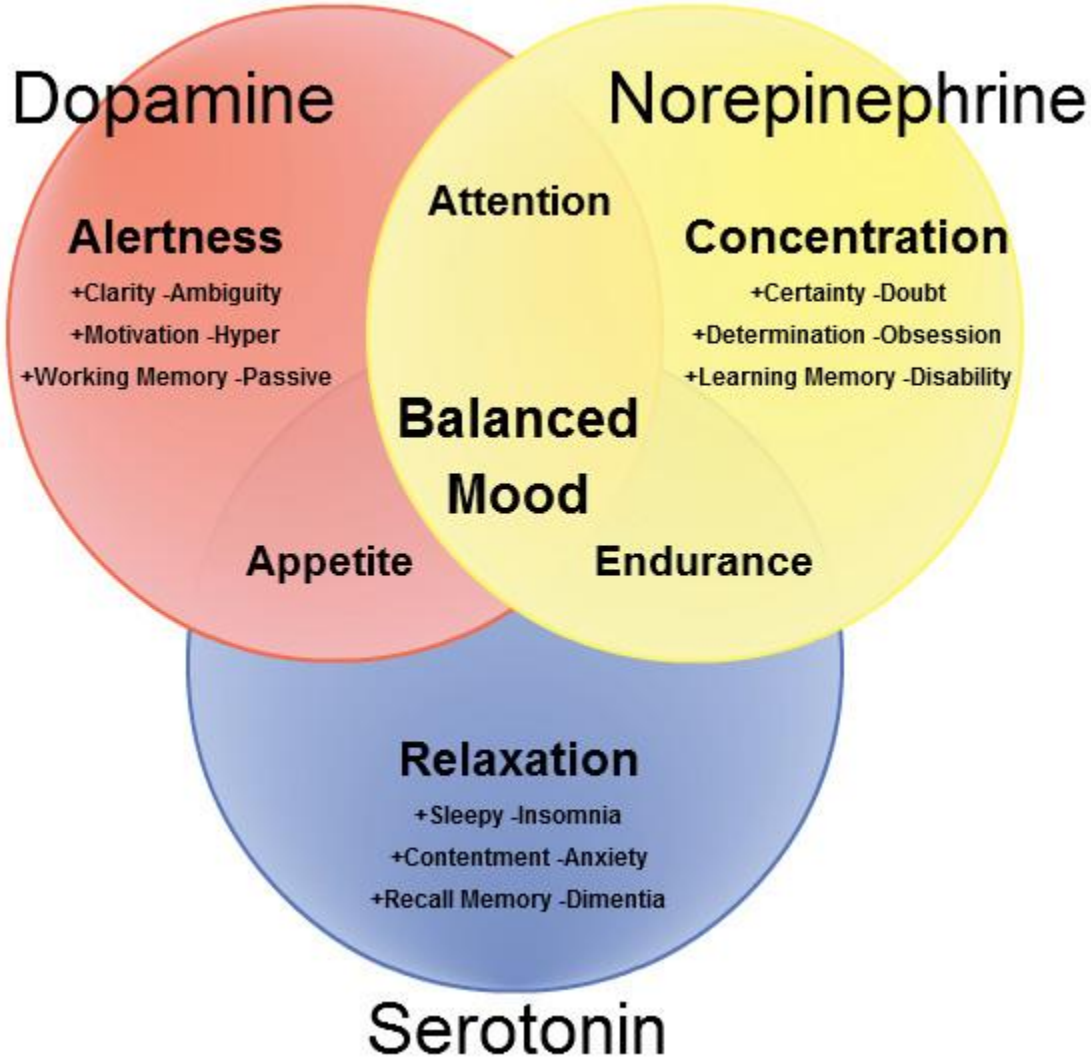
Neuromodulatory systems



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

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