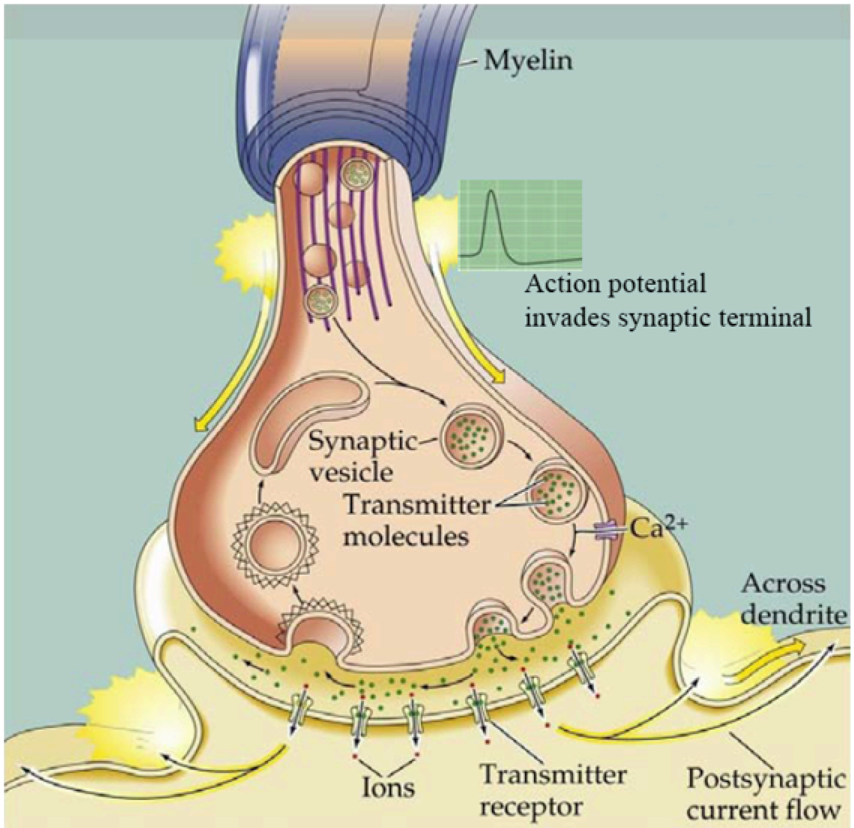
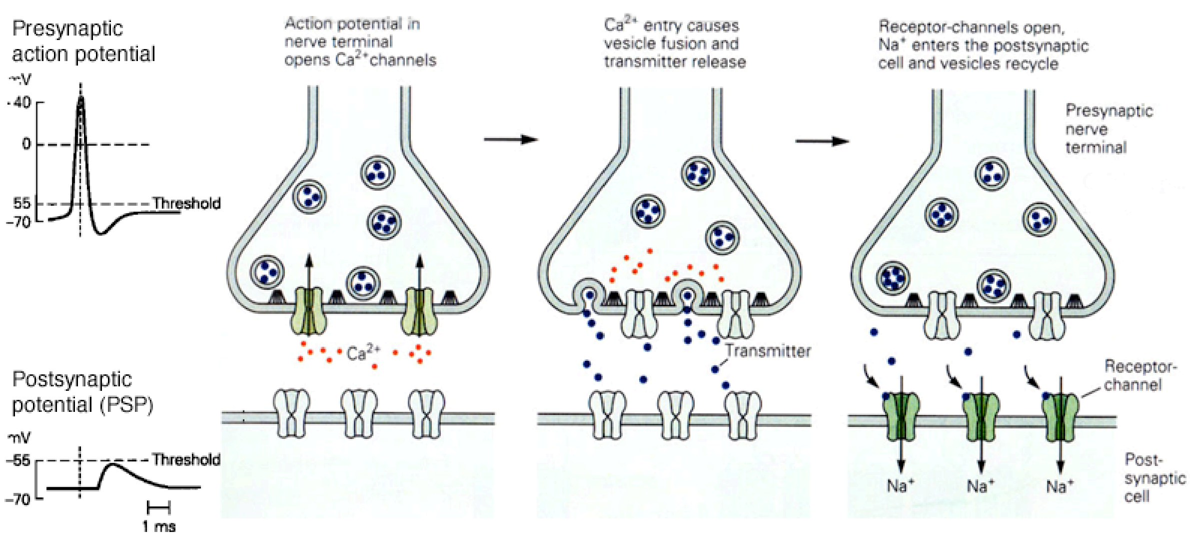
Synaptic Communication



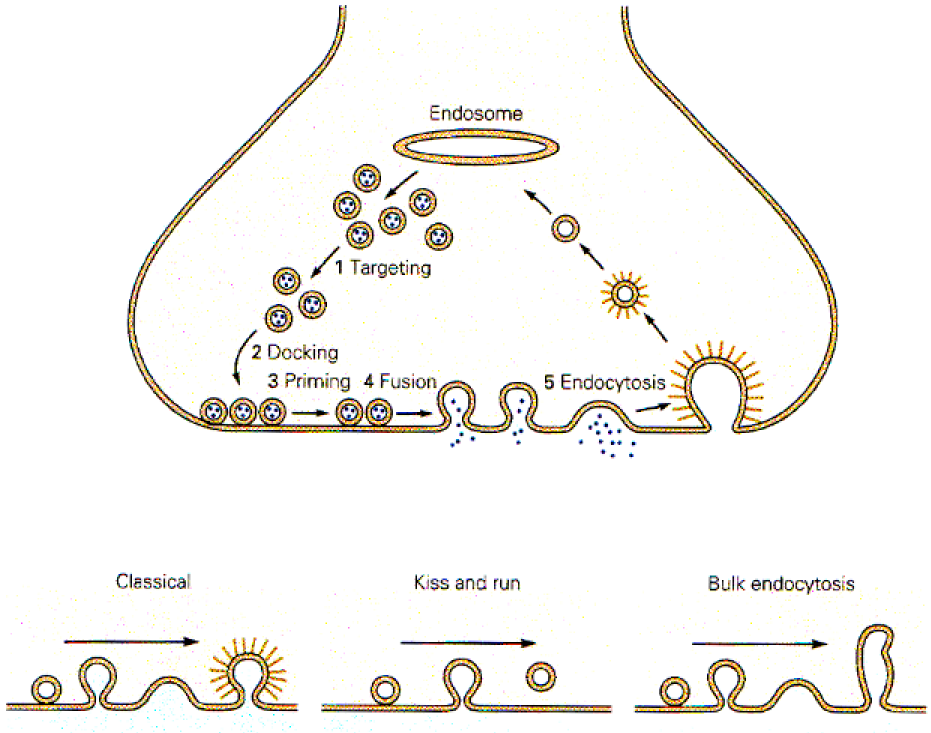
01_synapse.psd

Presynaptic Release of Neurotransmitter



02_release.psd

Vesicle Recycling

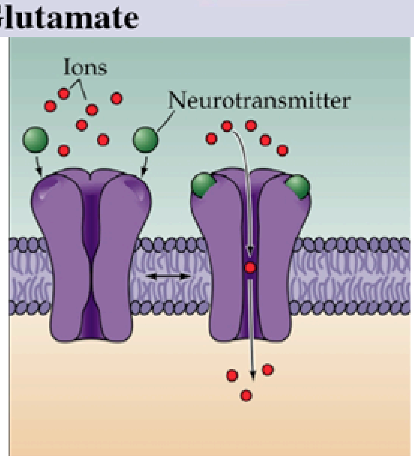


03_vesicles.psd

Neurotransmitter Types

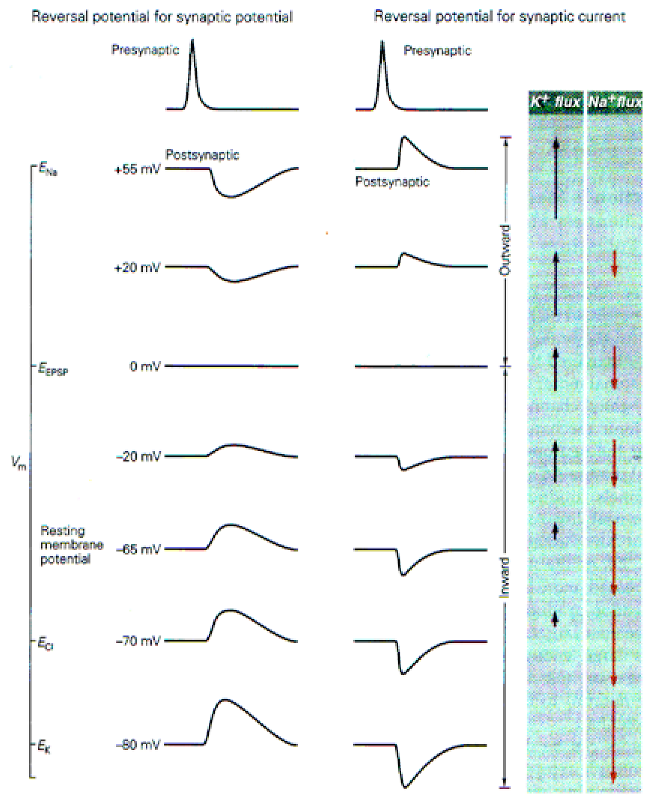
Receptor	AMPA	NMDA	Kainate	GABA	Glycine	nACh	Serotonin	Purines
Subunits	Glu R1	NR1	Glu R5	α_{1-7}	$\alpha1$	α_{2-9}	$5\text{-}HT_3$	P_{2X1}
	Glu R2	NR2A	Glu R6	β_{1-4}	$\alpha2$	β_{1-4}		P_{2X2}
	Glu R3	NR2B	Glu R7	γ_{1-4}	$\alpha3$	γ		P_{2X3}
	Glu R4	NR2C	KA1	δ	$\alpha4$	δ		P_{2X4}
		NR2D	KA2	ε	β			P_{2X5}
				ρ_{1-3}				P_{2X6}
								P_{2X7}

Glutamate



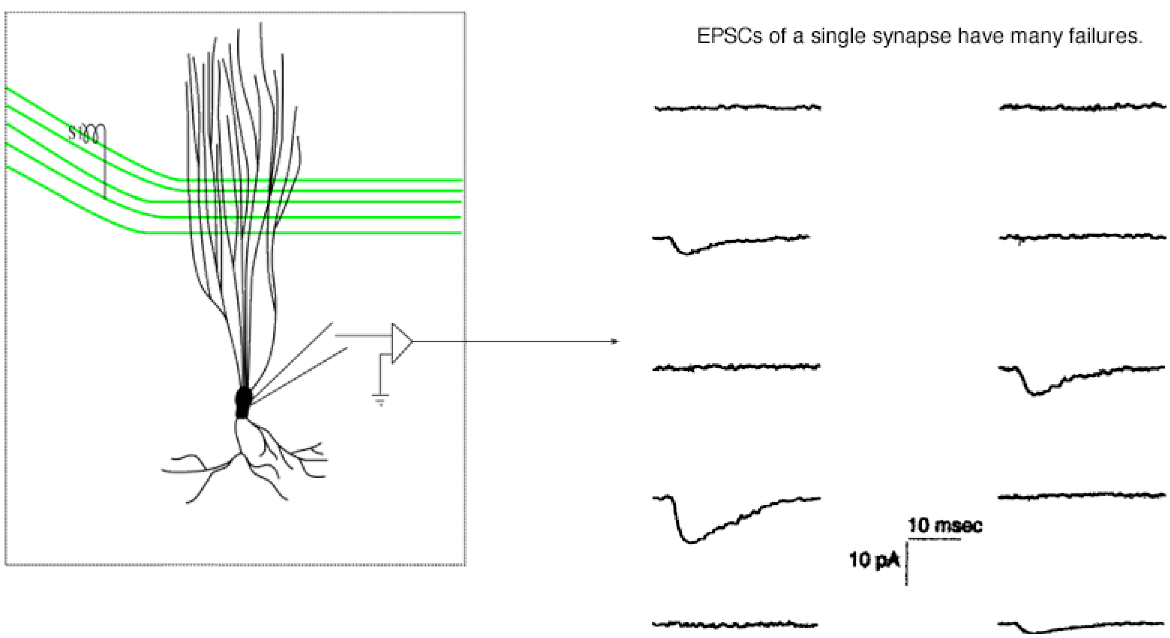
04_transmitters.psd

Postsynaptic Potential *vs* Postsynaptic Current



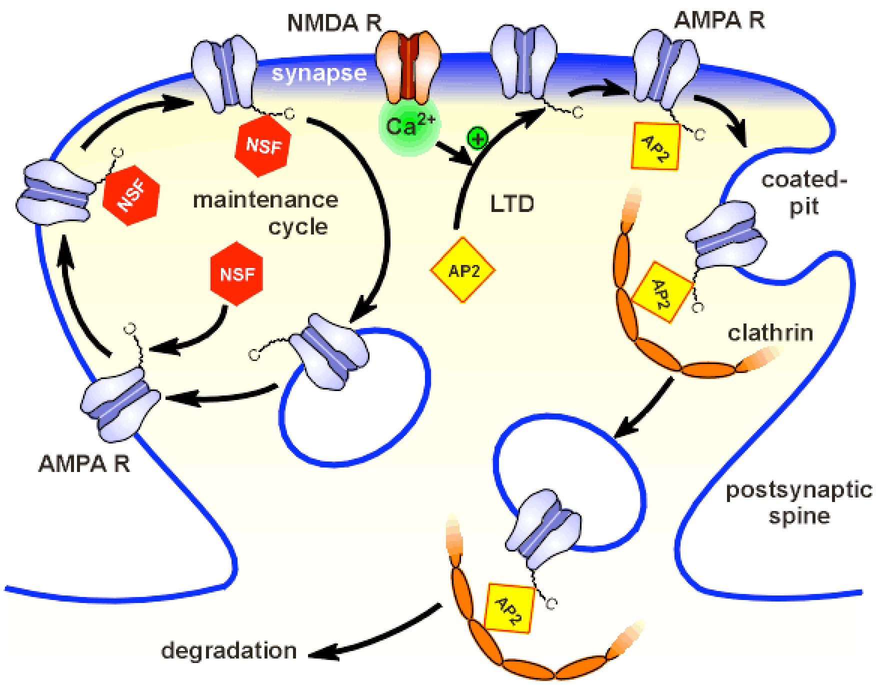
05_PSP.psd

Vesicle Release is a Stochastic Process



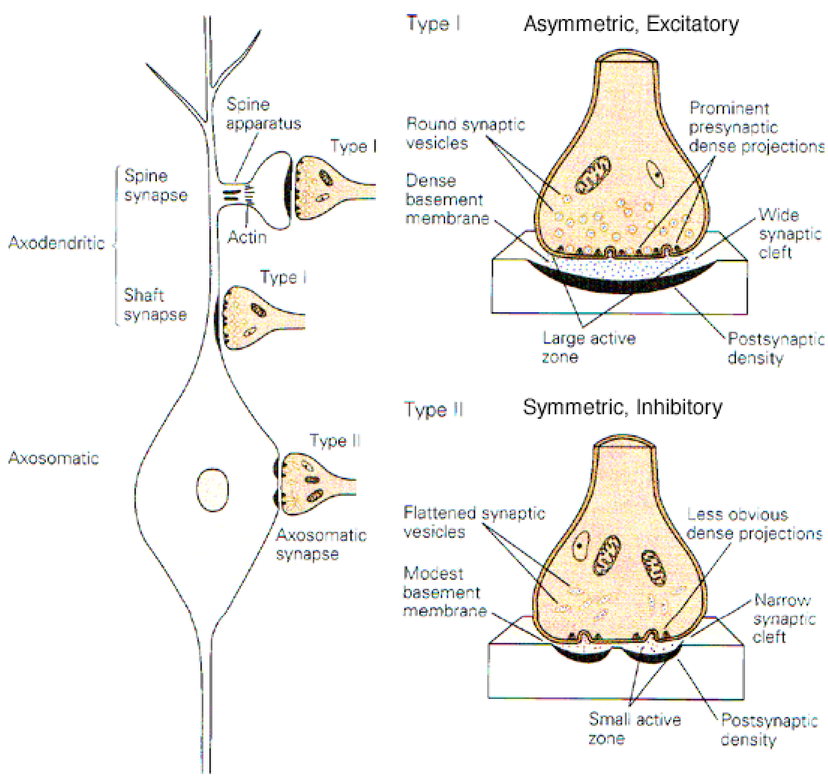
06_releaseProb.psd

Postsynaptic Receptor Number and Receptor Conductance Contribute to Synaptic "Weight"



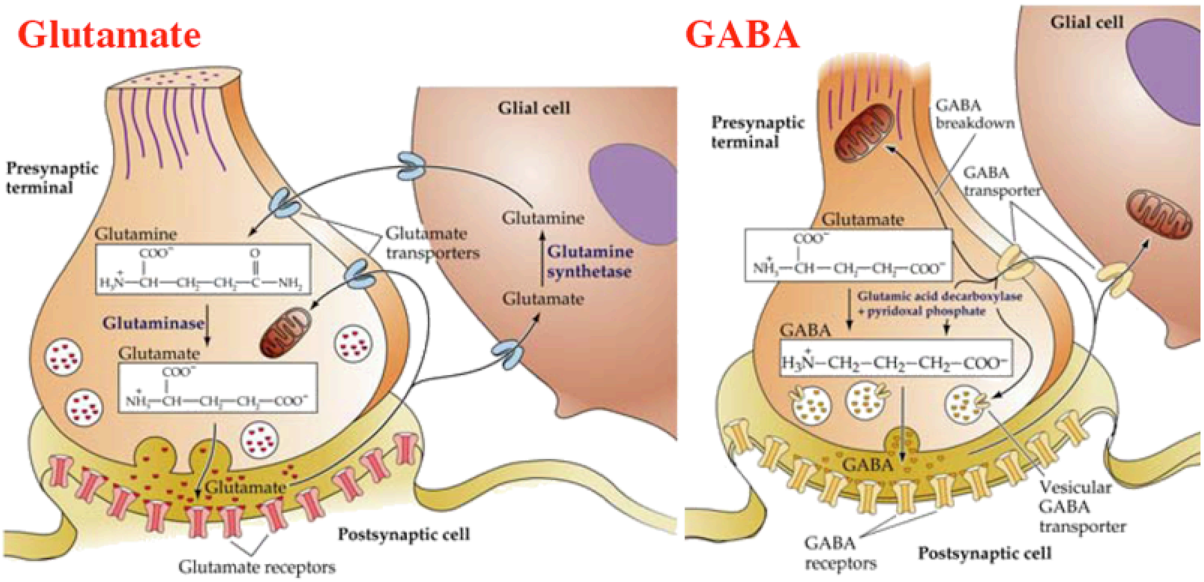
07_postStrength.psd

Morphological Synaptic Types



08_synTypes.psd

Glutamate Receptors are Excitory
GABA Receptors are Inhibitory

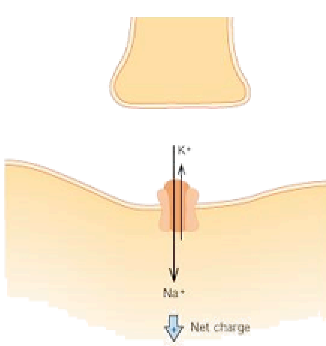


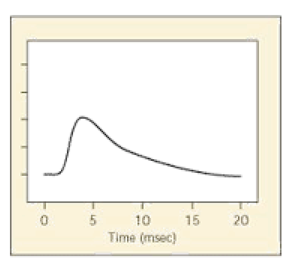
09_Glu_v_GABA.psd

Postsynaptic Current

$$I_{syn} = g_{syn}(t)(V - E_{syn})$$

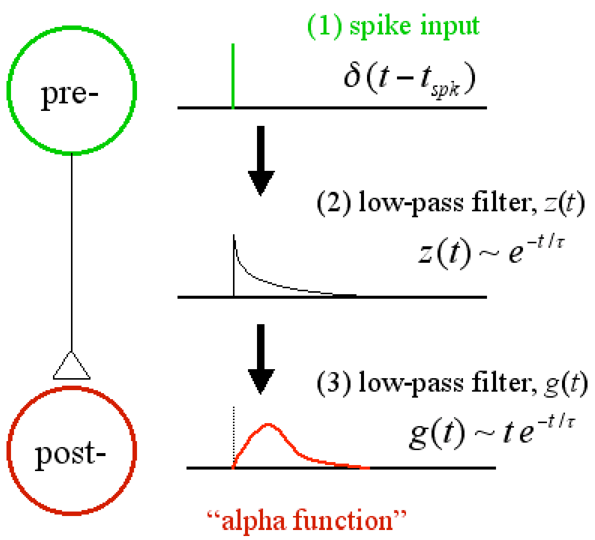
$g_{syn}(t)$ { Presynaptic release probability; Postsynaptic receptor conductance





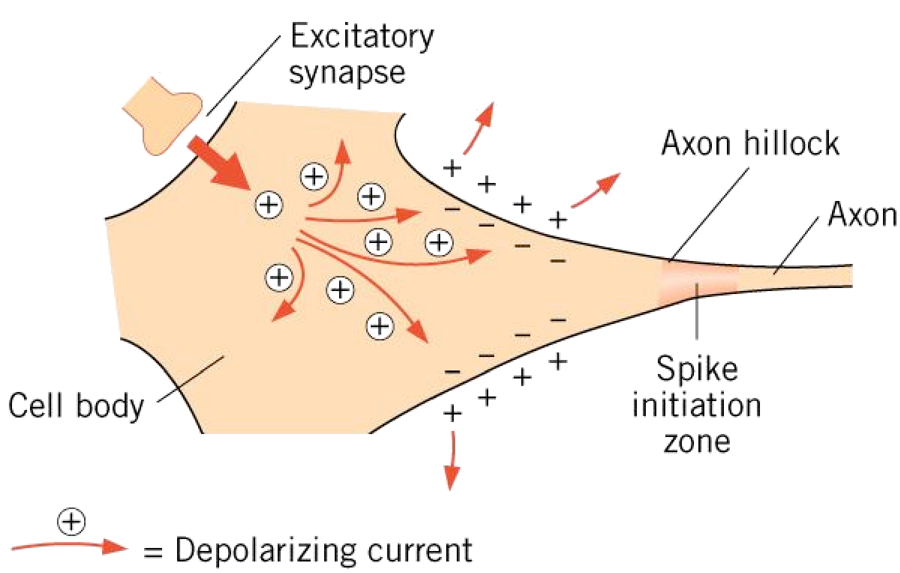
10_synCurrent.psd

Modeling Synaptic Inputs



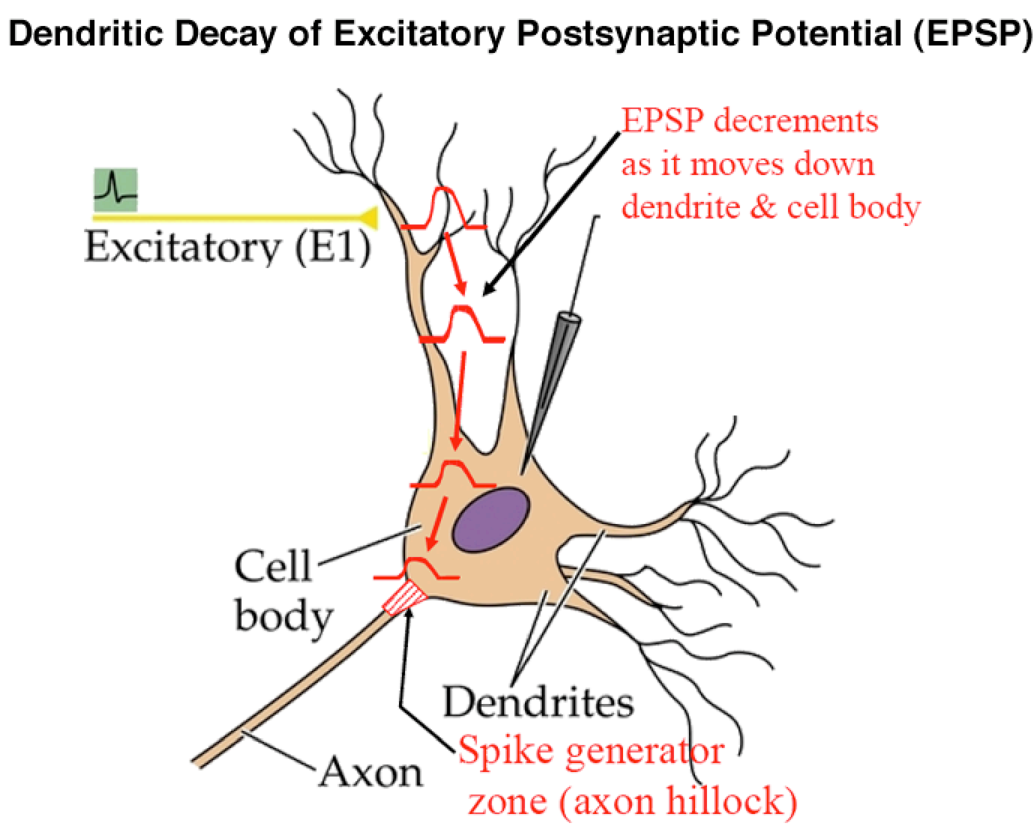
11_alpha.psd

Synaptic Currents Drive Postsynaptic Spike Generation



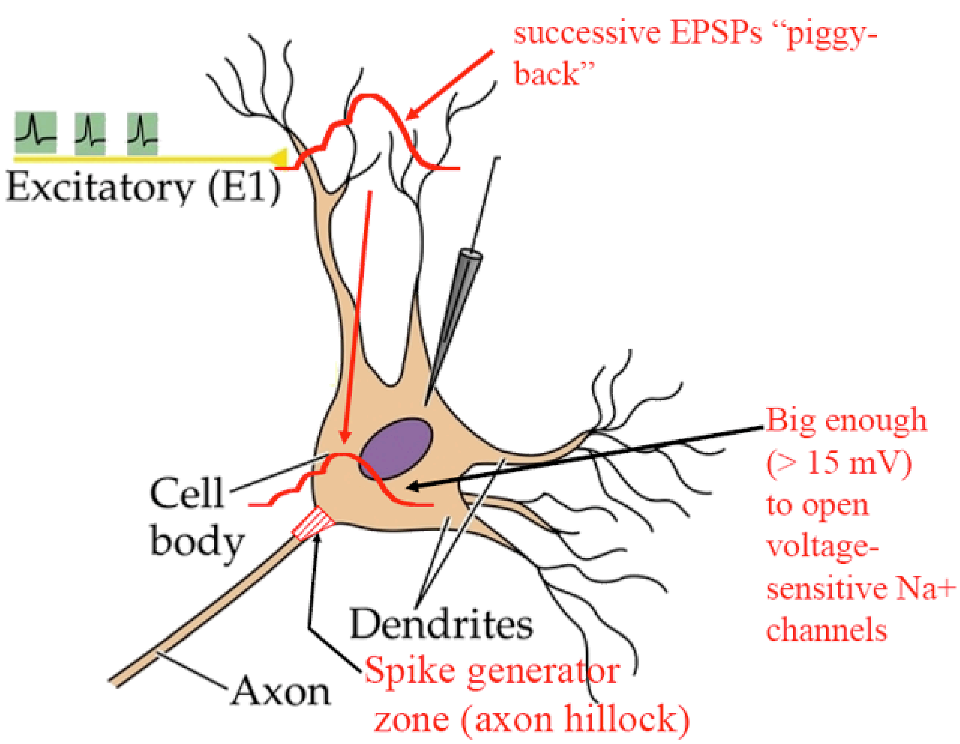
12_postSpikeGen.psd

11b_alphaSimul.psd



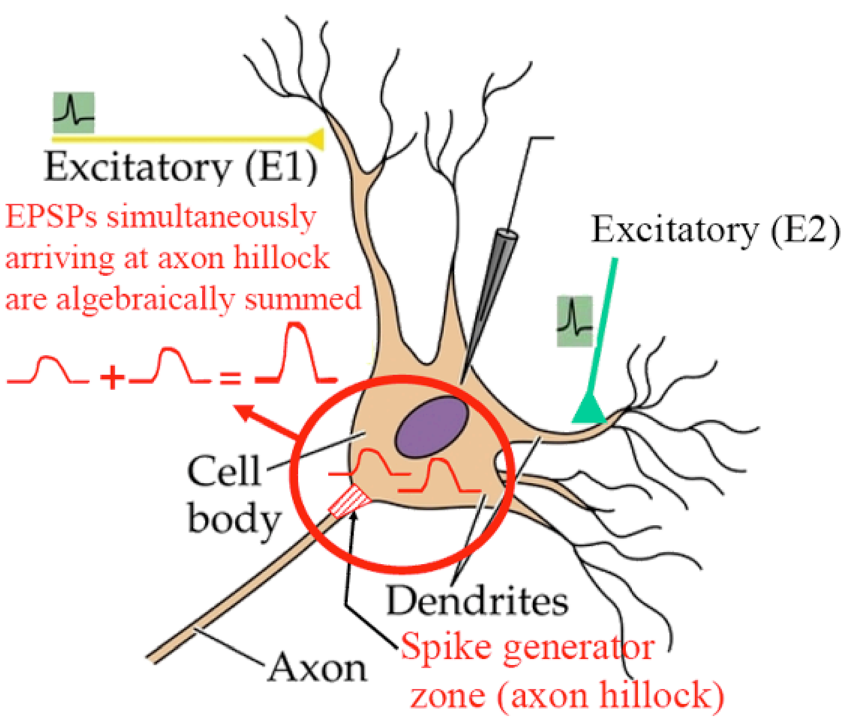
13_dendDecay.psd

Temporal Summation of EPSPs



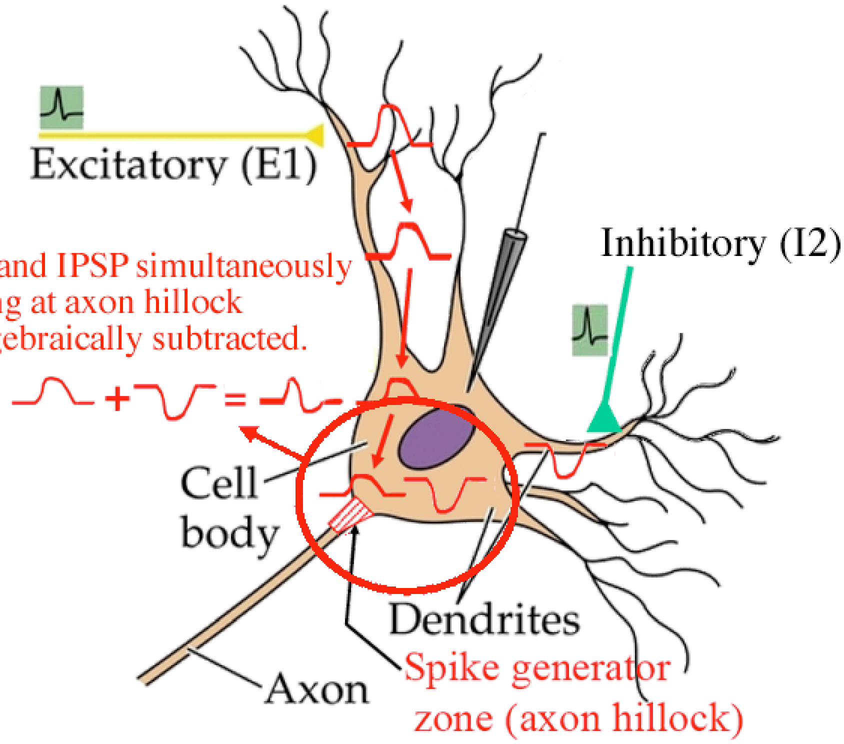
14_temporalSum.psd

Spatial Summation of EPSPs



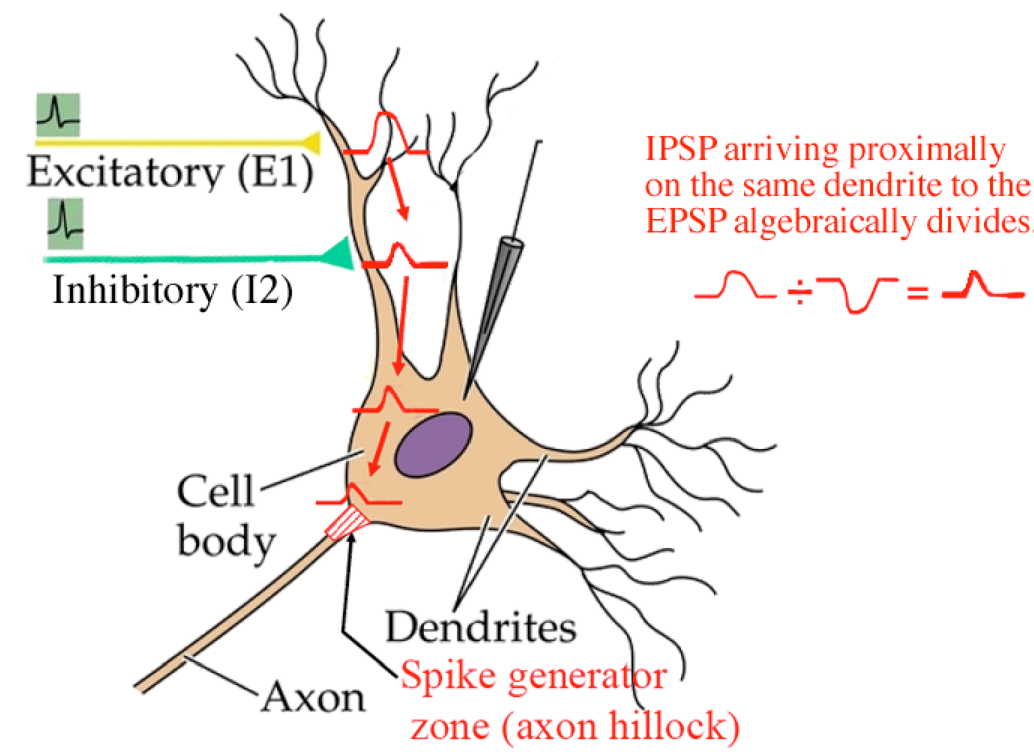
15_spatialSum.psd

Subtractive Inhibition

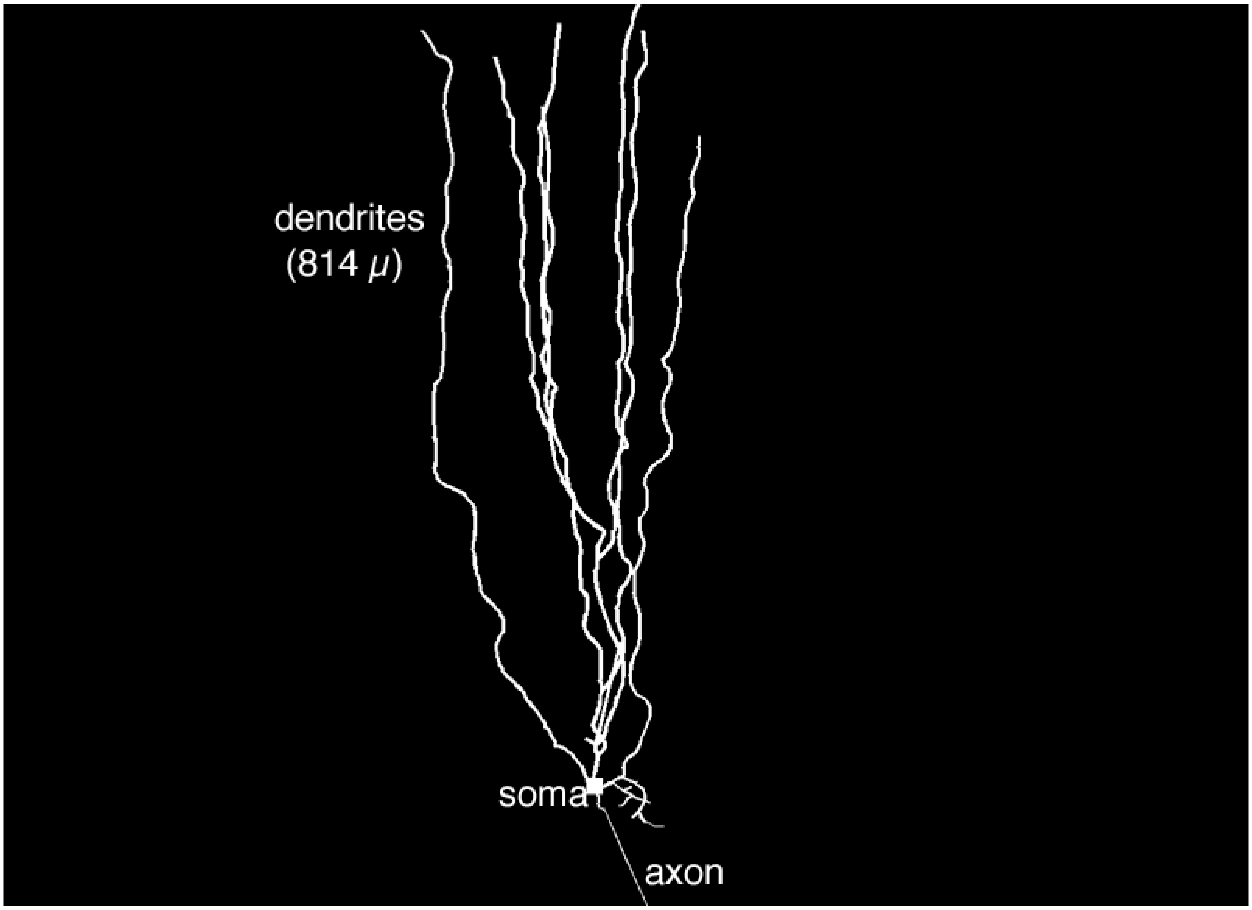


16_subtractInhib.psd

Shunting Inhibition is Divisive

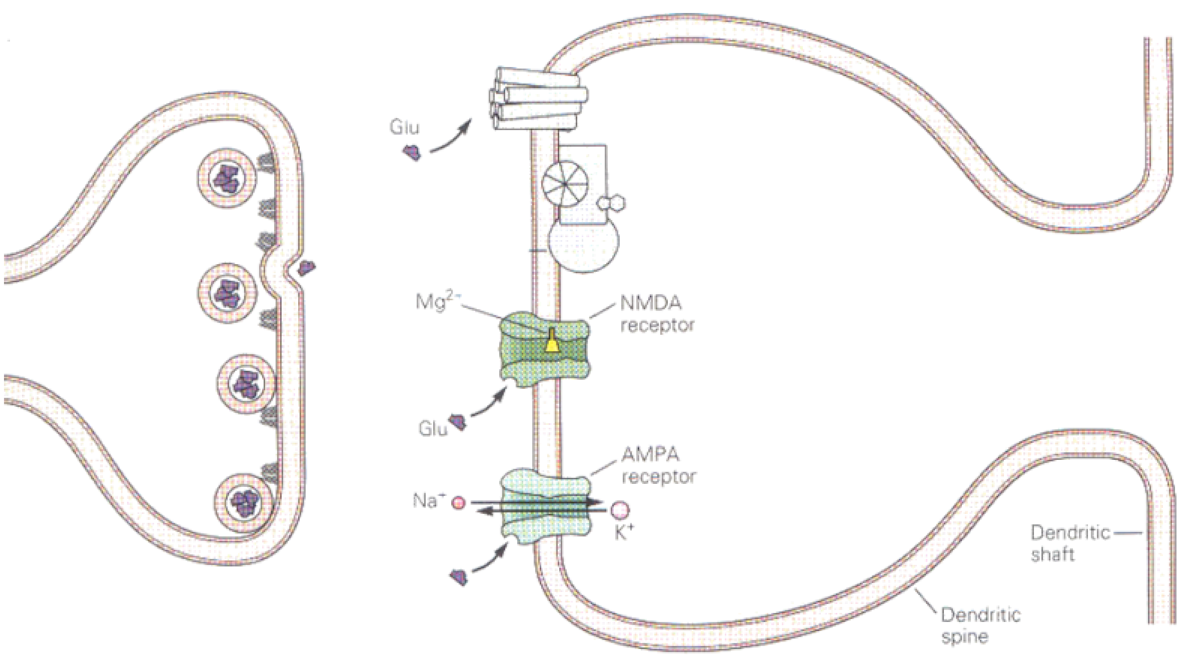


17_shuntingInhib.psd



17b_MGCellSimul.psd

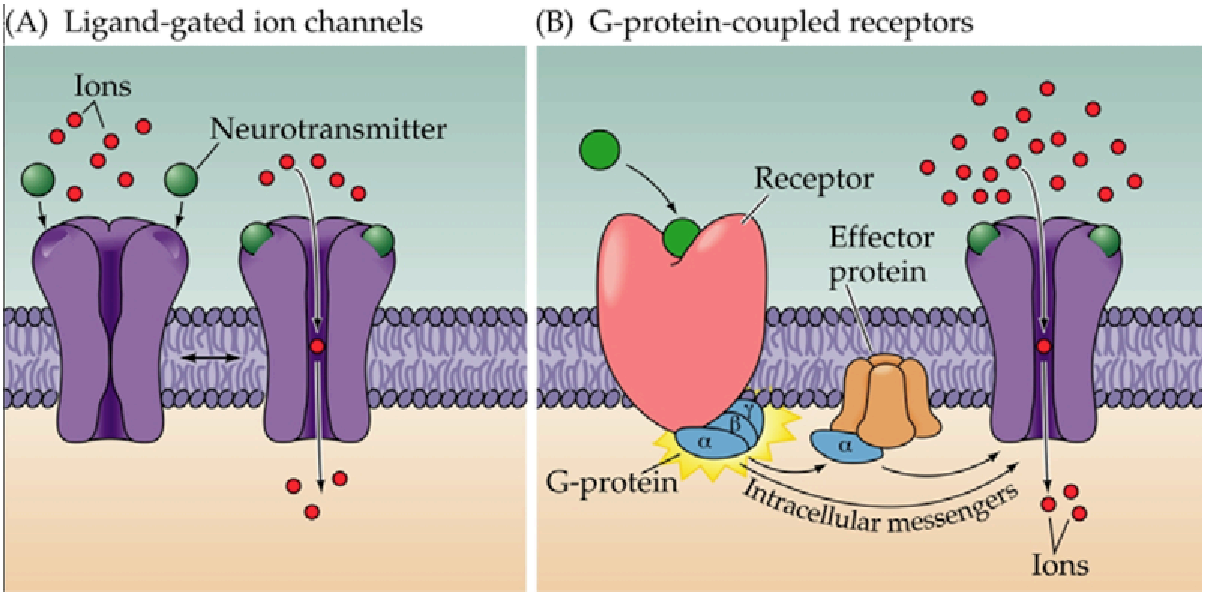
Receptor types: Ionotropic and Metabotropic



Kandel, Schwartz, and Jessell (2000)

21_receptorTypes.psd

Ionotropic Compared to Metabotropic Receptors



22_ionic_v_matabol.psd

Neurotransmitter Types

Ionotropic:

Receptor	AMPA	NMDA	Kainate	GABA	Glycine	nACh	Serotonin	Purines
Subunits	Glu R1	NR1	Glu R5	α_{1-7}	$\alpha 1$	α_{2-9}	5-HT_3	P_{2X1}
	Glu R2	NR2A	Glu R6	β_{1-4}	$\alpha 2$	β_{1-4}		P_{2X2}
	Glu R3	NR2B	Glu R7	γ_{1-4}	$\alpha 3$	γ		P_{2X3}
	Glu R4	NR2C	KA1	δ	$\alpha 4$	δ		P_{2X4}
		NR2D	KA2	ε	β			P_{2X5}
				ρ_{1-3}				P_{2X6}
								P_{2X7}

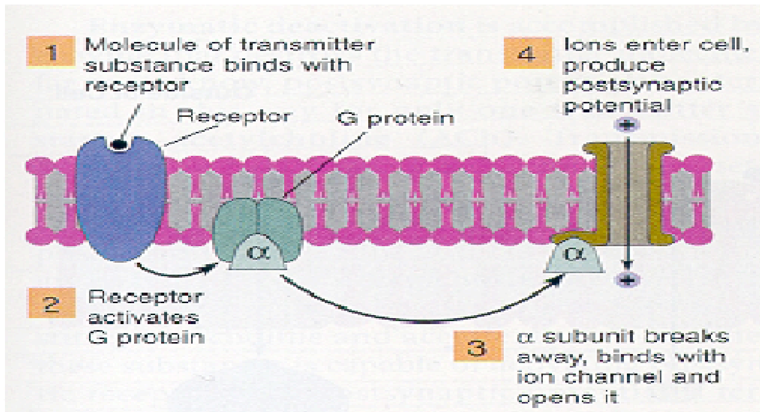
Glutamate

Metabotropic:

Receptor class	Glutamate	$GABA_B$	Dopamine	NE, Epi	Histamine	Serotonin	Purines	Muscarinic
Receptor subtype	Class I	$GABA_B$ R1	$D1_A$	$\alpha 1$	H1	5-HT 1	A type	M1
	mGlu R1	$GABA_B$ R2	$D1_B$	$\alpha 2$	H2	5-HT 2	A1	M2
	mGlu R5		D2	$\beta 1$	H3	5-HT 3	A2a	M3
	Class II		D3	$\beta 2$		5-HT 4	A2b	M4
	mGlu R2		D4	$\beta 3$		5-HT 5	A3	M5
	mGlu R3					5-HT 6	P type	
	Class III					5-HT 7	P2x	
	mGlu R4						P2y	
	mGlu R6						P2z	
	mGlu R7						P2t	
	mGlu R8						P2u	

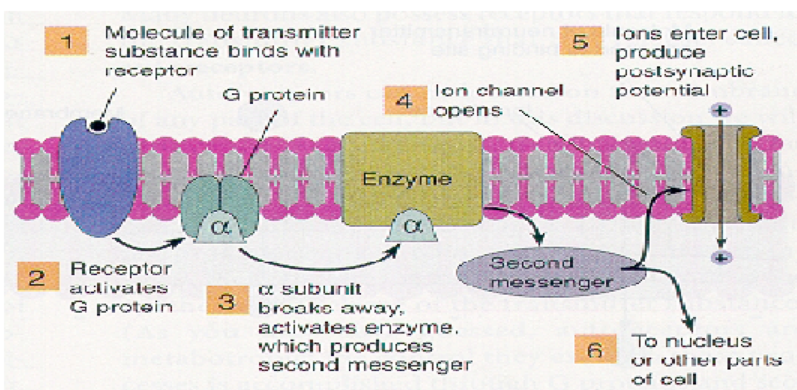
23_transmitters.psd

Direct G-protein Binding to Ion Channel

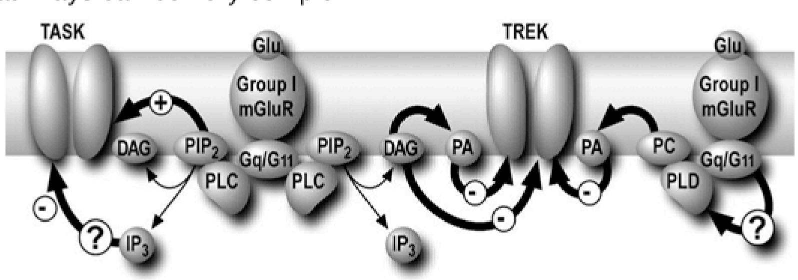


25_directLink.psd

G-protein Activates Ion Channel Indirectly

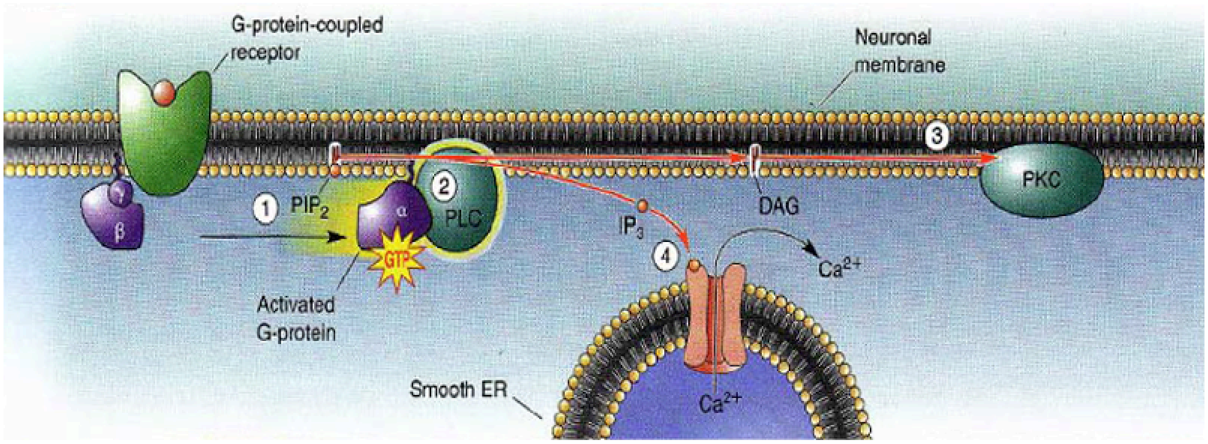


Signalling pathways can be very complex:



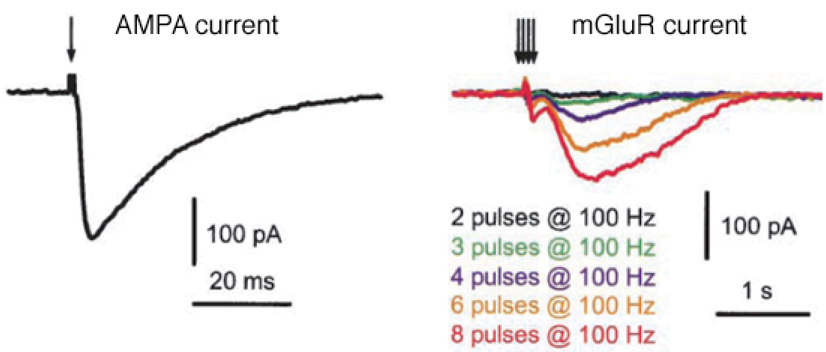
26_indirectLink.psd

Ca^{2+} Release from Intracellular Stores

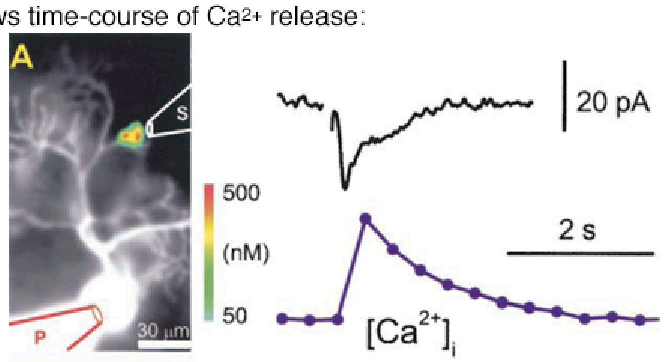


27_storedCa.psd

Slow mGlu-Receptor EPSP in Cerebellar Purkinje Cells



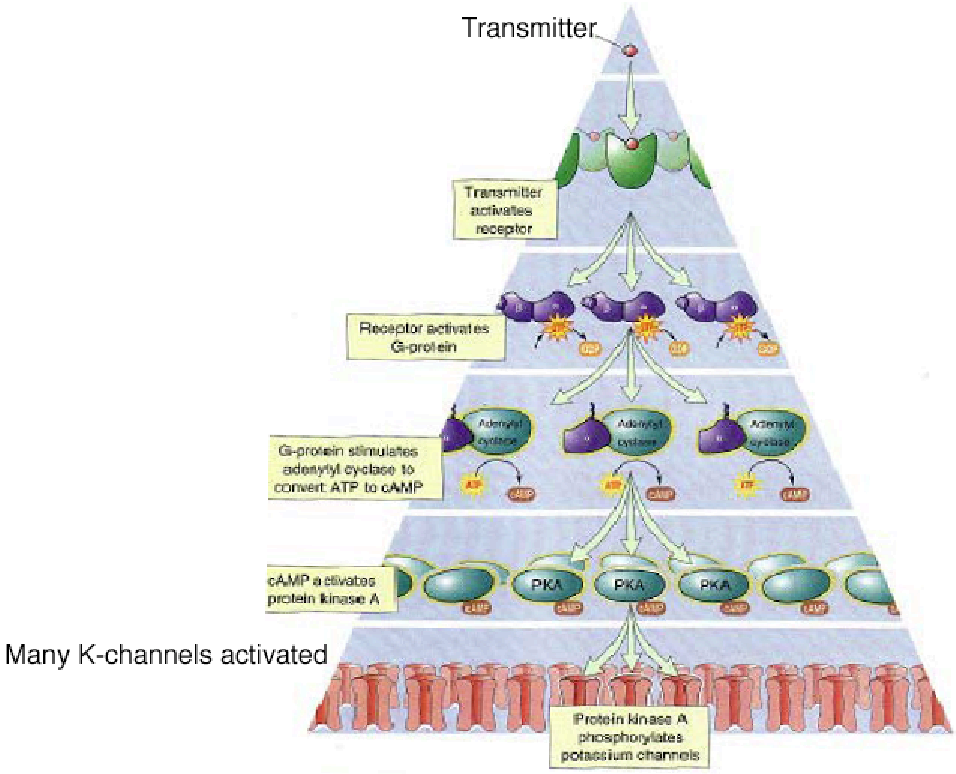
Calcium Imaging shows time-course of Ca^{2+} release:



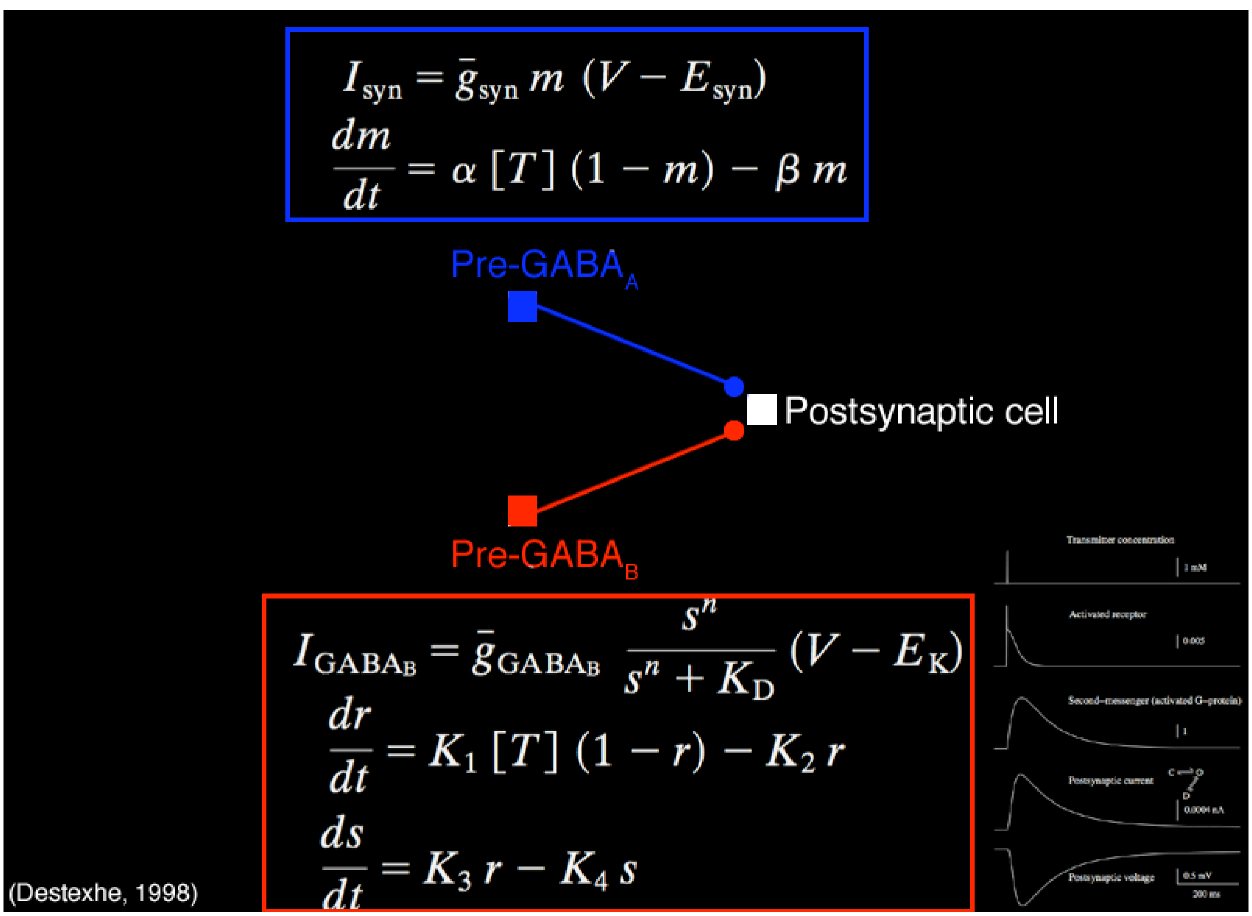
V. Coutinho and T. Knöpfel, Neuroscientist 8(6):551–561, 2002.
Metabotropic Glutamate Receptors:Electrical and Chemical Signaling Properties

28_slow.psd

Amplification of Signal Through a Chemical Cascade

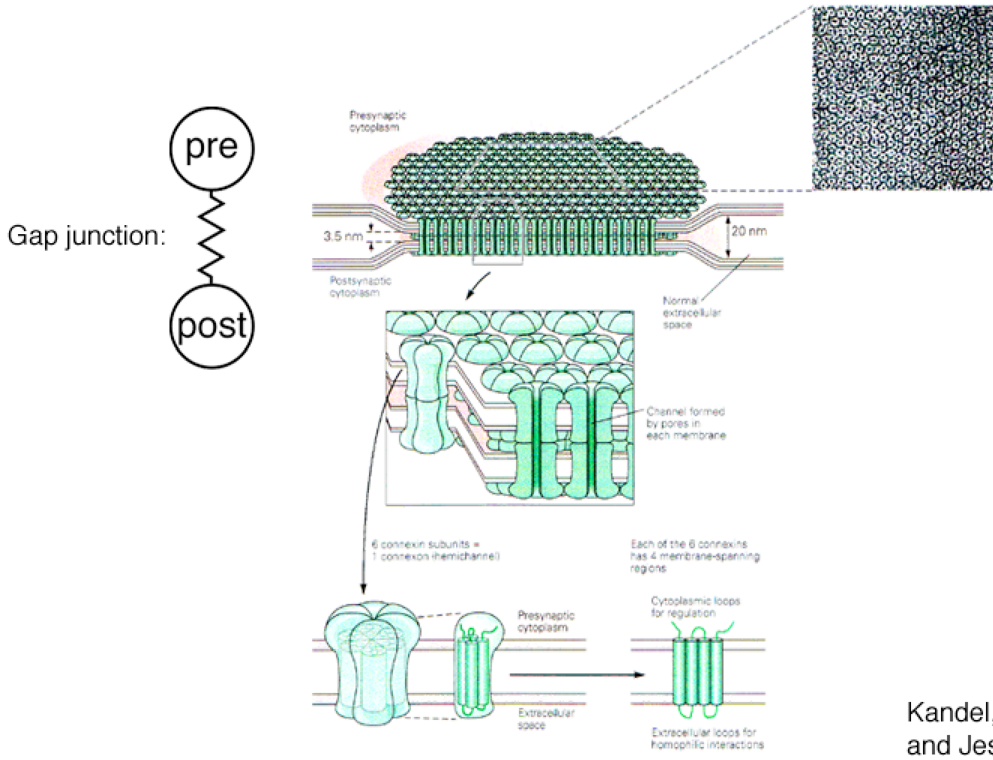


29_amplif.psd



29b_GABA.psd

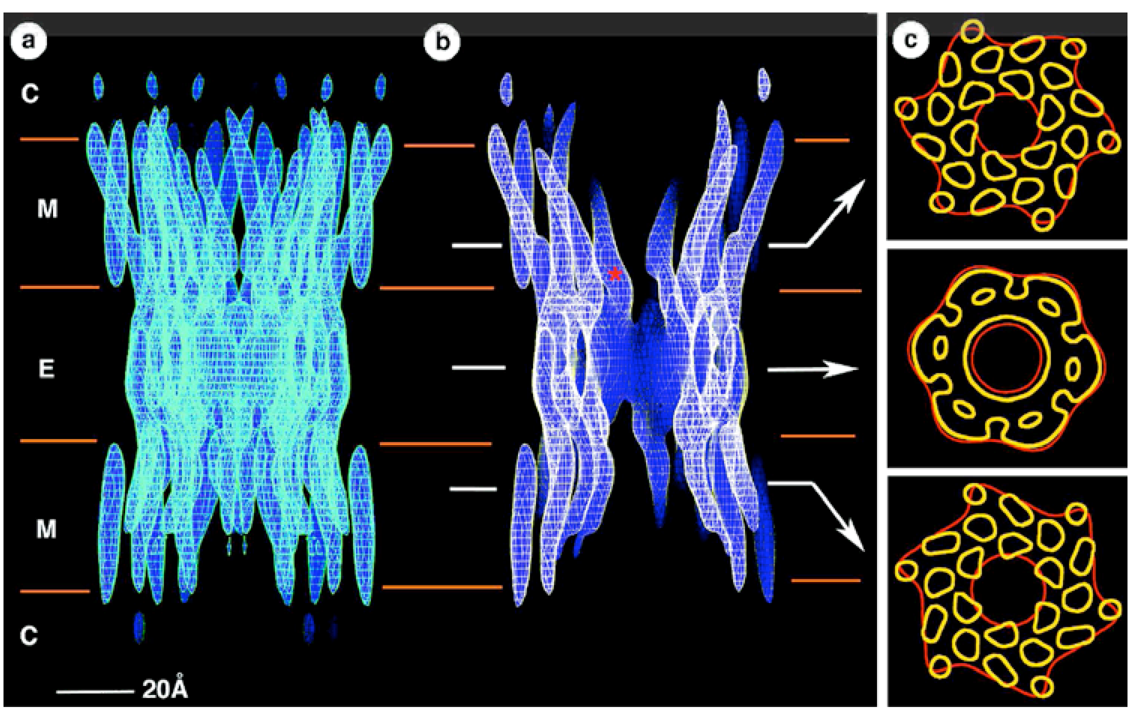
Gap Junctions: Direct Electrical Communication



Kandel, Schwartz, and Jessell (2000)

30_gapJunctions.psd

Asymmetries can Produce Voltage-Gating and Rectification

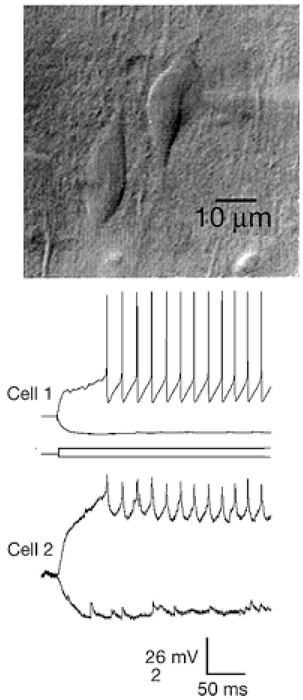


Using Gap Junctions as Basic Building Blocks, V. Shah and S. Ramu (2002)

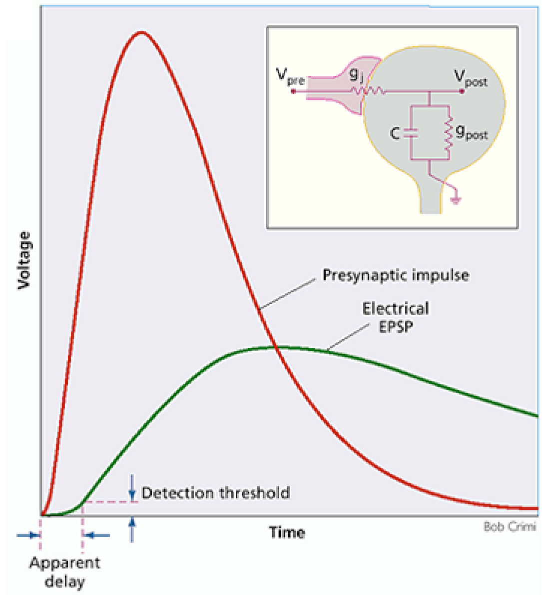
31_gapMolecule.psd

Electrical Transmission Between Neurons

2 cortical inhibitory neurons



Equivalent circuit of transmission at an electrical synapse.



The postsynaptic potential calculated from this circuit is slowed with respect to the presynaptic impulse because of time required to charge and discharge the capacitance. The postsynaptic potential has a significant latency because the detection threshold introduces delay.

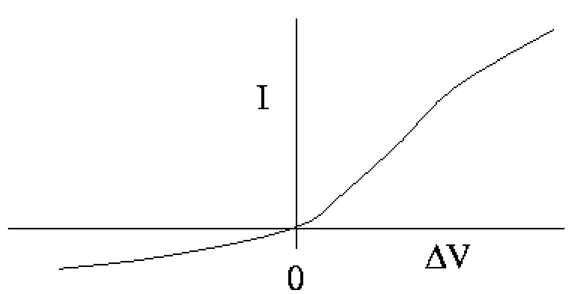
M.V.L. Bennett Nature Neuroscience 3, 7 - 9 (2000)

32_gapPair.psd

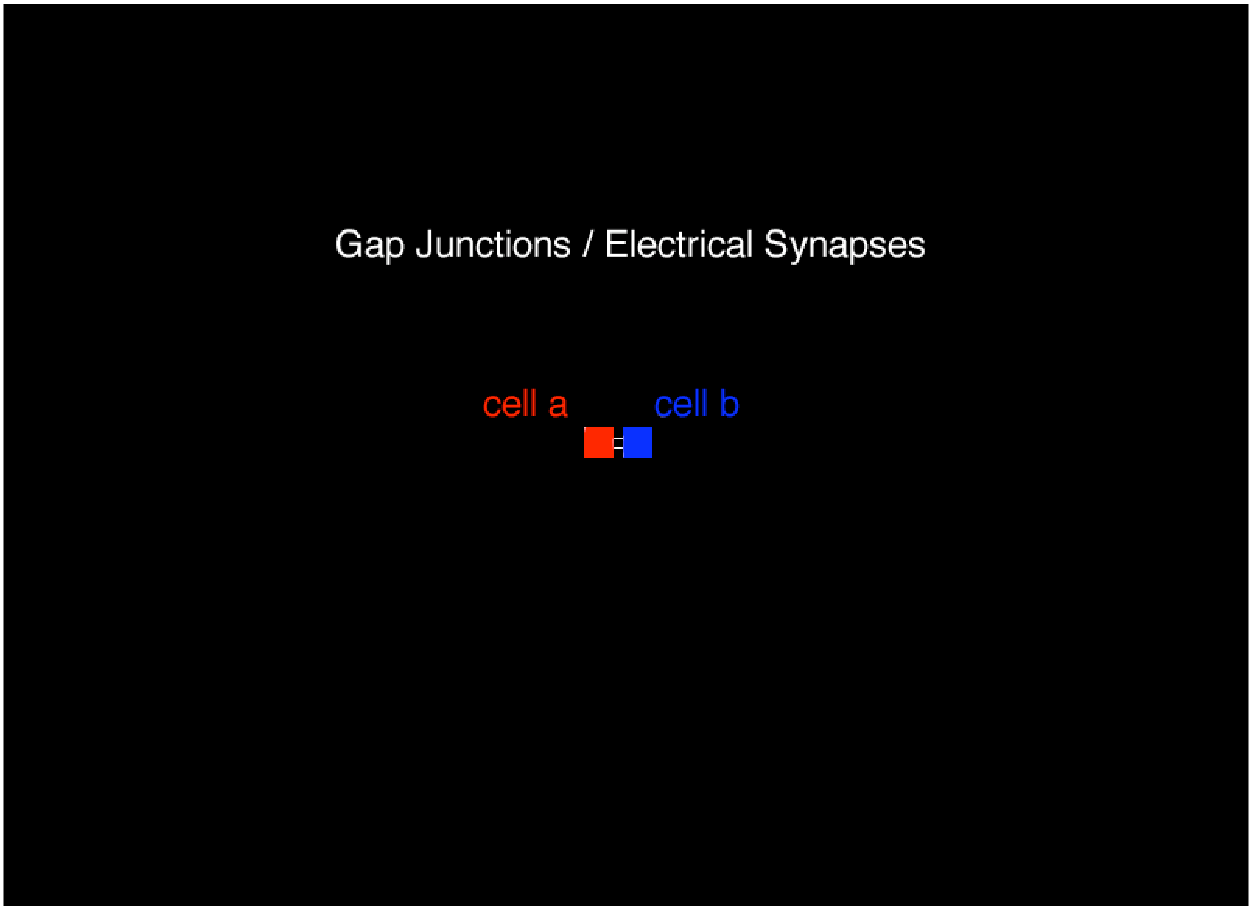
Simple Model Gap Junction

$$I_{gap} = g_{gap}(V_{post} - V_{pre})$$

Sometimes gap junctions act as rectifiers so that the positive and negative current flow is not equal for potential differences of the same magnitude:



33_gapModel.psd



32b_gap.psd