Information Transmission across Synapses

The basic process in a presynaptic neuron

Action potential from the axon

↓

Depolarization of the presynaptic terminal

↓

Opening of voltage-gated Ca^{2+} channels

↓

Ca^{2+} entry into presynaptic terminal

↓

Fusion of synaptic vesicle with presynaptic plasma membrane

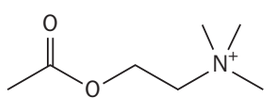
↓

Neurotransmitter release

Neurotransmitters

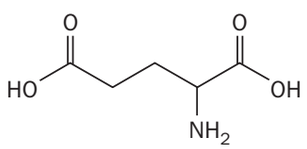
Table 3–2: Commonly used neurotransmitters

Neurotransmitter	Major uses in the vertebrate nervous system[1]
Acetylcholine	motor neurons that excite muscle; ANS[2] neurons; CNS excitatory and modulatory neurons
Glutamate	most CNS excitatory neurons; most sensory neurons
GABA	most CNS inhibitory neurons
Glycine	some CNS inhibitory neurons (mostly in the brainstem and spinal cord)
Serotonin (5-HT)	CNS modulatory neurons
Dopamine	CNS modulatory neurons
Norepinephrine	CNS modulatory neurons; ANS[2] neurons
Histamine	CNS modulatory neurons
Neuropeptides	usually co-released from excitatory, inhibitory, or modulatory neurons; neurosecretory cells

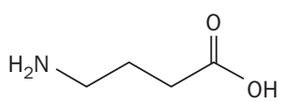


acetylcholine (ACh)

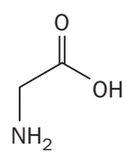
glutamate



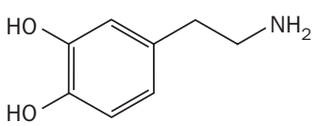
GABA



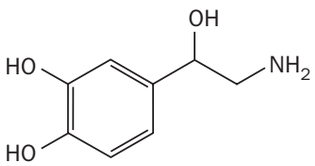
glycine



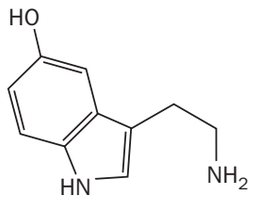
dopamine



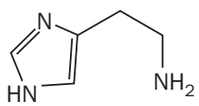
norepinephrine



serotonin

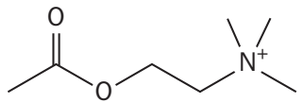


histamine



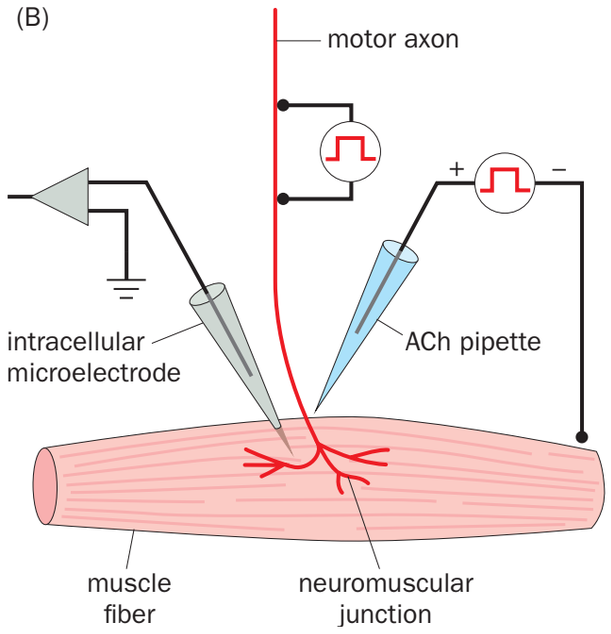
Neurotransmitter release evokes membrane potential change in the postsynaptic neuron

(A)

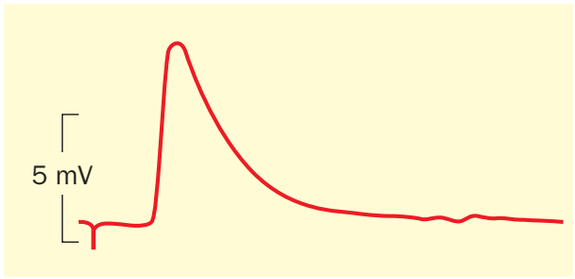


acetylcholine (ACh)

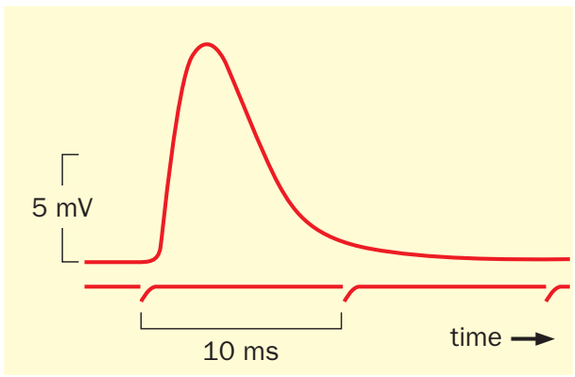
(B)



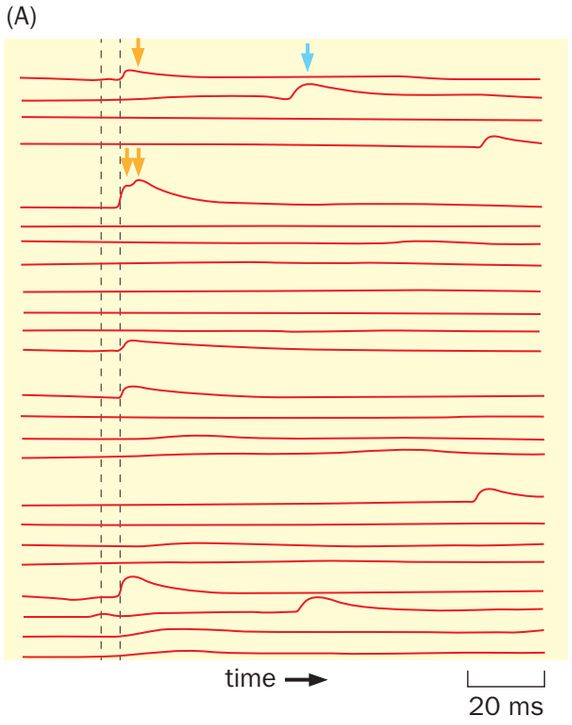
(C) nerve stimulation

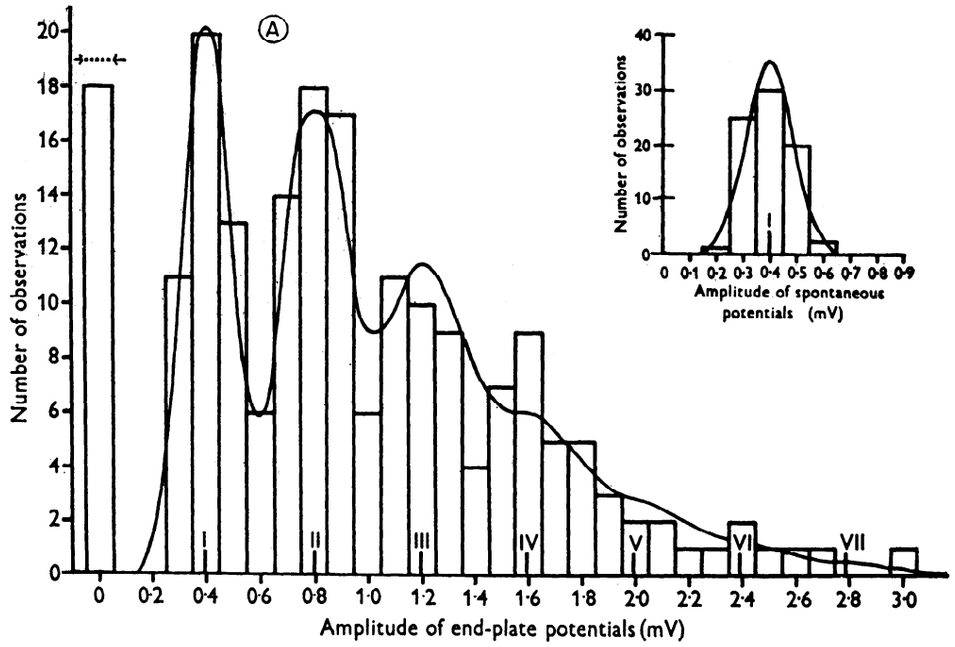


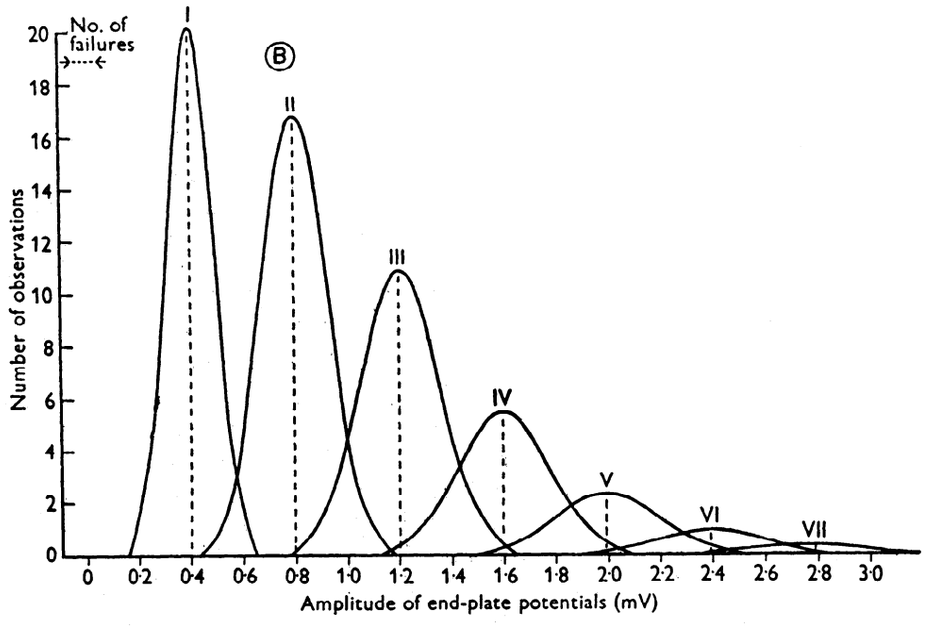
ACh iontophoresis



Quantal hypothesis of neurotransmitter release







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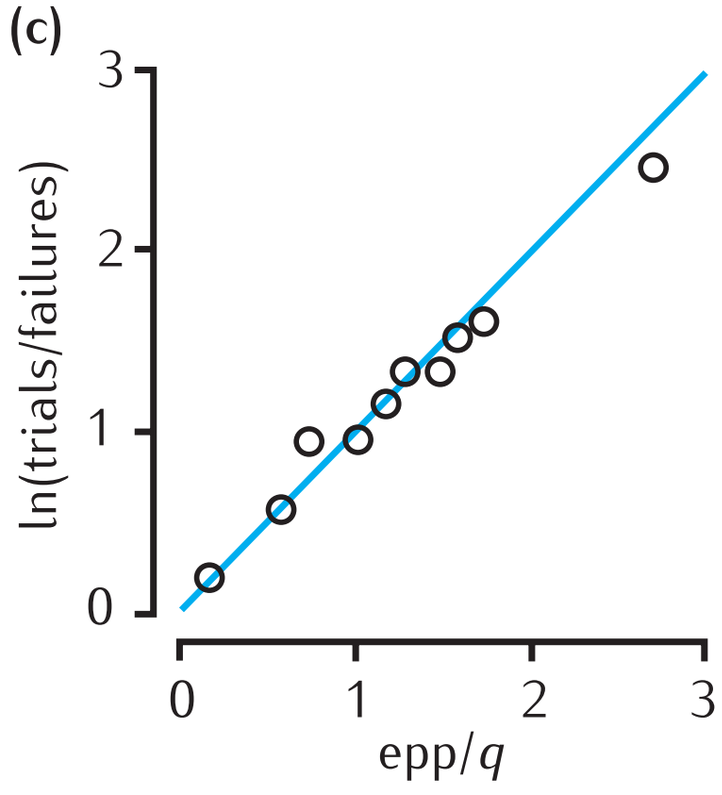
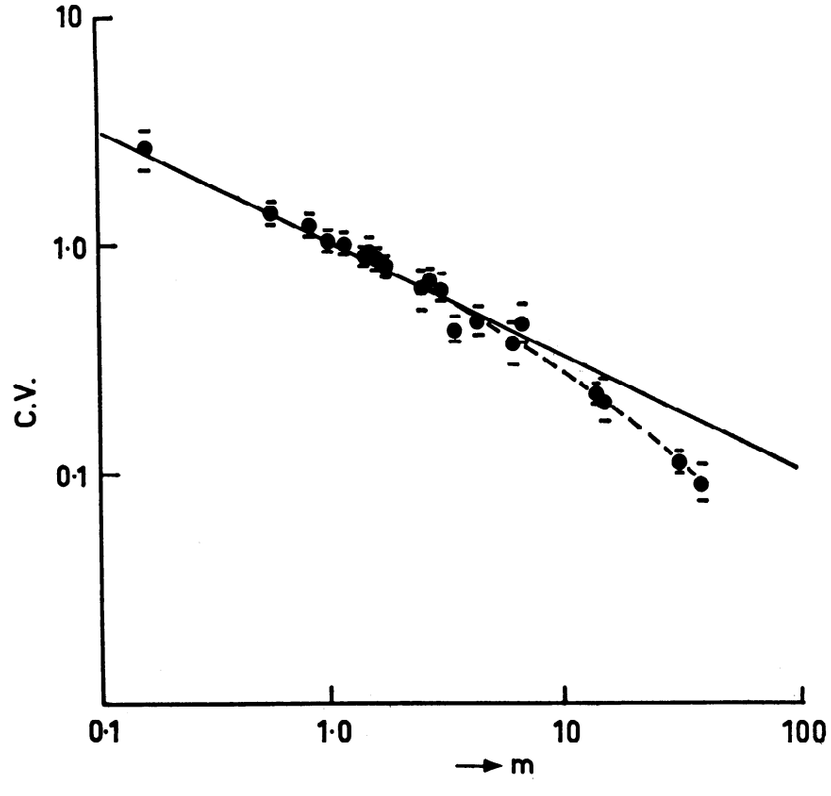




Neurotransmitters are released in discrete packets

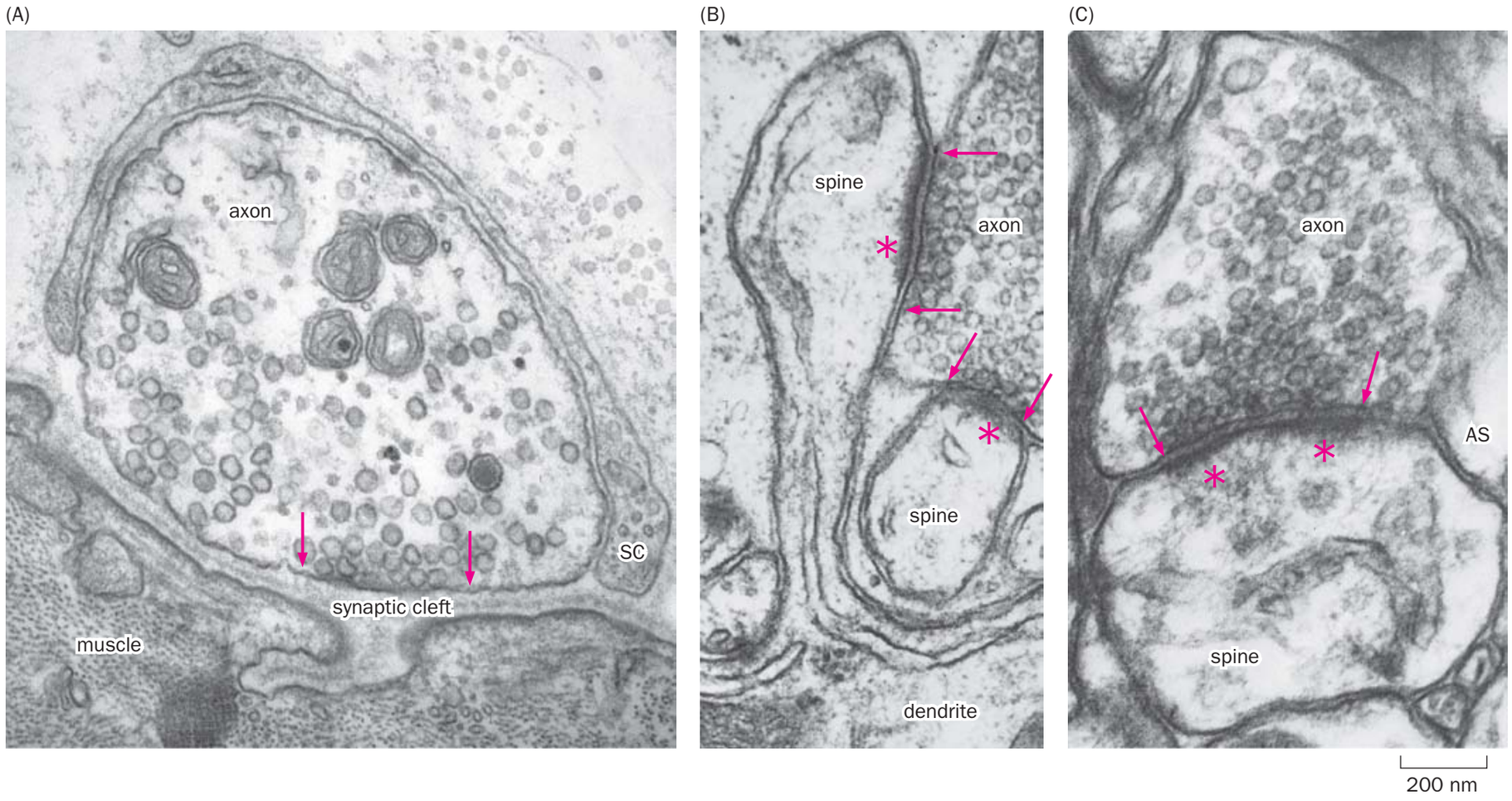


Figure 3–3 Structures of synapses revealed by electron microscopy. All images share the scale bar. Red asterisks indicate postsynaptic density. Pairs of arrows define the extent of the active zones in the presynaptic terminals. Note the abundance of ~40 nm diameter synaptic vesicles in each presynaptic terminal; some of these vesicles are 'docked' at the active zone ready for release. **(A)** A frog neuromuscular junction. The synaptic cleft is considerably wider than at the CNS synapses shown in the other two panels. SC indicates a Schwann cell process that wraps around the motor axon terminal. A typical motor axon forms hundreds of such presynaptic terminals onto a muscle fiber. **(B)** Two synapses formed between a single axon and two Purkinje cell dendritic spines in rat cerebellar cortex. **(C)** A synapse from human cerebral cortex. AS indicates an astrocyte process that wraps around many CNS synapses. (A, courtesy of Jack McMahan; B & C, courtesy of Josef Spacek and Kristen M. Harris, Synapse Web.)

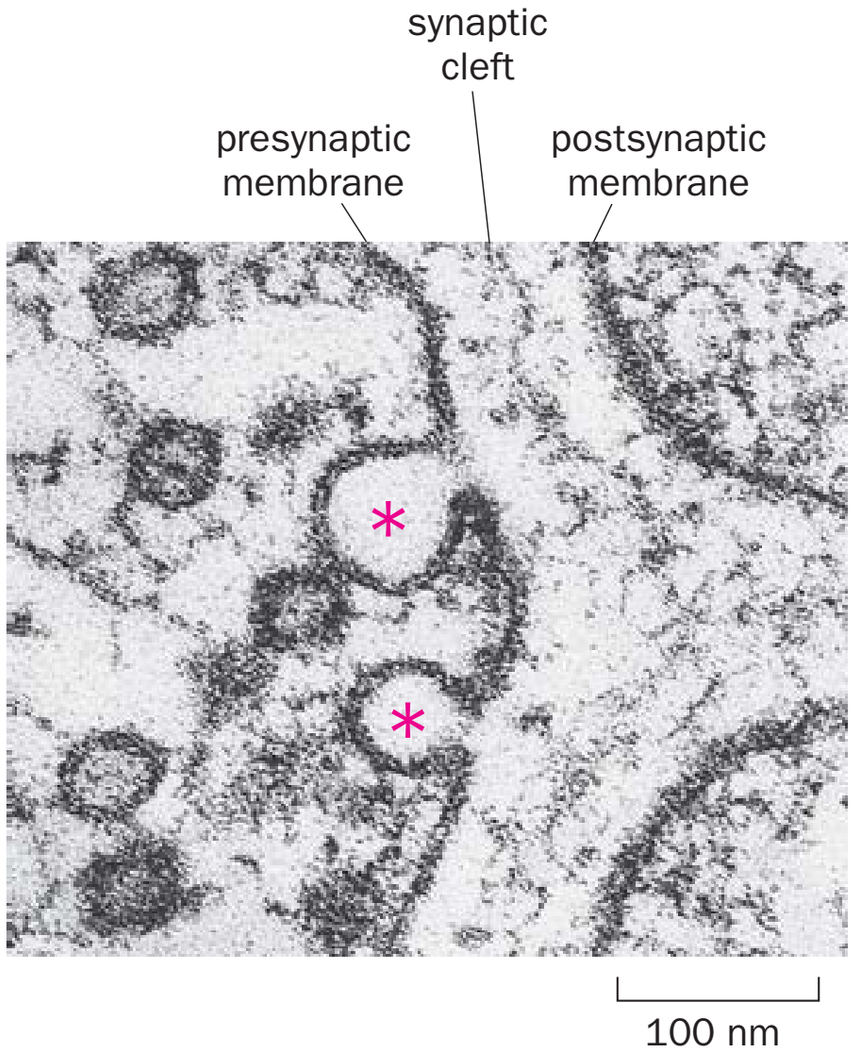


Figure 3–4 Synaptic vesicle fusion caught in action. This electron micrograph was taken from a frog neuromuscular junction preserved 3–5 ms after nerve stimulation, revealing the fusion of two synaptic vesicles (red asterisks) with the presynaptic plasma membrane. (Courtesy of John Heuser. See also Heuser JE & Reese TS [1981] *J Cell Biol* 88:564–580.)

How do neurotransmitters act on postsynaptic neurons?

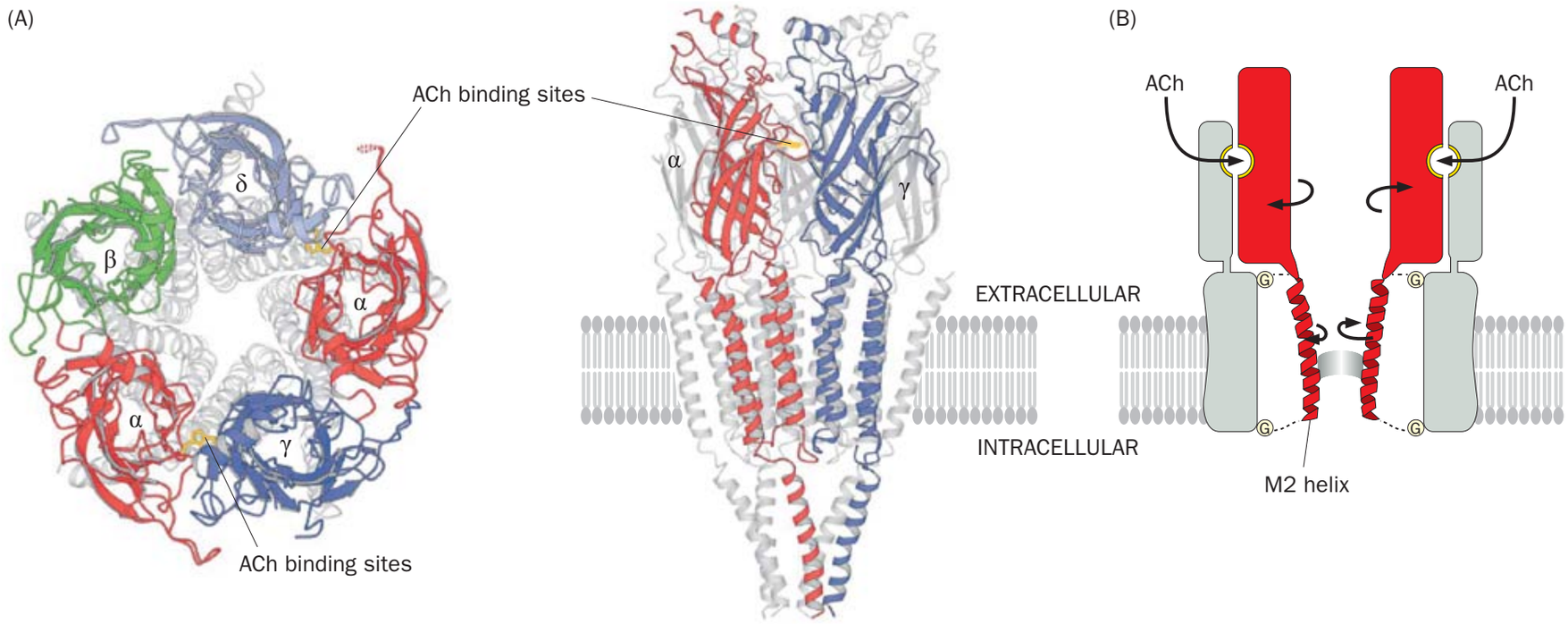
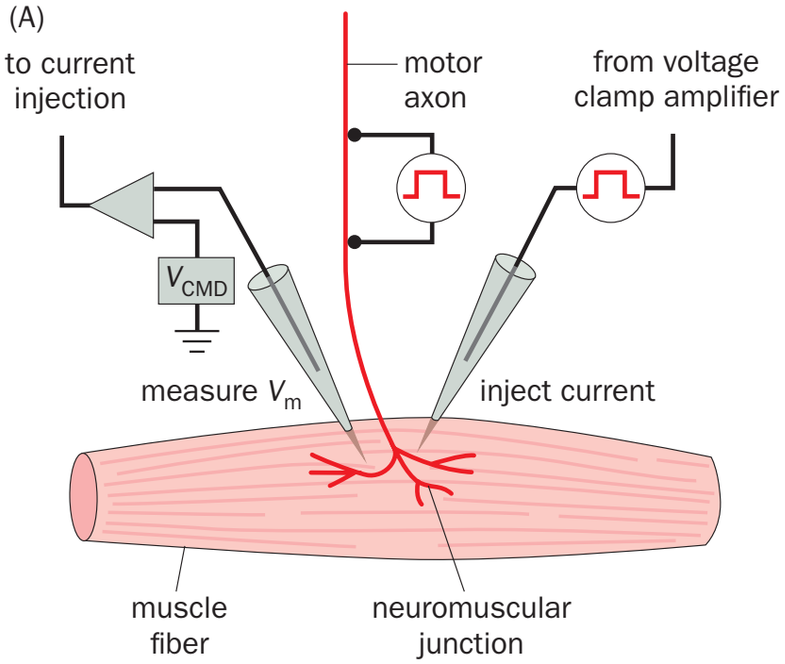
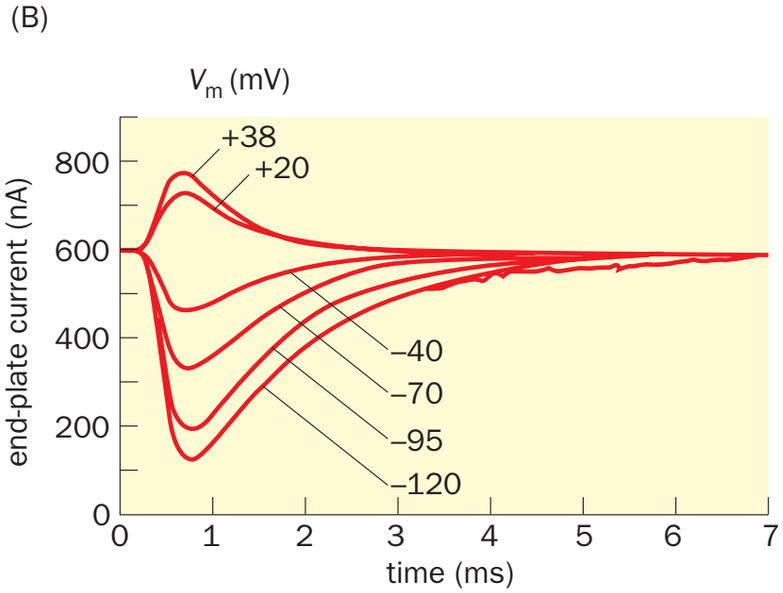
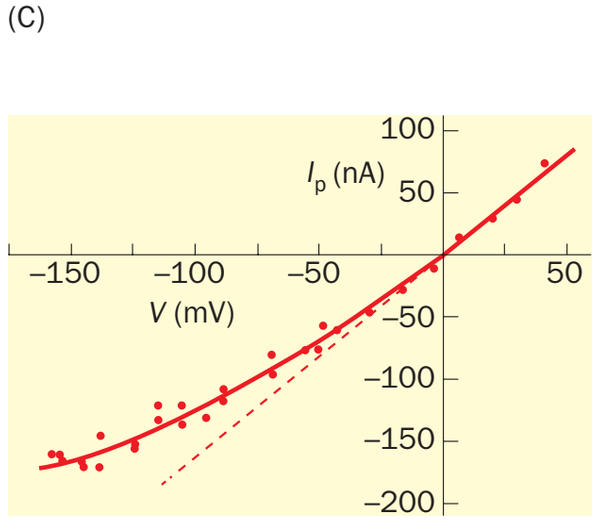


Figure 3–20 AChR structure and gating model. (A) Structure of *Torpedo* AChR in a closed state at a resolution of 4 Å as determined by electron microscopy. Left, a surface view from the extracellular side. The tryptophan in the α subunit implicated in ACh binding is highlighted in gold. Only the extracellular portions are colored. Right, a side view showing the transmembrane helices. The front α and γ subunits are highlighted in color. **(B)** A model for AChR activation. ACh binding induces a rotation of part of the extracellular domain of the α-subunit (red). This rotation triggers a conformational change in the transmembrane helix M2 that lines the ion conduction pore, leading to the opening of the ion gate. Dotted lines with circled Gs (for glycine residues) indicate that M2 is connected with the rest of the protein by flexible loops. (A, from Unwin N [2005] *J Mol Biol* 346:967–989. With permission from Elsevier Inc.; B, adapted from Miyazawa A, Fujiyoshi Y & Unwin N [2003] *Nature* 423:949–955. With permission from Macmillan Publishers Ltd.)

Reversal potential of a synapse







Excitatory and Inhibitory Synapses

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