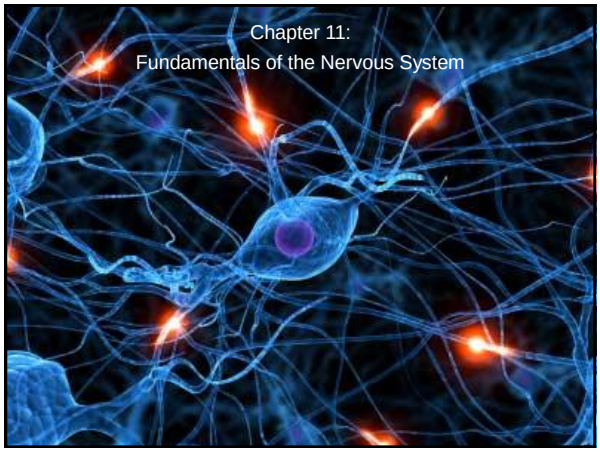
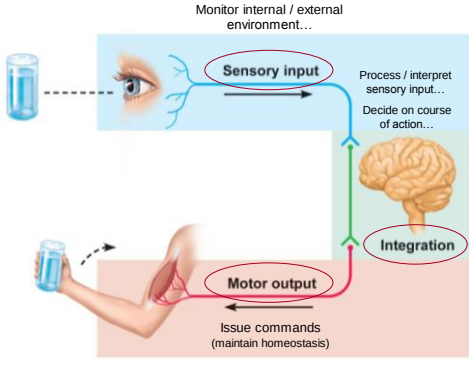
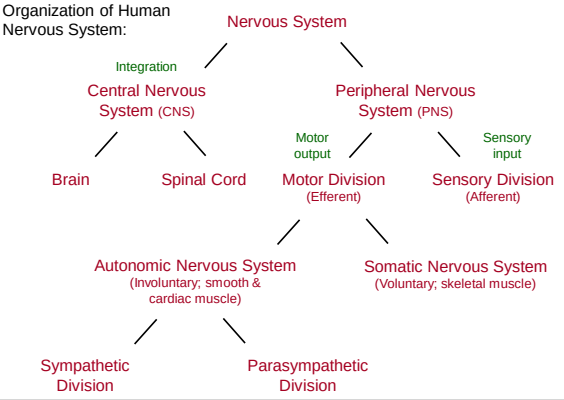


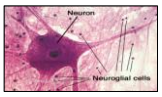
Functions of Nervous System:



Marieb & Hoehn – Figure 11.1

Organization of Human Nervous System:





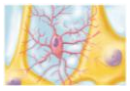
Histology of Nervous System:

A. Neuroglia (supporting cells – "nerve glue")

Central Nervous System (CNS)

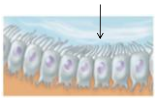
(most common)

Astrocytes:
- anchor neurons to capillaries
- repair damaged neural tissue
- maintain "blood / brain barrier"



Microglia:
- macrophages; engulf invaders

ciliated



Ependymal cells:
- line canals / ventricles of brain
- produce cerebrospinal fluid (CSF)

Oligodendrocytes:
- Insulate neurons (myelin sheath)

Peripheral Nervous System (PNS)

Schwann cells:
- Insulate neurons (myelin sheath)

Satellite cells:
- Function similar to astrocytes

Histology of Nervous System:

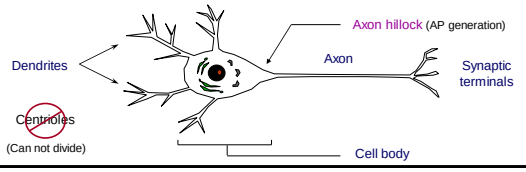
- Long-lived (~ 100 years)
- High metabolic rate

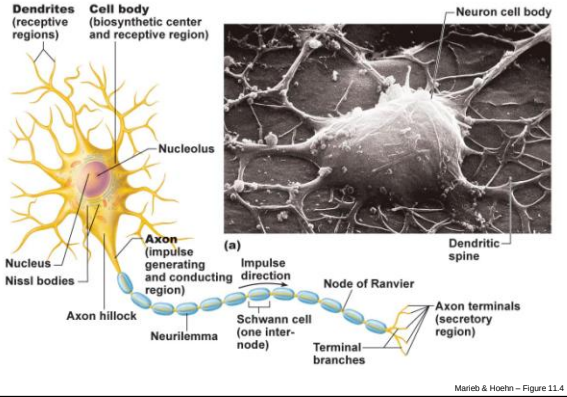
B. Neurons

- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

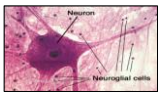
Neuron Anatomy:

1) Dendrites: Receive information (environment / other neurons)
2) Cell body (soma): Integrates information / initiate response
3) Axon: Conducts action potential (AP – electrical impulse)
4) Synaptic terminals: Transmit signal (other neurons / effector organs)





Marieb & Hoehn – Figure 11.4

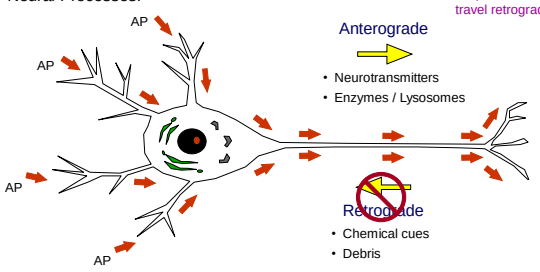


Histology of Nervous System:
- Long-lived (~ 100 years)
- High metabolic rate

B. Neurons
- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

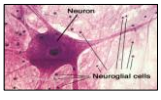
Neural Processes:

Action potentials never travel retrograde



- Neurotransmitters
- Enzymes / Lysosomes

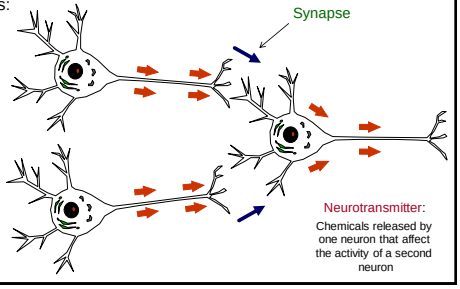
- Chemical cues
- Debris



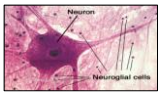
Histology of Nervous System:
- Long-lived (~ 100 years)
- High metabolic rate

B. Neurons
- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

Neural Processes:



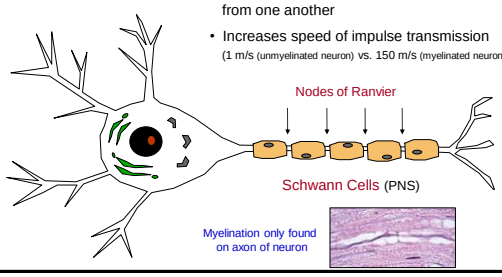
Neurotransmitter:
Chemicals released by one neuron that affect the activity of a second neuron

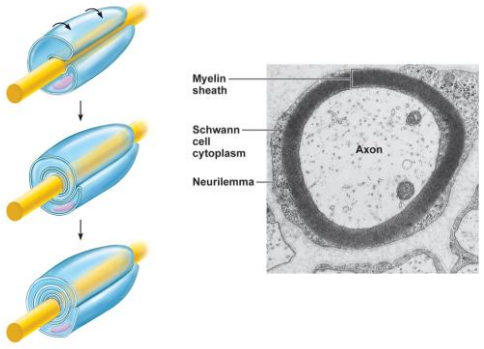


Histology of Nervous System:
- Long-lived (~ 100 years)
- High metabolic rate

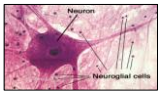
B. Neurons
- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

Myelination:
- Protects / electrically insulates neurons from one another
- Increases speed of impulse transmission
  (1 m/s (unmyelinated neuron) vs. 150 m/s (myelinated neuron))





Marieb & Hoehn – Figure 11.5



Histology of Nervous System:

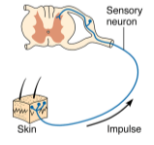
- Long-lived (~ 100 years)
- High metabolic rate

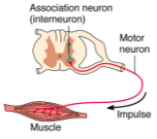
B. Neurons

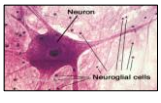
- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

Functional Classification of Neurons:

1) Sensory (Afferent) Neurons:
   - Carries information from sensory receptors to CNS
2) Motor (Efferent) Neurons:
   - Carries information from CNS to effector organs
3) Association Neurons (Interneurons):
   - Interconnects neurons in brain / spinal cord







Histology of Nervous System:

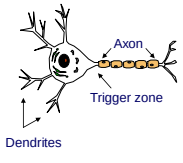
- Long-lived (~ 100 years)
- High metabolic rate

B. Neurons

- Specialized "excitable" cells
- Allow for communication throughout body (via electrical impulses)

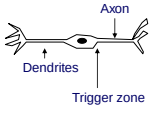
Structural Classification of Neurons (# of processes):

Multipolar
(≥ 3 processes)



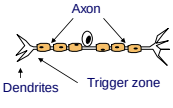
- Motor neurons
- Interneurons

Bipolar
(2 processes)



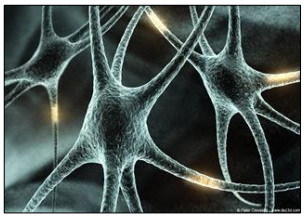
- Sensory neurons (e.g., special sense organs)

Unipolar
(1 process)



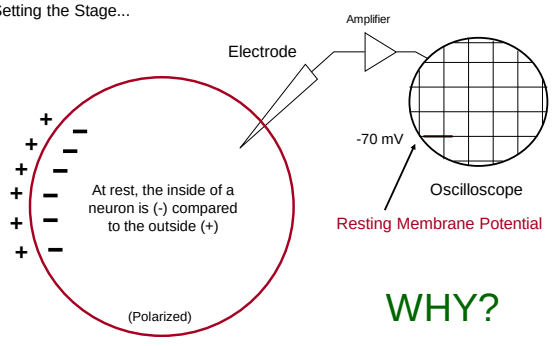
- Sensory neurons (PNS)

Neurons are highly *irritable*



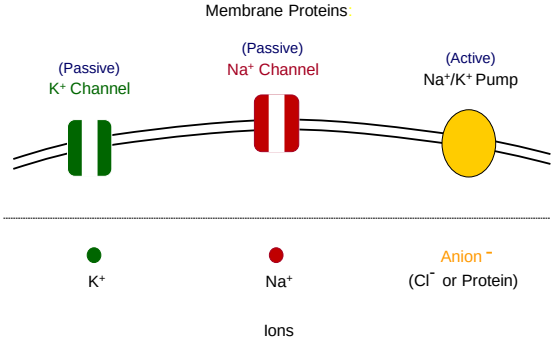
If adequately stimulated, an electrical impulse (action potential) is conducted along the axon...

Setting the Stage...



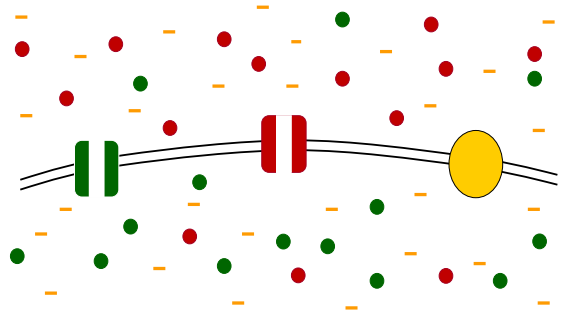
WHY?

Resting Membrane Potential:



Resting Membrane Potential:

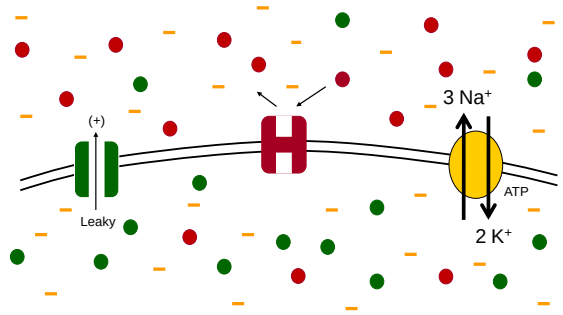
>> Na^+ outside



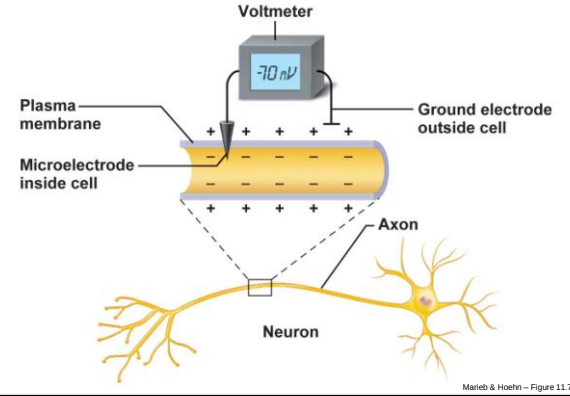
>> K^+ inside

In the beginning... Charge equal across membrane

Resting Membrane Potential:



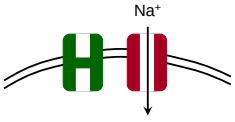
Net effect: More (+) ions move out than in (neg. charge develops inside cell)

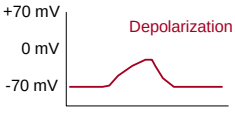


Neurons use changes in membrane potential to communicate:

- Stimulus opens ion gates:

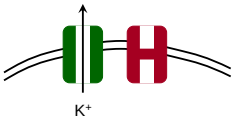
1) Open Na^+ gates

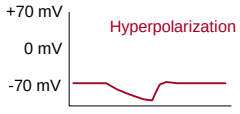




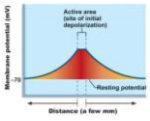
- Inside becomes less negative

2) Open K^+ gates





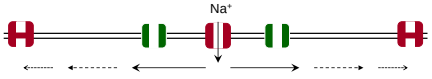
- Inside becomes more negative



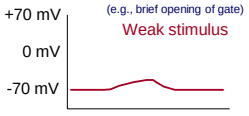
Types of Signals used by Neurons:

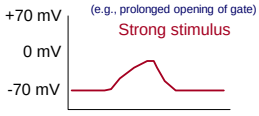
1) Graded Potentials (Short-range communication)

- Local changes in membrane potential (limited range)



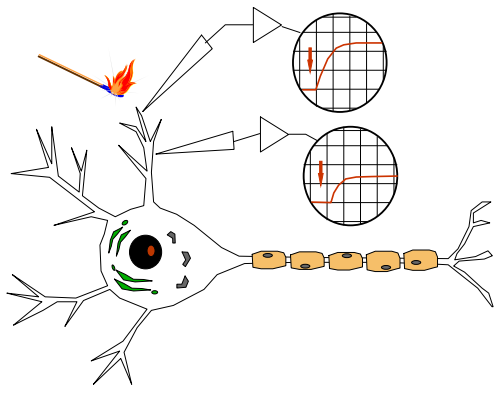
- Magnitude of potential depends on stimulus strength





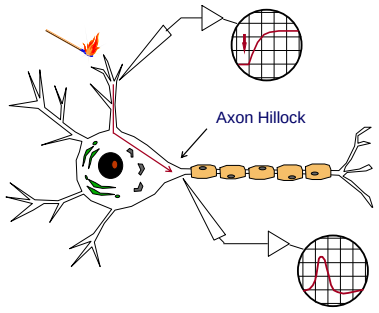
- Magnitude of potential decreases with distance from source

Marieb & Hoehn – Figure 11.10



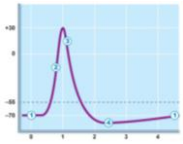
Types of Signals used by Neurons:

1) Graded Potentials (Short-range communication)
   - Graded potentials initiate action potentials



Types of Signals used by Neurons:

2) Action Potentials (Long-range communication)
   - Short-lived, self-propagating depolarization event
   - Occurs only along axon of neuron (or muscle sarcolemma)
   - Magnitude of signal independent of signal strength (all-or-none principle)

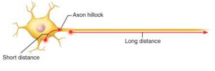


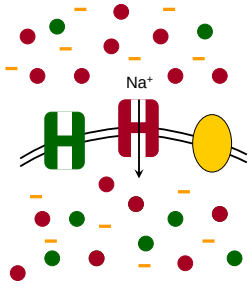
Cell interior goes from (-) to (+)

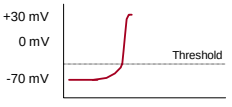
Marieb & Hoehn – Figure 11.11

Types of Signals used by Neurons:

2) Action Potentials (Long-range communication)
   - Action Potential Events:

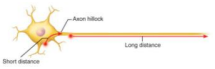






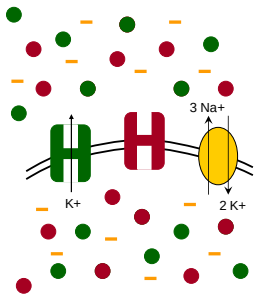
1) Graded potential (depolarization) reaches axon hillock
2) Event reaches threshold; Na^+ gates open (voltage-gated)
   - Positive feedback cycle (all-or-none event)
3) Membrane reverses polarity; Na^+ gates close (~ +30 mV)

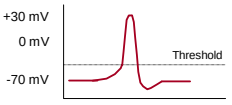
Types of Signals used by Neurons:



2) Action Potentials (Long-range communication)

- Action Potential Events:

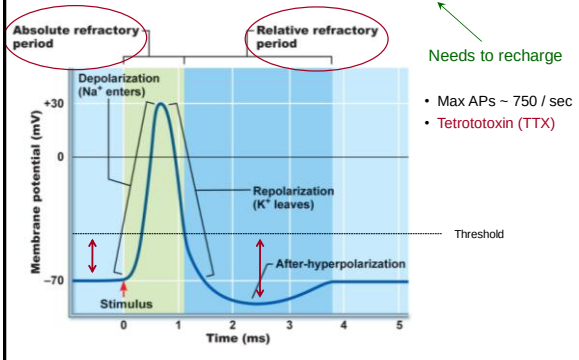




4) K^+ gates open (voltage gated); cell repolarizes

5) Cell returns to resting membrane potential
   - Na^+ / K^+ pumps re-establish solute concentrations

Refractory Period: Cell can not fire additional APs...



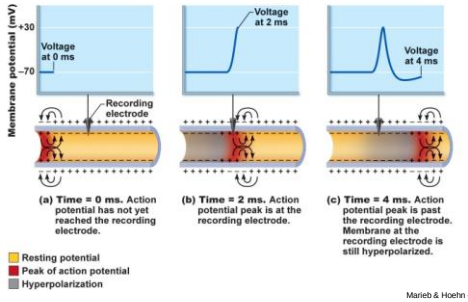
Needs to recharge

- Max APs ~ 750 / sec
- Tetrototoxin (TTX)

Marieb & Hoehn – Figure 11.14

How Does an Action Potential Move Down an Axon?

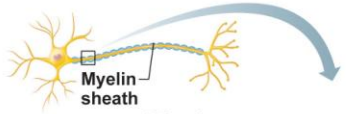
1) Continuous Conduction (unmyelinated axons)
   - Chain-reaction along membrane of axon (slow – 10 m/s)

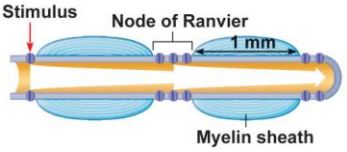


Marieb & Hoehn – Figure 11.12

How Does an Action Potential Move Down an Axon?

2) Saltatory Conduction (myelinated axons)
   - Action potential jumps from node to node (fast – 150 m/s)





Demyelination:
- Loss of myelination
- Multiple Sclerosis

Marieb & Hoehn – Figure 11.15

Coding for Stimulus Intensity:

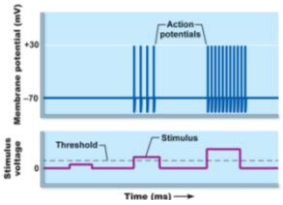
Remember:

Magnitude of signal is independent of signal strength
(signal fixed → all-or-none)

However:

Rate is not fixed

↑ AP frequency = ↑ stimulus
(the stronger the stimulus, the more AP's per second)



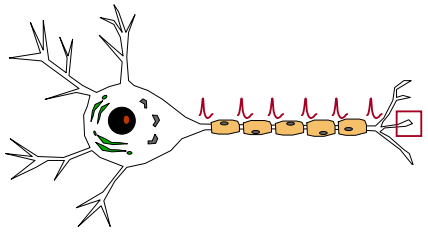
Marieb & Hoehn – Figure 11.13

How Do Neurons Communicate Together?

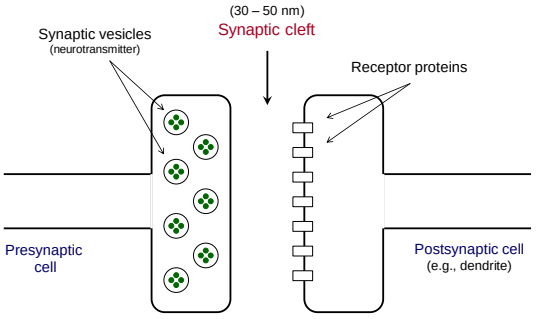
Synapse: Functional point of contact between two neurons or between a neuron and an effector cell

Electrical Synapse:
Gap junctions connect cells allowing for direct transfer of ions

Chemical Synapse:
Neuotransmitters (chemicals) mediate signal transfer (unidirectional…)

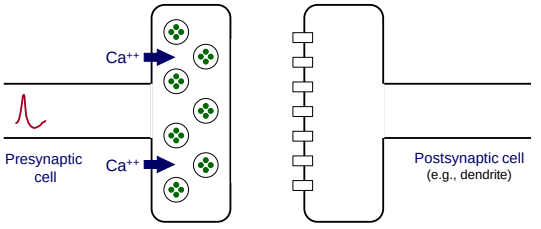


Events at a Chemical Synapse:



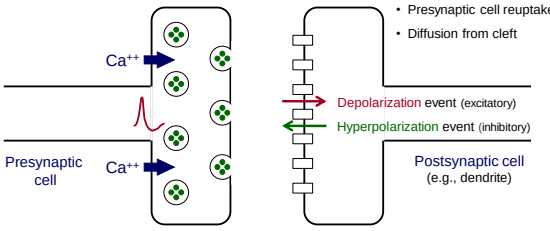
Events at a Chemical Synapse:

1) Action potential arrives at synaptic terminal
2) Ca^{++} voltage gates open; Ca^{++} enters cell
3) Synaptic vesicles fuse with plasma membrane



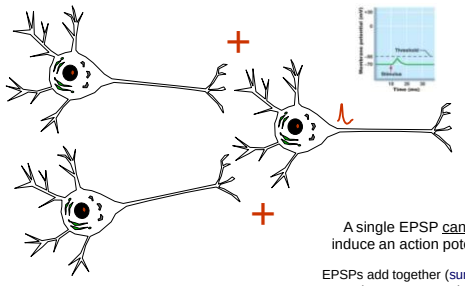
Events at a Chemical Synapse:

1) Action potential arrives at synaptic terminal
2) Ca^{++} voltage gates open; Ca^{++} enters cell
3) Synaptic vesicles fuse with plasma membrane
3) Neurotransmitter released into synaptic cleft (exocytosis)
4) Neurotransmitter binds with postsynaptic receptors
5) Neurotransmitter removal
   - Enzyme degradation
   - Presynaptic cell reuptake
   - Diffusion from cleft



Neuron activity depends on a balance of excitatory and inhibitory input:

EPSP
(Excitatory Postsynaptic Potential)

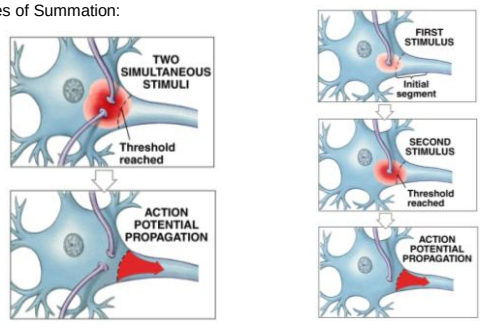


A single EPSP cannot induce an action potential

EPSPs add together (summate) to trigger postsynaptic cell

Marieb & Hoehn – Figure 11.18

Types of Summation:

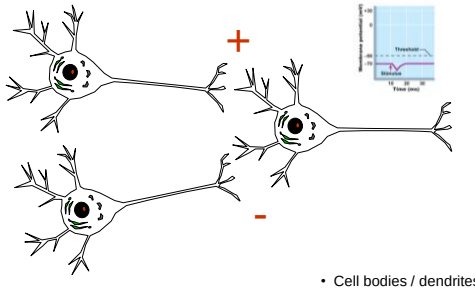


Spatial Summation:
Simultaneous stimulation from separate synapses

Temporal Summation:
Repeated stimulation from a single synapse

Neuron activity depends on a balance of excitatory and inhibitory input:

IPSP
(Inhibitory Postsynaptic Potential)

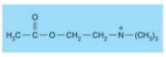


- Cell bodies / dendrites may have > 10,000 connections

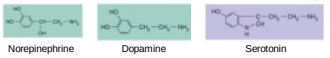
Marieb & Hoehn – Figure 11.18

At present,
~ 50 neurotransmitters
identified

Types of Neurotransmitters (based on structure):

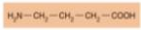


1) Acetylcholine
- Widespread in system
  - CNS / PNS
  - Neuromuscular junction



Norepinephrine Dopamine Serotonin

2) Biogenic Amines (amino-acid derivatives)
- Broadly distributed in brain
- Emotional behavior ("feel good" effects)



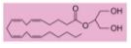
GABA (gamma-aminobutyric acid)

3) Amino Acids
- Located primarily in CNS
- Inhibitory effect

Endorphins

4) Peptides
- Located primarily in CNS

Endorphins: Natural opiates
Substance P: Pain mediator



Endocannabinoid

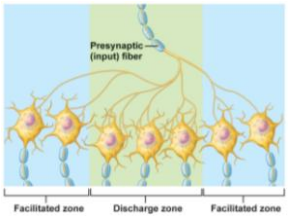
5) Gases / Lipids
- Located in CNS / PNS

Nitric Oxide(NO): Muscle relaxation
Endocannabinoid: Memory

Basic Concepts of Neural Integration:

Neuronal Pool: Group of association neurons (interneurons) that perform a specific function (may be localized or diffuse…)

- Output may: 1) stimulate / depress other pools
  2) affect interpretation of sensory input
  3) directly control motor output



Marieb & Hoehn – Figure 11.21

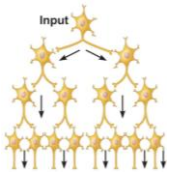
Discharge Zone:
Portion of neuronal pool most likely to respond to direct input

Facilitated Zone:
Portion of neuronal pool that requires additional input from other sources before adequately stimulated

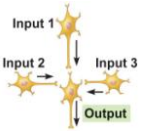
Basic Concepts of Neural Integration:

Determine the neuronal pool's functional capabilities

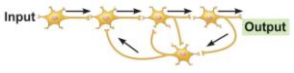
Circuit: Pattern of synaptic connections in a neuronal pool



Diverging Circuit
(1 neuron → > 1 neurons)
Amplifies signal
(e.g., motor output)



Converging Circuit
(> 1 neuron → 1 neurons)
Concentrates signal
(e.g., sensory input)



Reverberating Circuit
(1 neuron → 1 neurons)
(positive feedback)

Prolongs signal
(e.g., repetition activity)

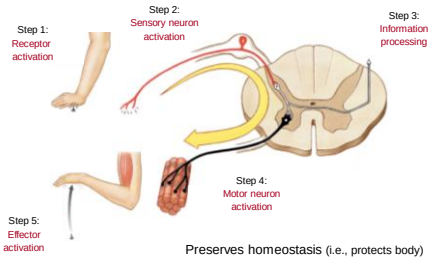
Marieb & Hoehn – Figure 11.22

Patterns of Neural Processing:

1) Serial Processing: Step-wise passing of information through various neurons / neuronal pools

Reflex:

Rapid, automatic response to specific stimuli



Preserves homeostasis (i.e., protects body)

Patterns of Neural Processing:

2) Parallel Processing: Simultaneous processing of information through multiple neurons / neuronal pools