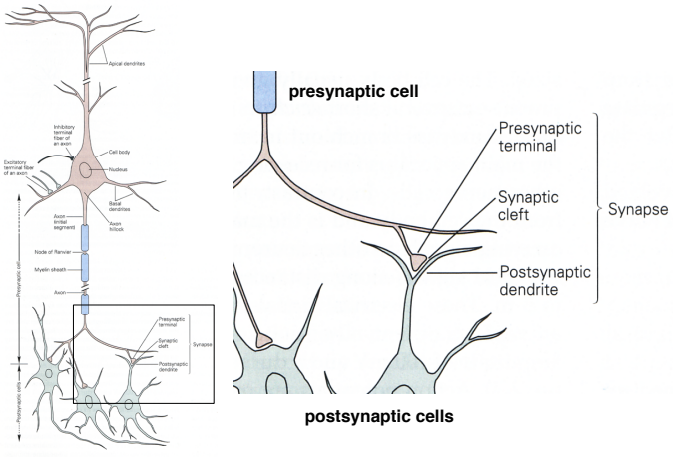
Neuron: Synapse



https://www.youtube.com/watch?v=Dd9vsZEFz1s

Chemical and Electrical Synapses

1. Electrical Synapse

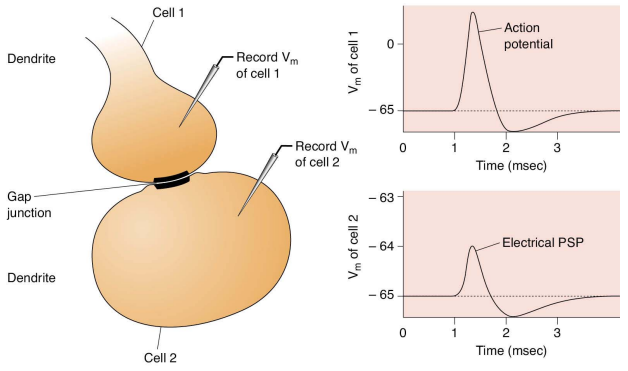
Continuous cytoplasm through gap junction channels.

Electrical transmission by ion currents moving through gap junction channels.

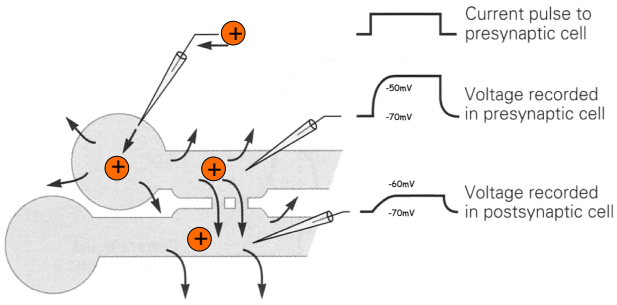
Properties:

No delay in AP moving between cells;

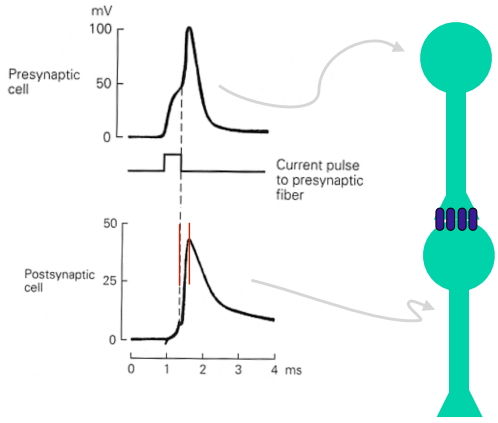
bidirectional transmission.

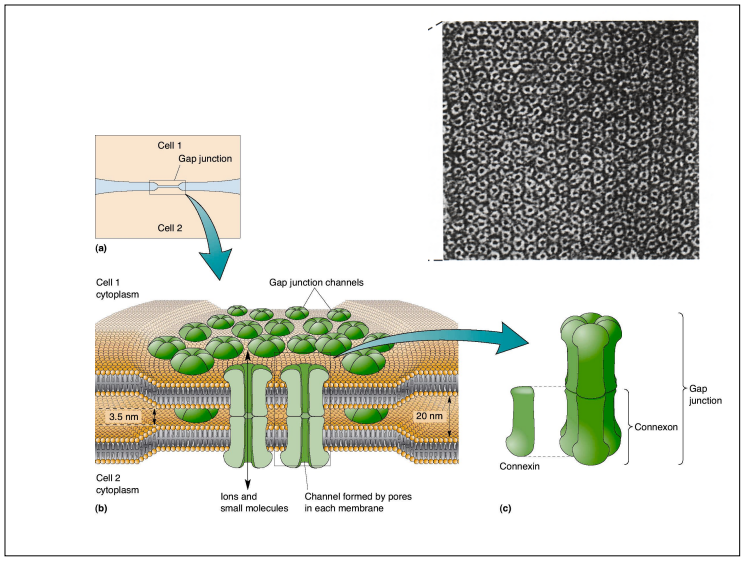


Current flows easily thru Gap Junctions

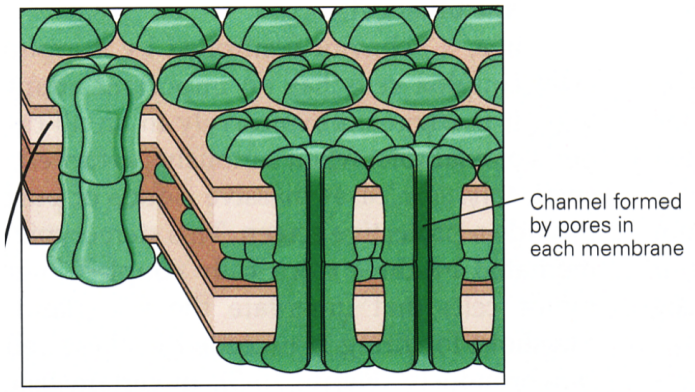


AP crosses Electrical Synapse instantly

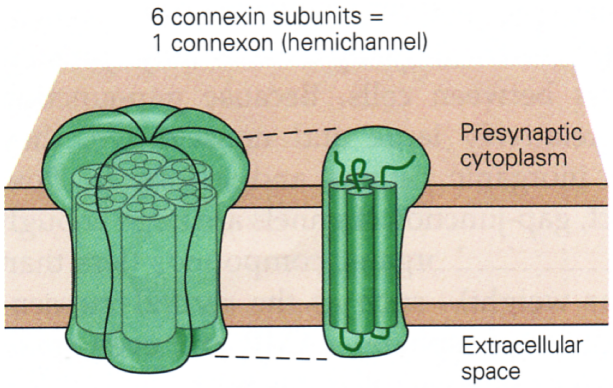




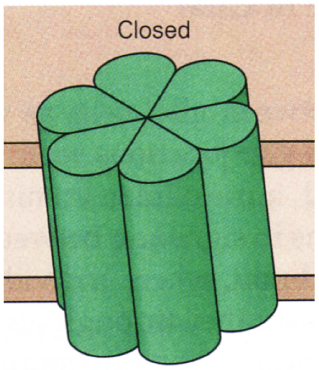
Gap Junction channels



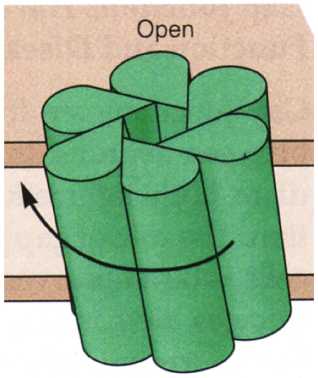
Connexon and Connexin subunits



Opening Connexon



Opening Connexon



Chemical and Electrical Synapses

2. Chemical Synapse

Discontinuous space between the cells.

Synapses contains presynaptic **vesicles**, postsynaptic **receptors**.

Signal is transmitted across the synapse by chemical molecules (not ions) = **neurotransmitters**.

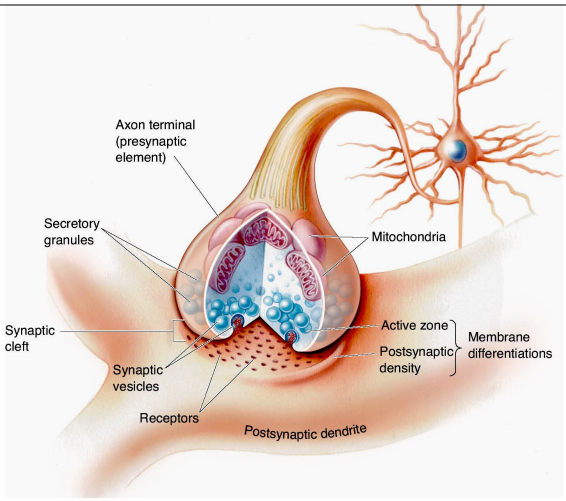
(There are many different neurotransmitters, and many different receptor types.)

Properties: 1-5 ms **delay** between cells; unidirectional transmission.

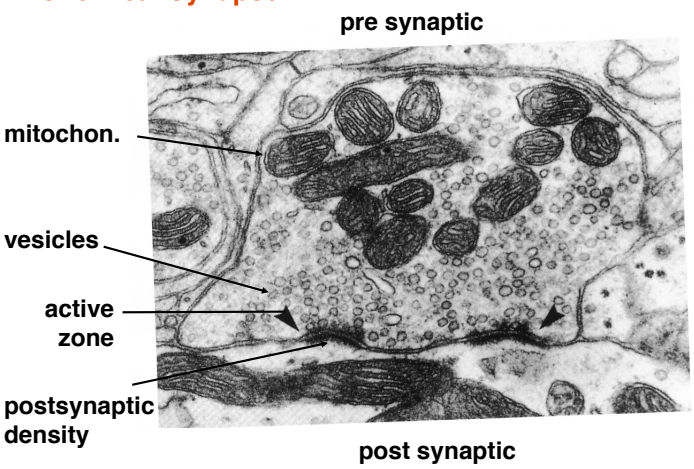
Chemical synapse can be excitatory or inhibitory

Excitatory: raise Vm closer to threshold for AP (depolarize target cell)

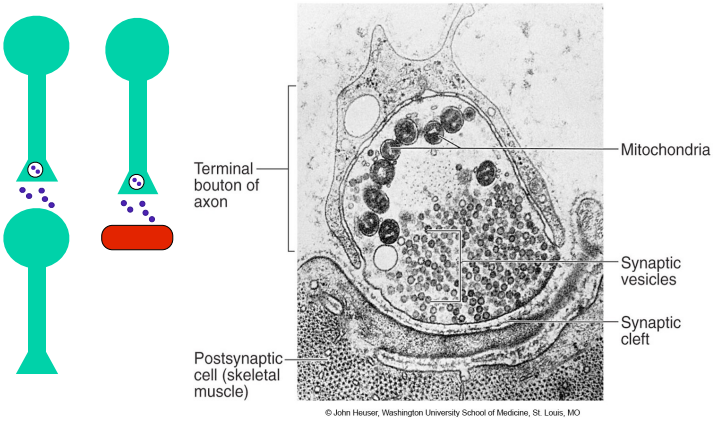
Inhibitory: lower Vm away from threshold (hyperpolarize target cell).



Chemical Synapse



Chemical Synapse



Fox Figure 7.22

Chemical Synapse

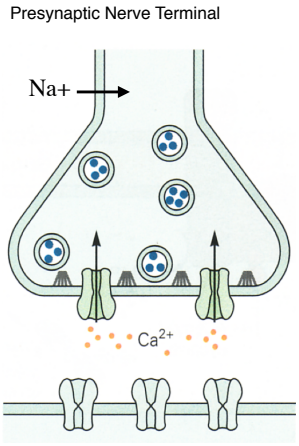
Ca2+ induced release of Neurotransmitter

1. Action potential causes voltage sensitive Ca2+ channels to open; Ca^{2+} enters the presynaptic nerve terminal.
2. Ca^{2+} causes vesicles to fuse with presynaptic membrane; neurotransmitter molecules are released into the synapse by exocytosis.
3. Neurotransmitter binds to receptors on postsynaptic cell; if receptors are ligand-gated Na^+ channels, then Na^+ enters postsynaptic cell.
4. Influx of Na^+ causes depolarization of target cell.

(if Cl^- channels are opened, then neurotransmitter lowers V_m and thus has inhibitory effect)

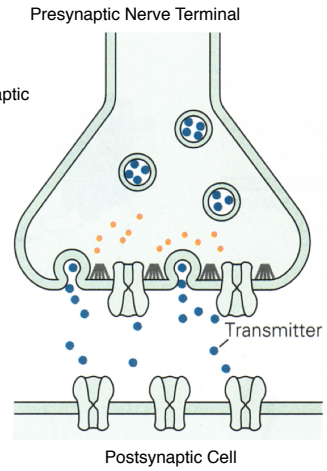
Chemical Synapse

1. Action potential causes voltage sensitive Ca2+ channels to open; Ca^{2+} enters the presynaptic nerve terminal



Chemical Synapse

2. Ca^{2+} causes vesicles to fuse with presynaptic membrane; neurotransmitter molecules are released into the synapse by exocytosis.

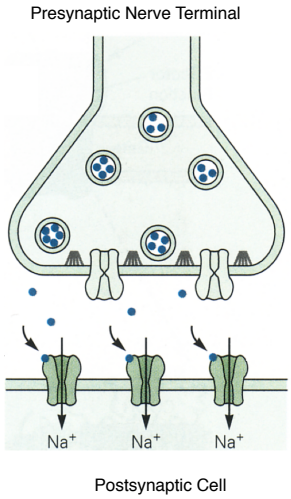


Chemical Synapse

3. Neurotransmitter binds to receptors on postsynaptic cell; if receptors are ligand-gated Na^+ channels, then Na^+ enters postsynaptic cell

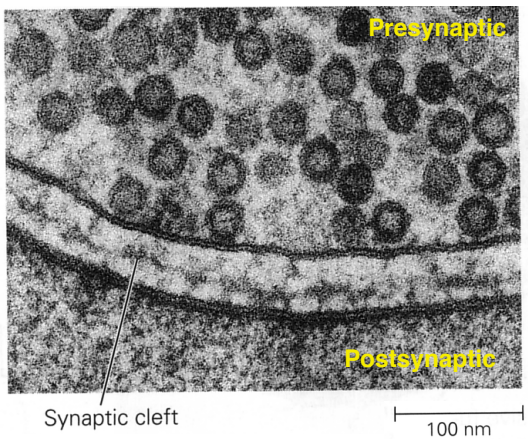
4. Influx of Na^+ causes depolarization of target cell

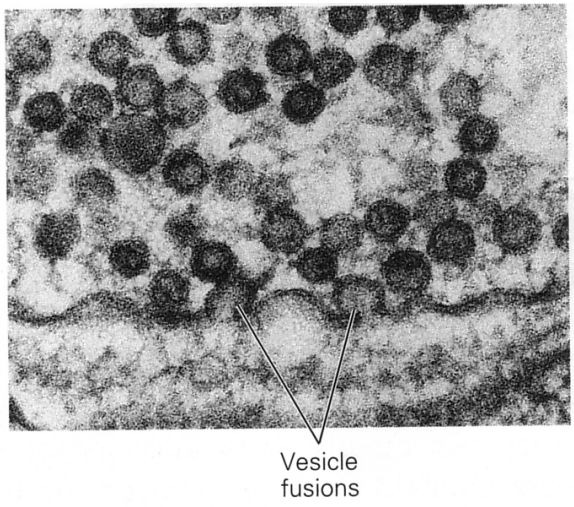
(if Cl^- channels are opened, then neurotransmitter lowers V_m and has inhibitory effect)

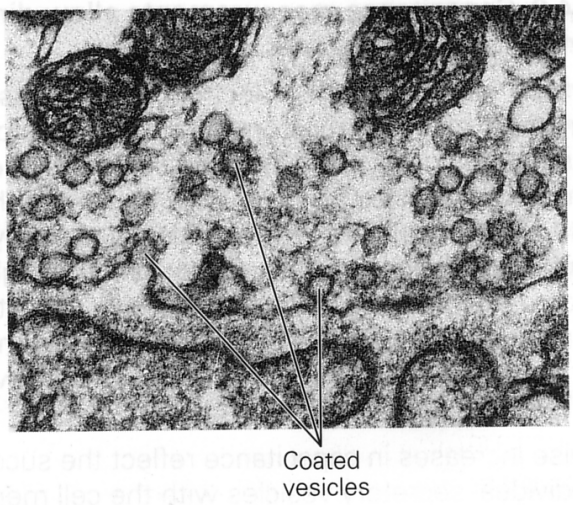


Presynaptic Membrane

(thin section with electron microscope)

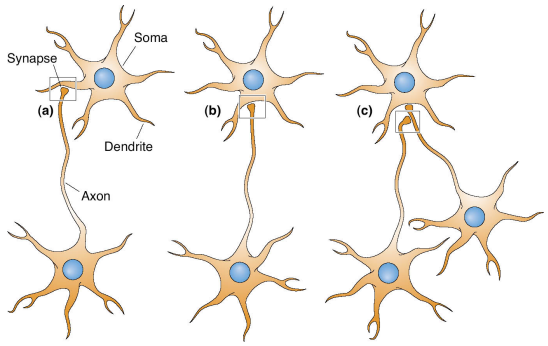






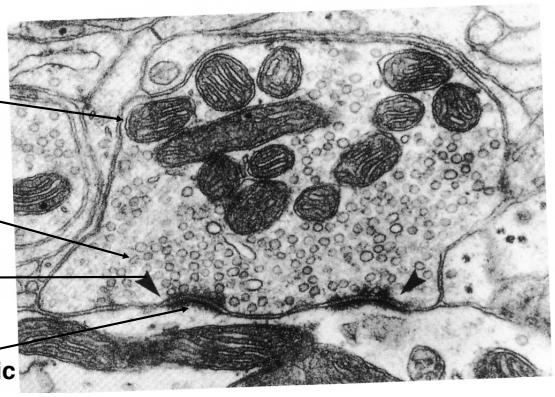
Types of synapses

from/to	Axon	dendrite	soma
Axon	axoaxonix	axodendritic	axosomatic
Dendrite	dendroaxonic	dendrodendritic	dendrosomatic



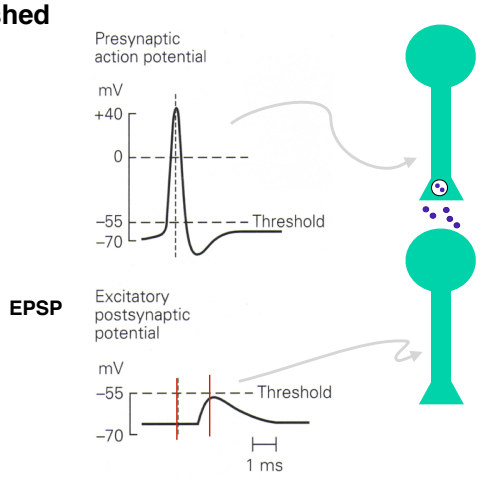
Chemical Synapse

pre synaptic



post synaptic

AP crosses Chemical Synapse slowly and is diminished



Integration and Summation by Neurons

Neurotransmitter-gated receptor ion channels
Neurotransmitter binds to receptor channel, causing the channel to open and let ions flow into the target cell.

(There are many different neurotransmitters, and many different receptor types.)

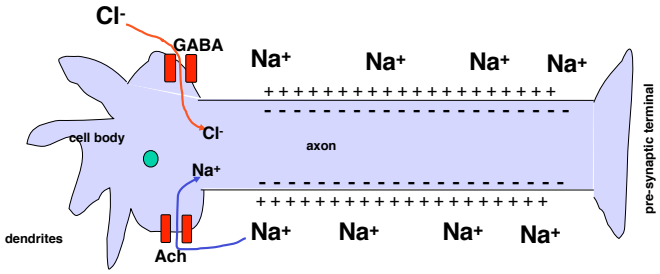
Receptor channel could be Na^+ channel or Cl^- channel
Influx of Na^+ raises V_m = exictatory postsynaptic potential (**EPSP**)
Influx of Cl^- lowers V_m = inhibitory postsynaptic potential (**IPSP**)

Summation
If multiple epsp's combine to raise V_m above threshold for action potential, then neuron will fire an action potential.

If IPSPs combine with EPSPs, then lower V_m due to ipsp will cancel out epsp's, and action potentials will be inhibited.

A neuron integrates excitatory and inhibitory inputs to produce a subtle pattern of firing that reflects multiple influences

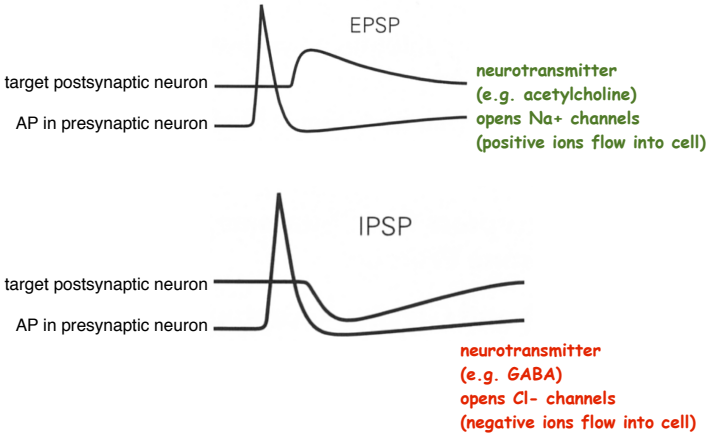
Membrane Potential of Neuron



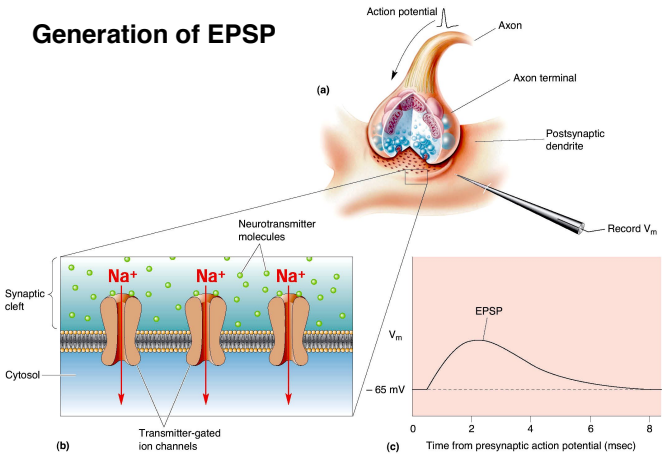
Excitatory Neurotransmitters cause Na^+ channels to open and let Na^+ into the neuron (making inside positive).

Inhibitory Neurotransmitters let Cl^- into the neuron (make inside even more negative).

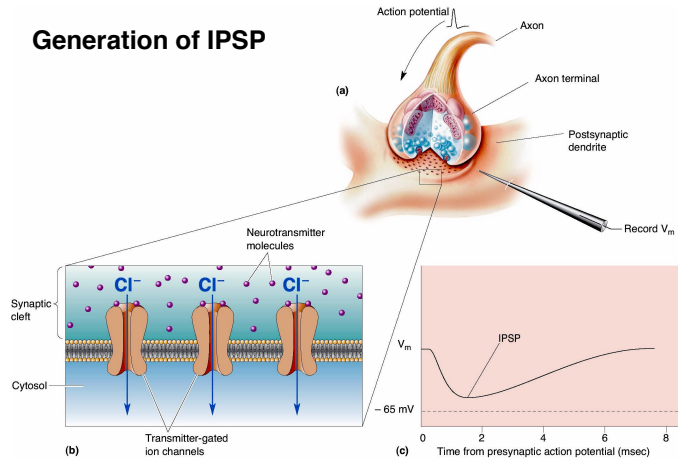
EPSP and IPSP:
Excitatory and Inhibitory postsynaptic potentials



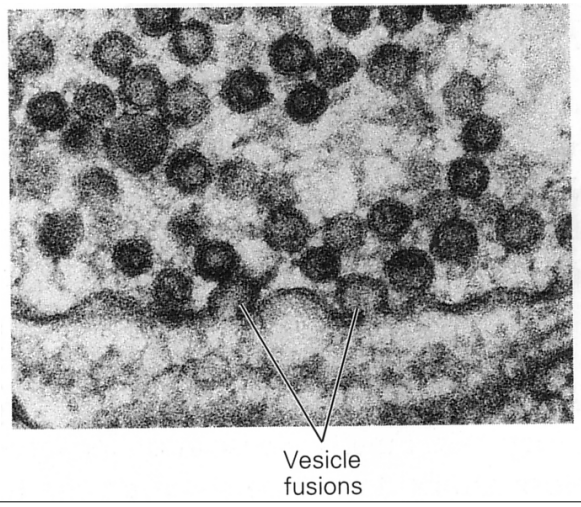
Generation of EPSP



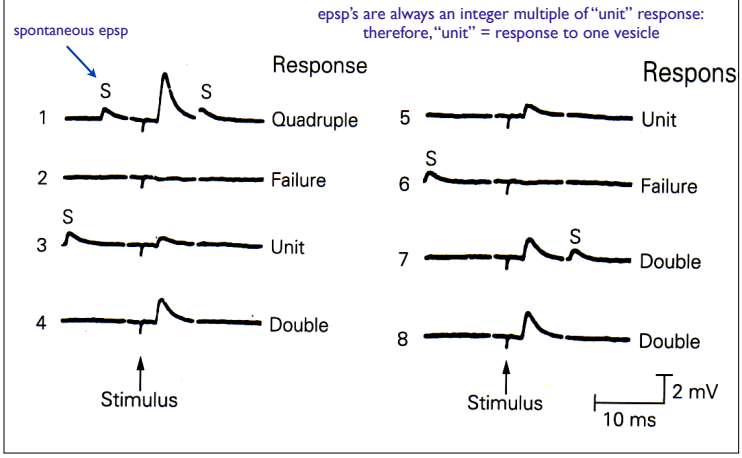
Generation of IPSP



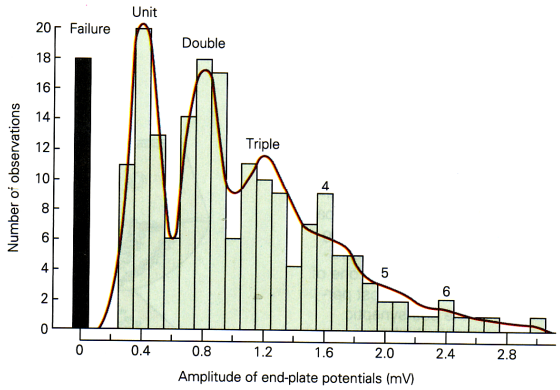
One vesicle = one quantum of neurotransmitter



Listen to noise of spontaneous and mini excitatory postsynaptic potentials (epsp's)



Histogram of size of Postsynaptic Responses



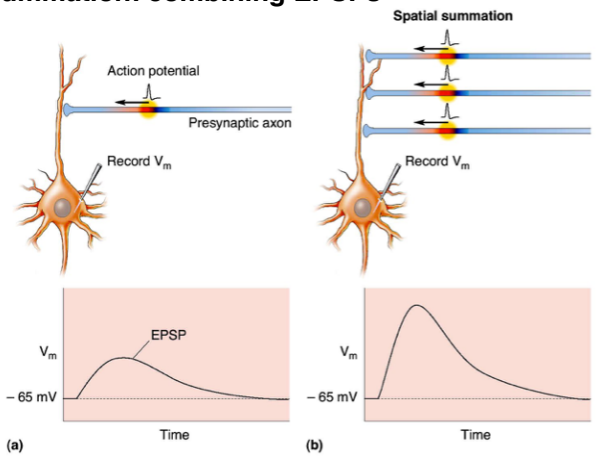
Summation

Multiple excitatory inputs combine to generate big enough epsp to cause AP

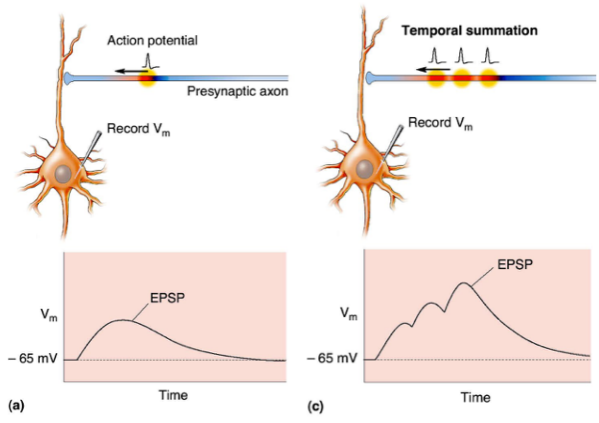
1. Temporal - one input, adds epsp multiple times

2. Spatial - multiple inputs at different synapses that summate at same time

Summation: combining EPSPs

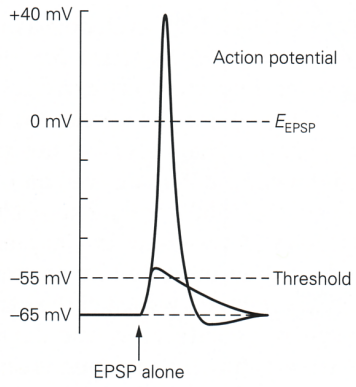


Summation: combining EPSPs



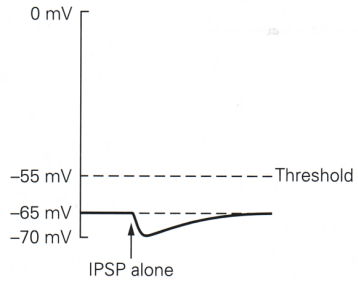
Summation: Combining EPSPs and IPSPs

EPSP alone



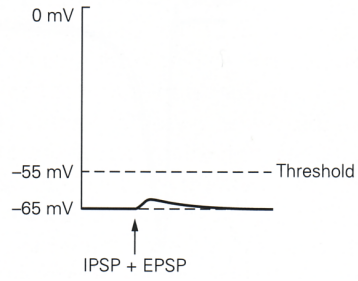
Summation: Combining EPSPs and IPSPs

IPSP alone

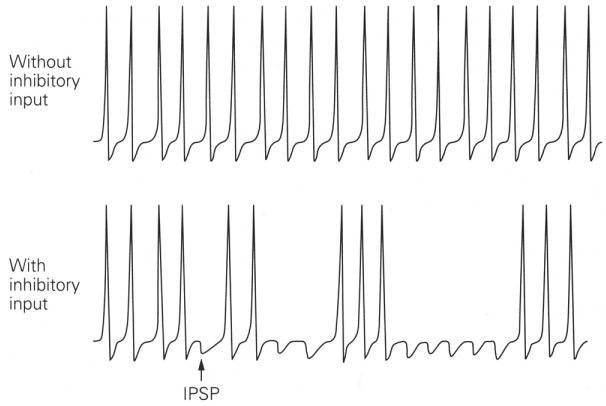


Summation: Combining EPSPs and IPSPs

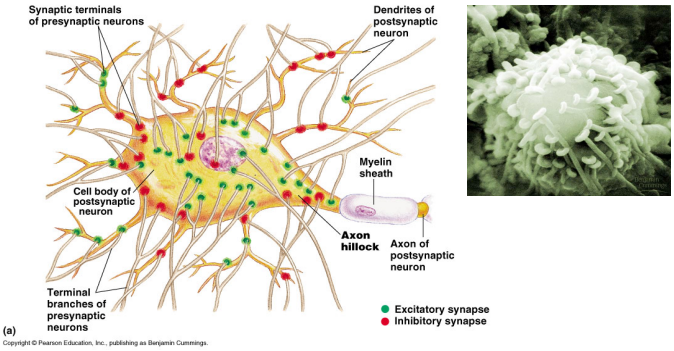
EPSP + IPSP



Effect of IPSPs on action potentials



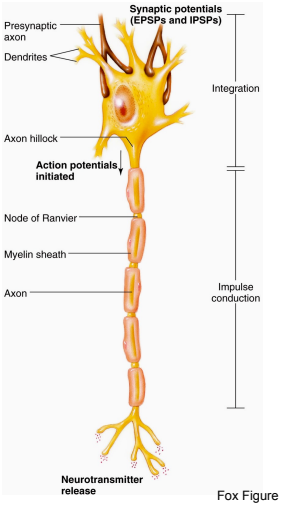
Campbell Figure 48.13 Integration of multiple synaptic inputs



Neuron sums up net change in positive and negative charges; if positive enough, then it fires.

Conclusions

A neuron integrates excitatory and inhibitory inputs to produce a subtle pattern of firing that reflects multiple influences



Fox Figure 7.24