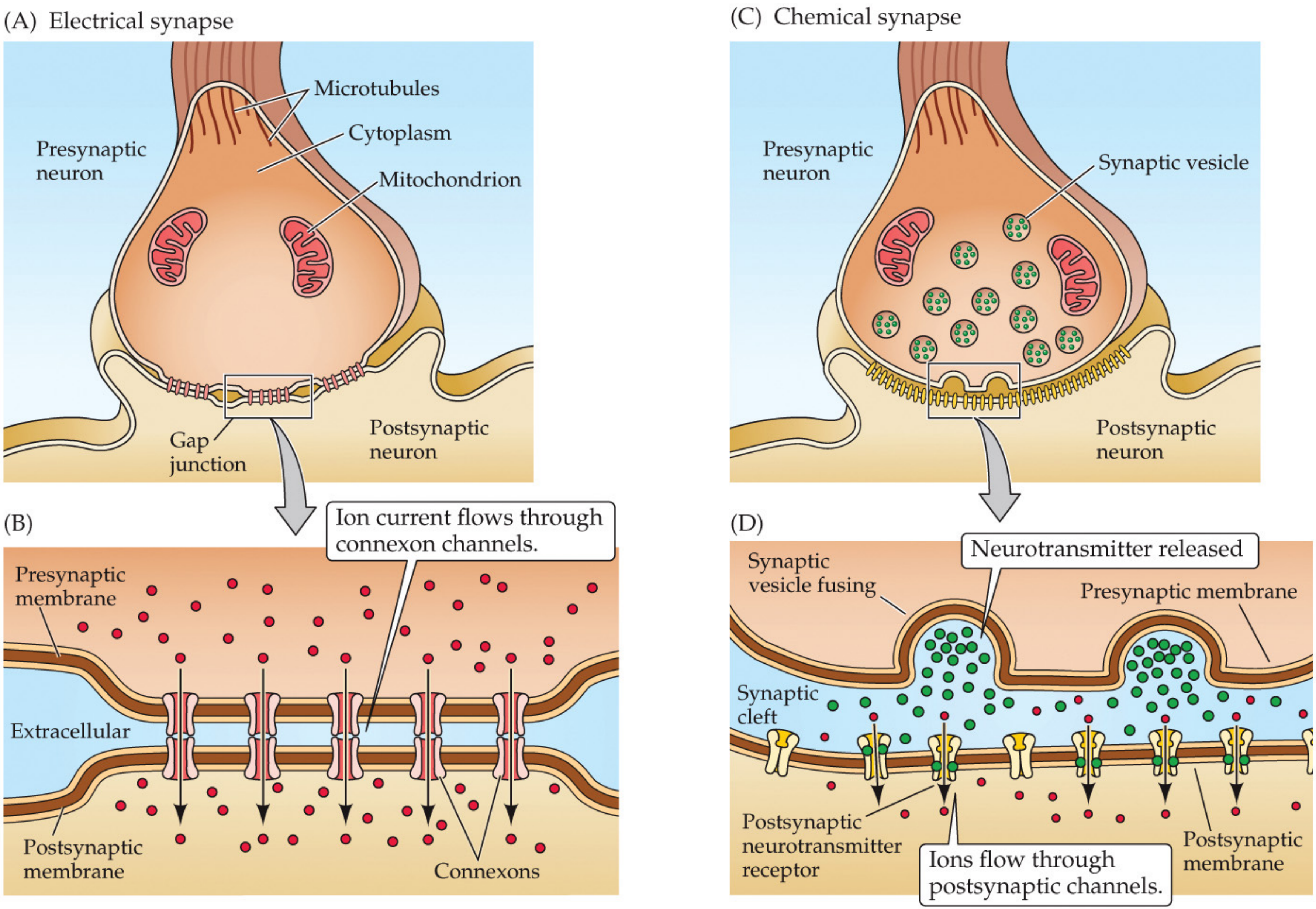
BMD ENG 301Quantitative Systems Physiology (Nervous System)

Lecture 10: Synaptic Transmission
2022_v2

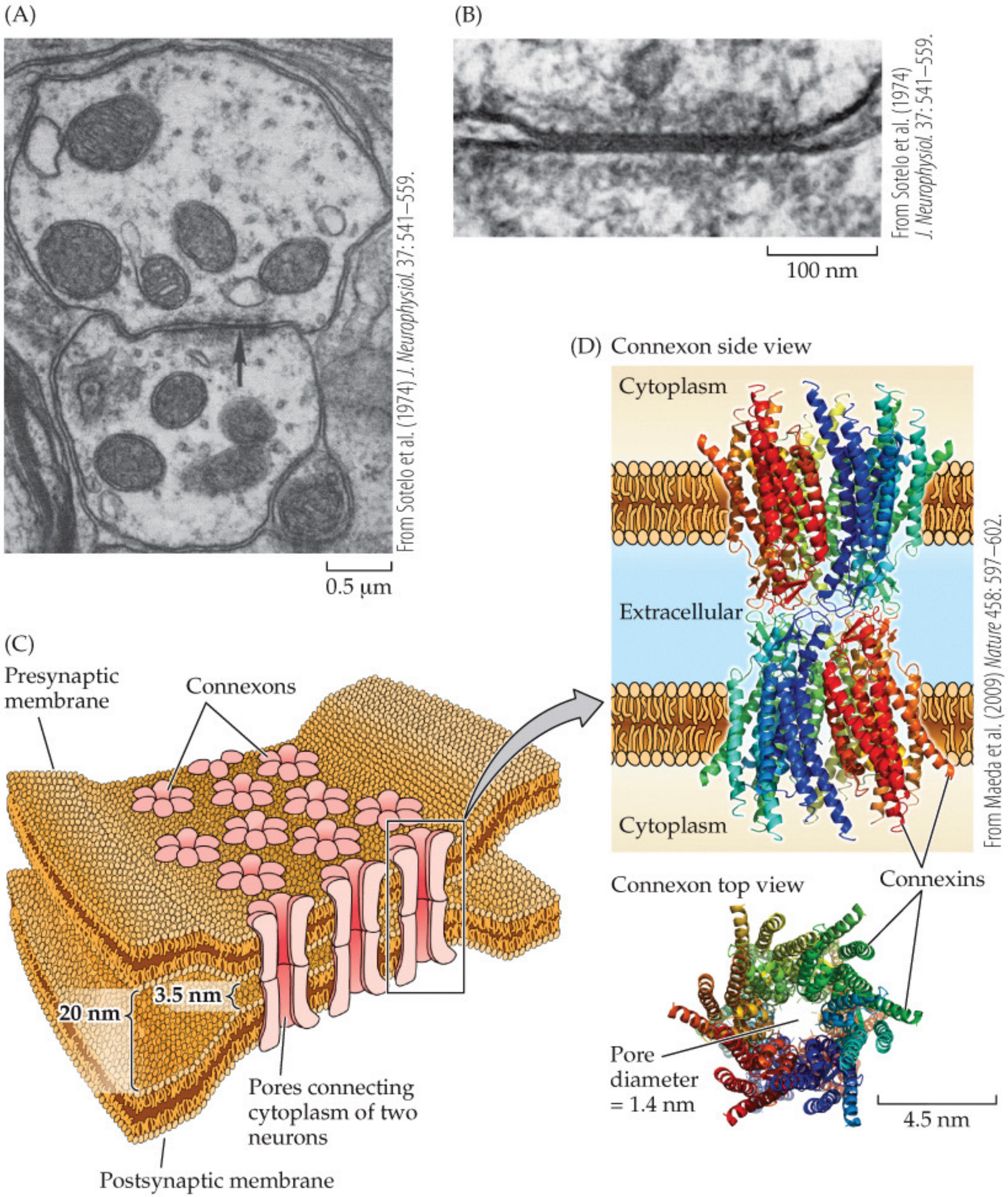
Professor Malcolm A. MacIver

Electrical and chemical synapses differ fundamentally in their transmission mechanisms



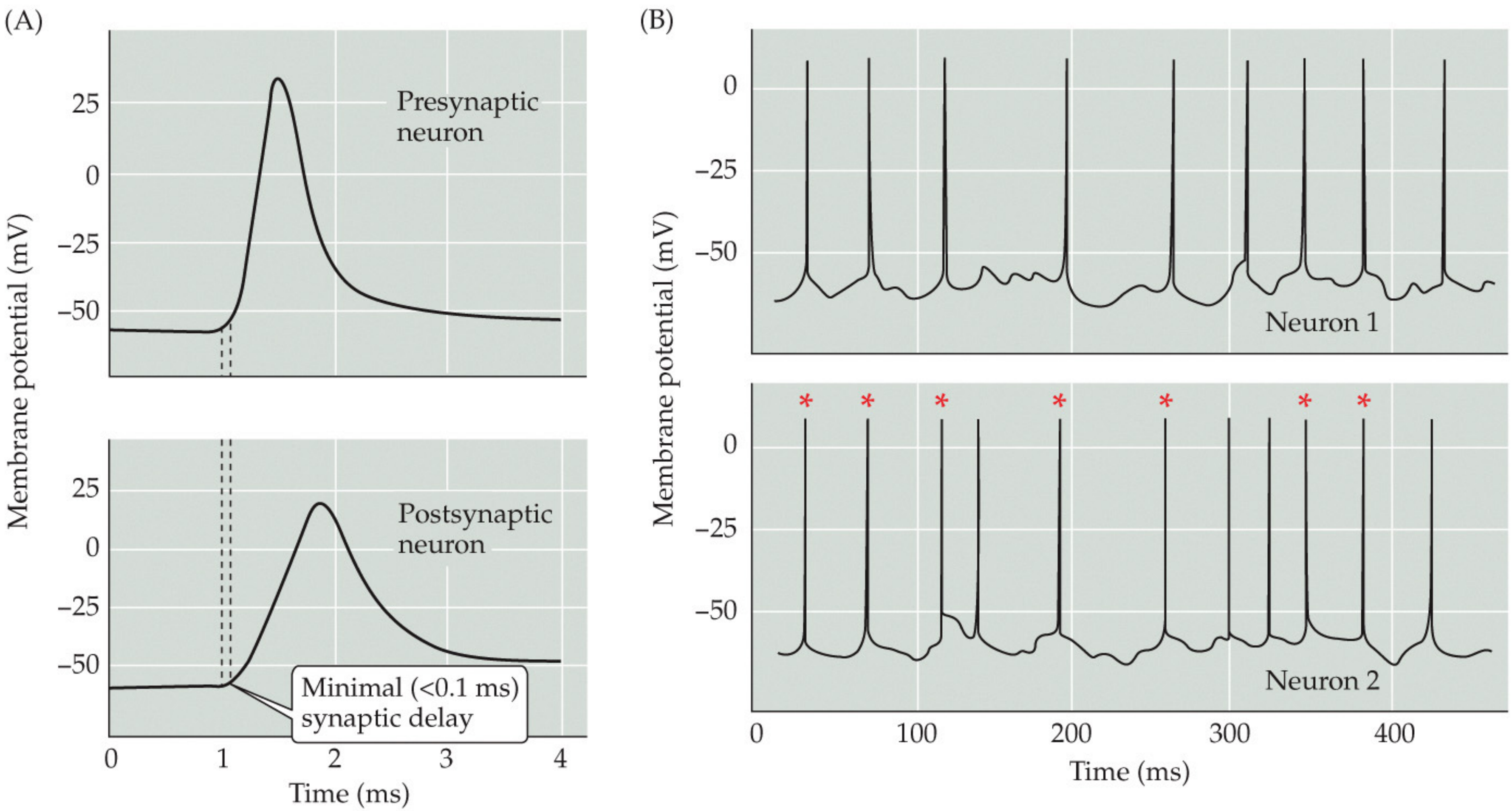
NEUROSCIENCE 6e, Figure 5.1

Structure of electrical synapses



NEUROSCIENCE 6e, **Figure 5.2**

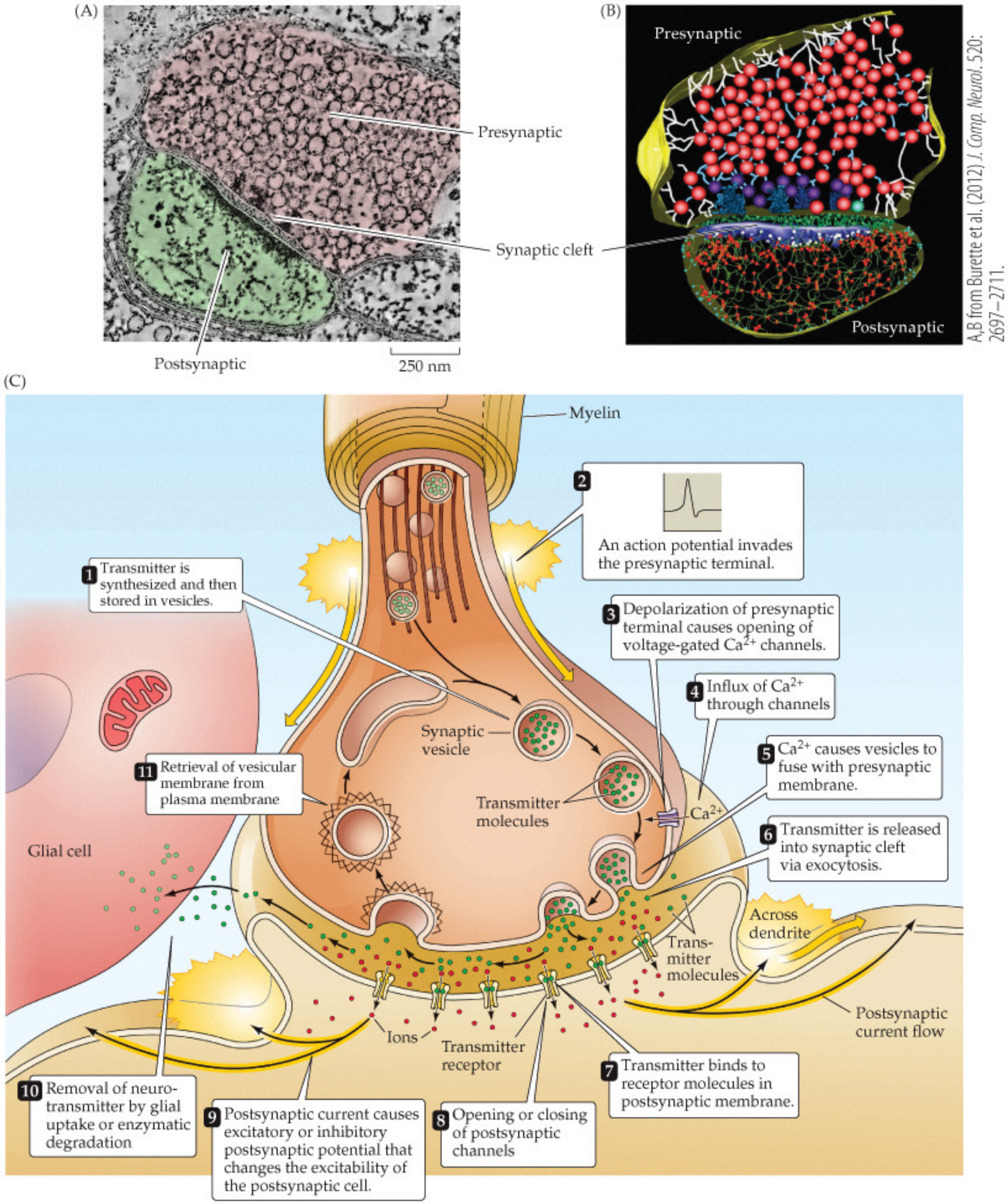
Function of gap junctions at electrical synapses



A after Furshpan and Potter (1959) *J. Physiol.* (Lond.) 145: 289–324. B after Beierlein and Connors (2000) *Nature Neurosci.* 3: 904–910.

***NEUROSCIENCE 6e*, Figure 5.3**

Structure and function of chemical synapses



NEUROSCIENCE 6e, Figure 5.4
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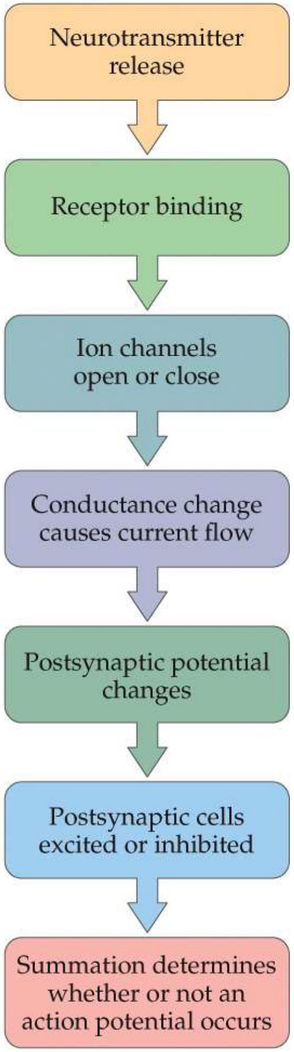

Presynaptic Neuron

Postsynaptic Neuron

NEUROSCIENCE 6e, Figure 5.21
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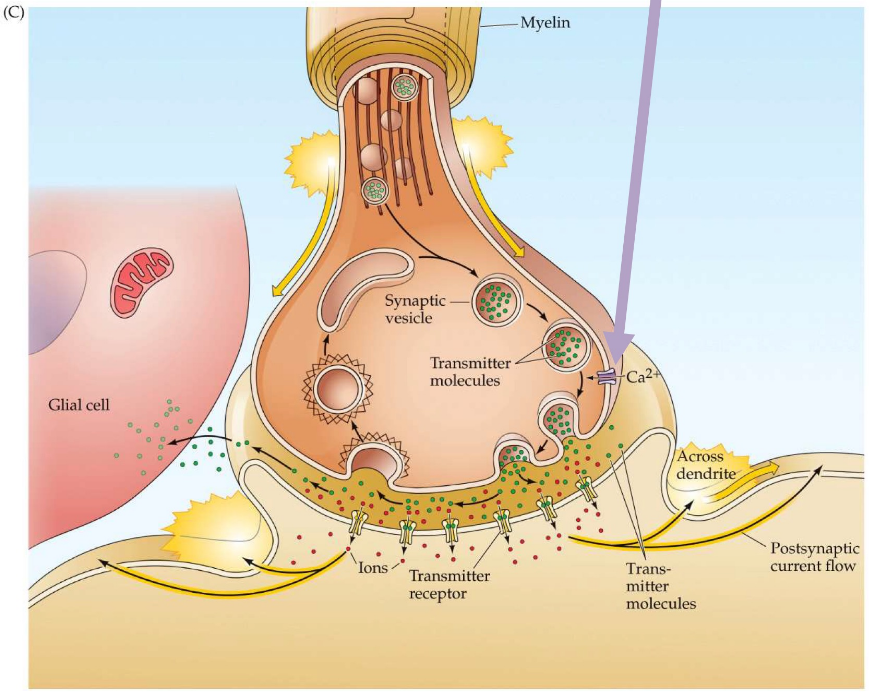
2. Influx of Ca^{2+} ions triggers vesicle release of neurotransmitters

Voltage-gated calcium channels open upon depolarization from the action potential



NEUROSCIENCE 6e, Figure 5.4 (Part 3)

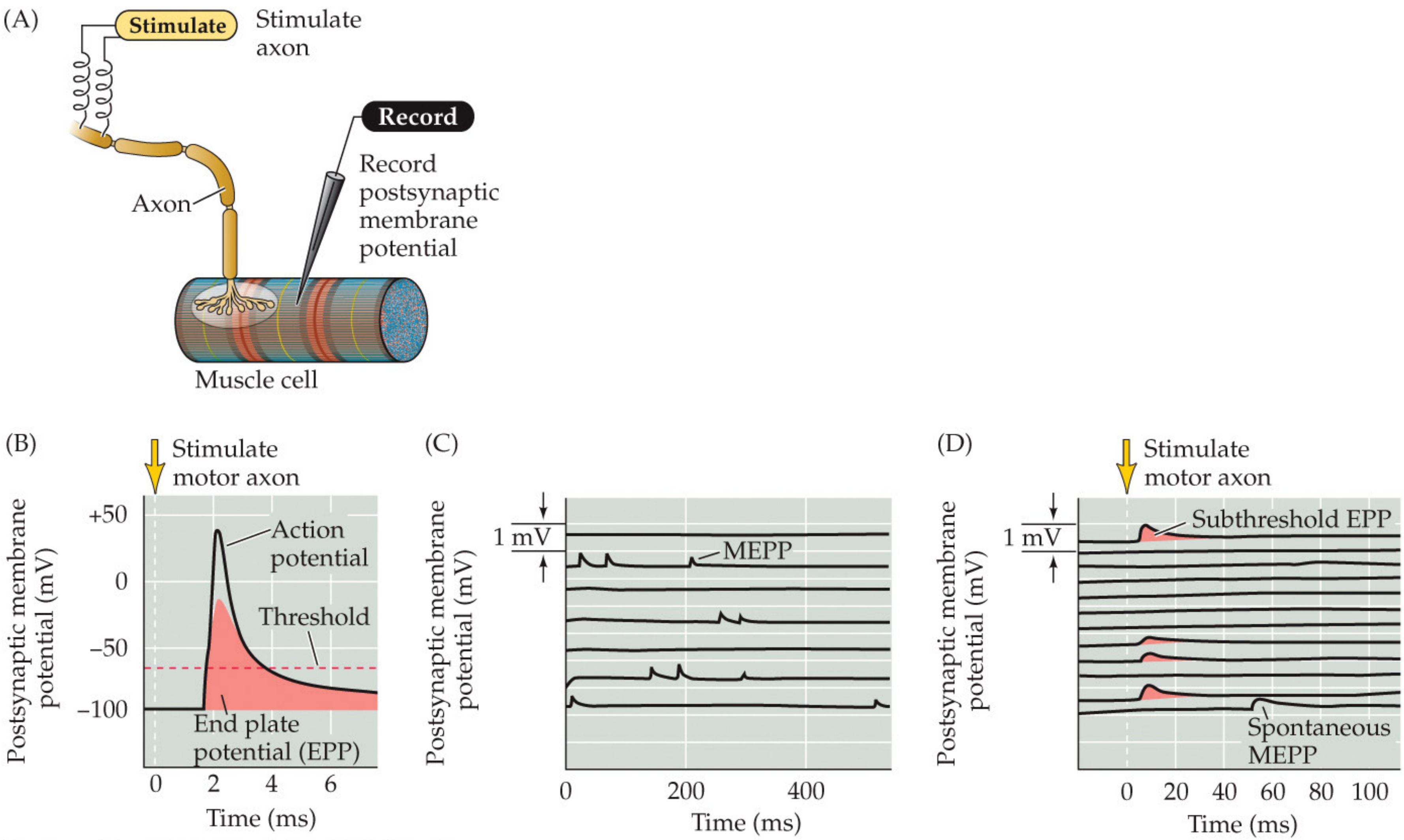
TABLE 2.1 ■ Extracellular and Intracellular Ion Concentrations

	Concentration (m*M*)	
Ion	**Intracellular**	**Extracellular**
Squid neuron		
Potassium (K^+)	400	20
Sodium (Na^+)	50	440
Chloride (Cl^-)	40–150	560
Calcium (Ca^{2+})	0.0001	10
Mammalian neuron		
Potassium (K^+)	140	5
Sodium (Na^+)	5–15	145
Chloride (Cl^-)	4–30	110
Calcium (Ca^{2+})	0.0001	1–2

NEUROSCIENCE 6e, Table 2.1

Ca^{2+} is a critical intracellular signaling molecule!

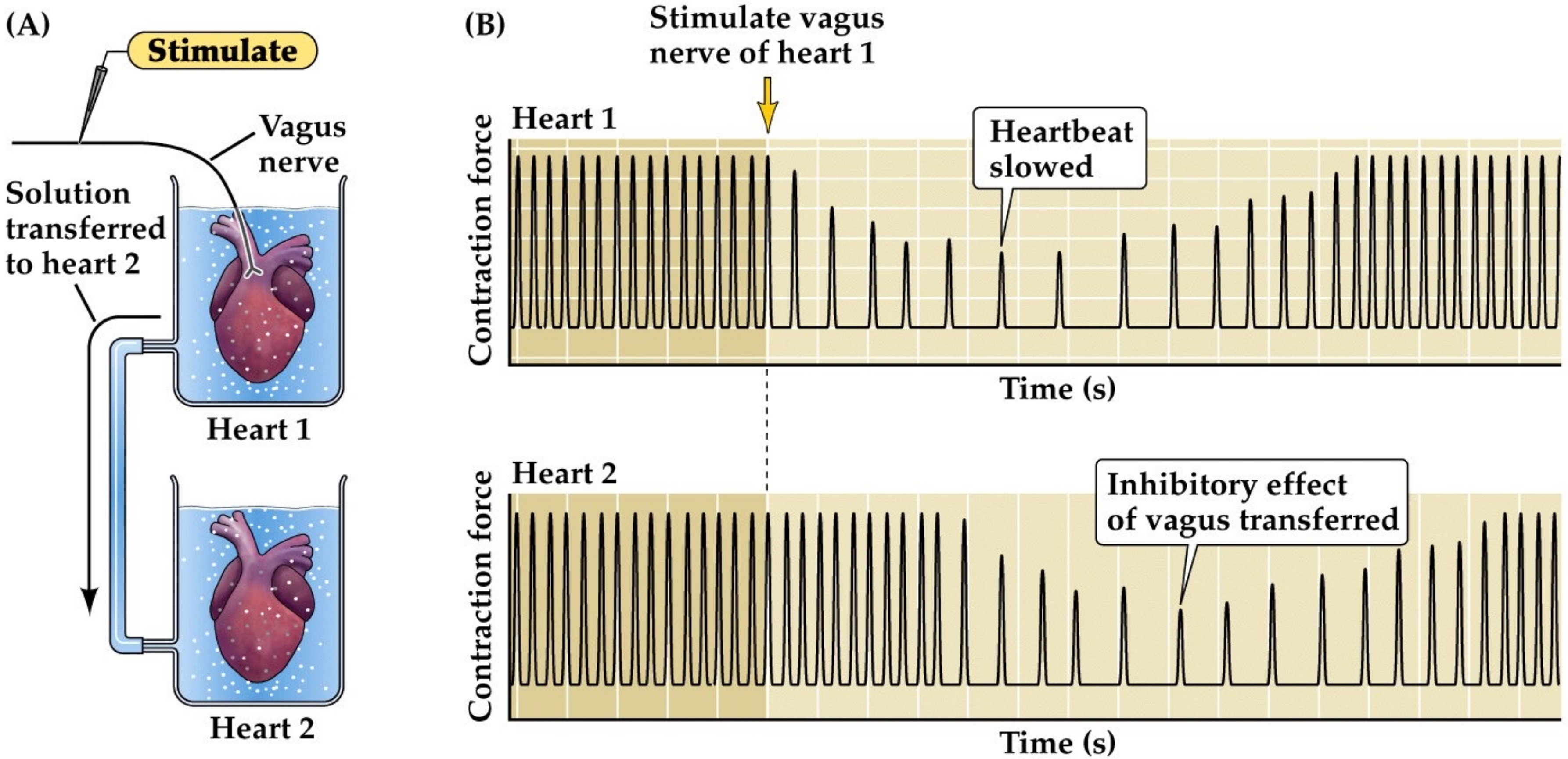
Synaptic transmission at the neuromuscular junction



After Fatt and Katz (1952) *J. Physiol.* (Lond.) 117: 109–127.

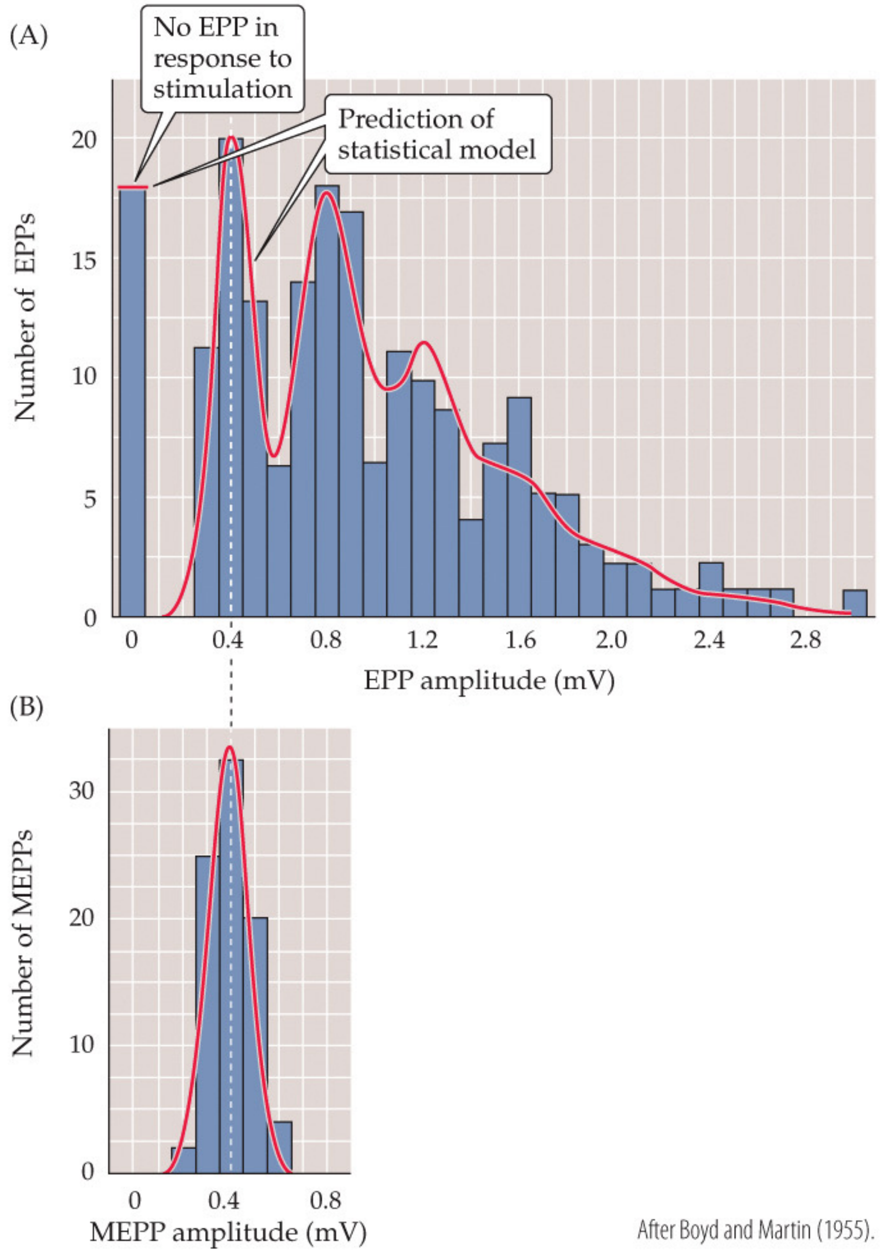
***NEUROSCIENCE 6e*, Figure 5.5**

Figure 5.4 Loewi's experiment demonstrated chemical neurotransmission



NEUROSCIENCE 5e, **Figure 5.4**

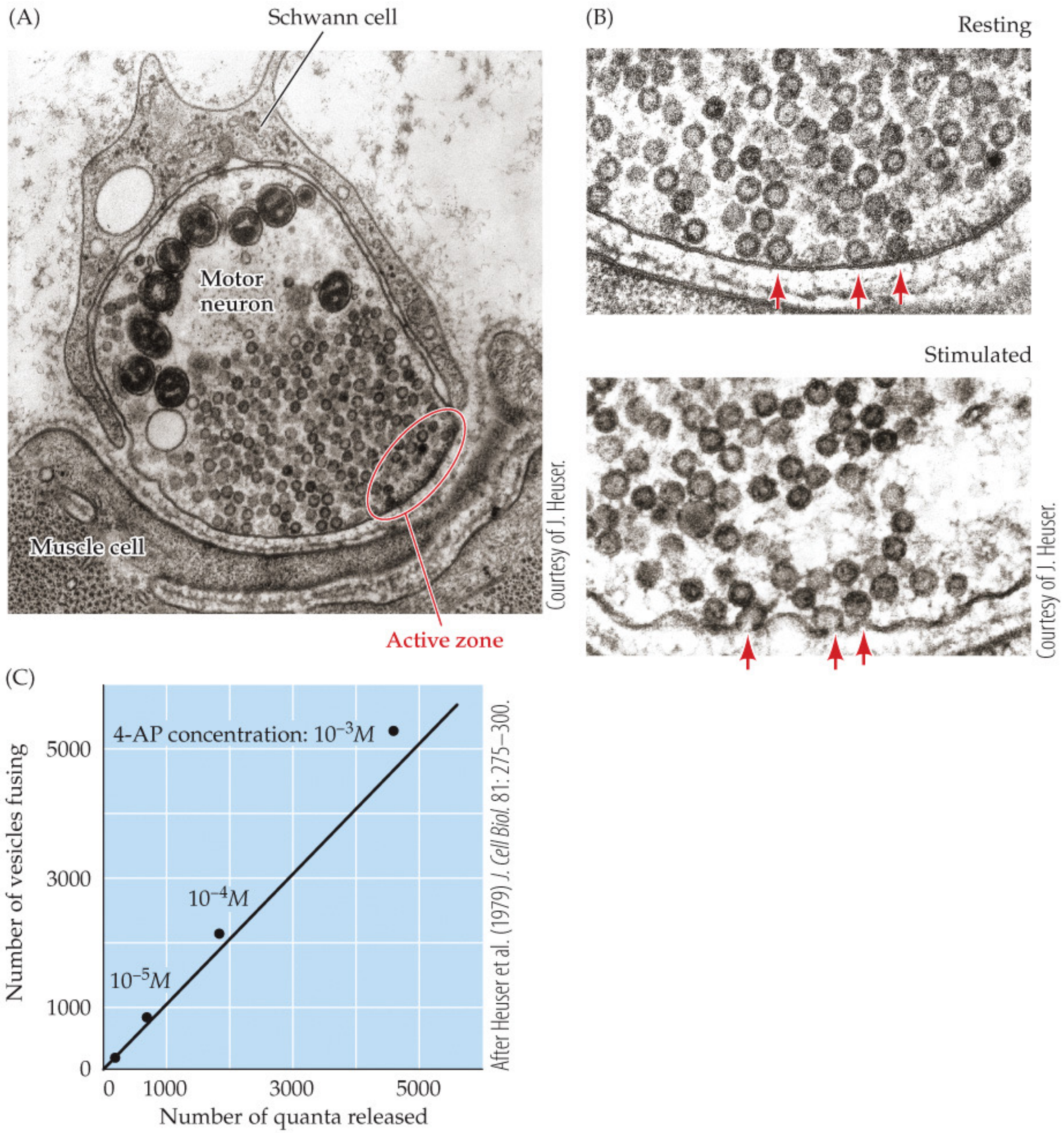
Quantized distribution of EPP amplitudes evoked in a low-Ca^{2+} solution



After Boyd and Martin (1955).

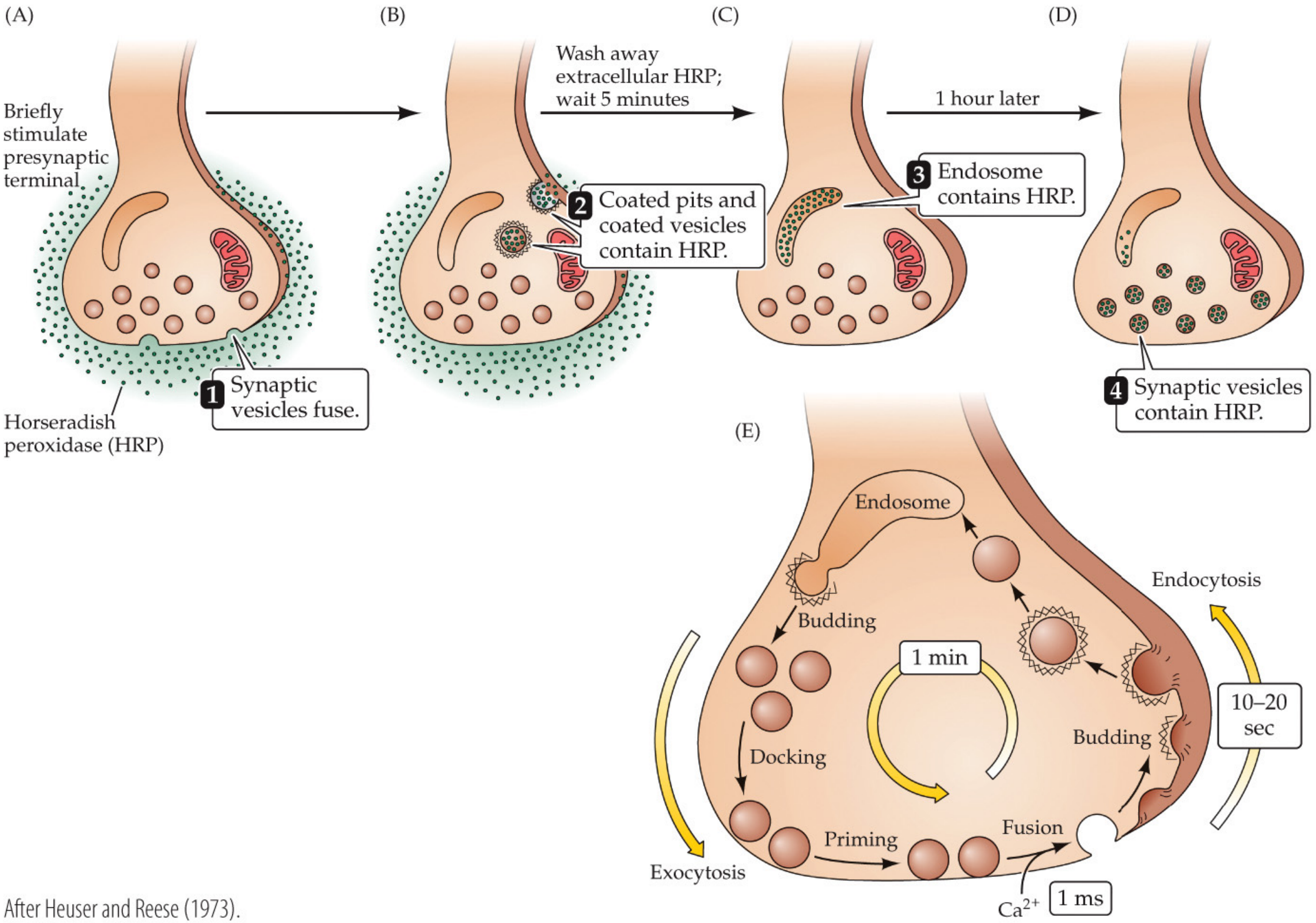
NEUROSCIENCE 6e, Figure 5.6

Relationship between synaptic vesicle exocytosis and quantal transmitter release



NEUROSCIENCE 6e, Figure 5.7

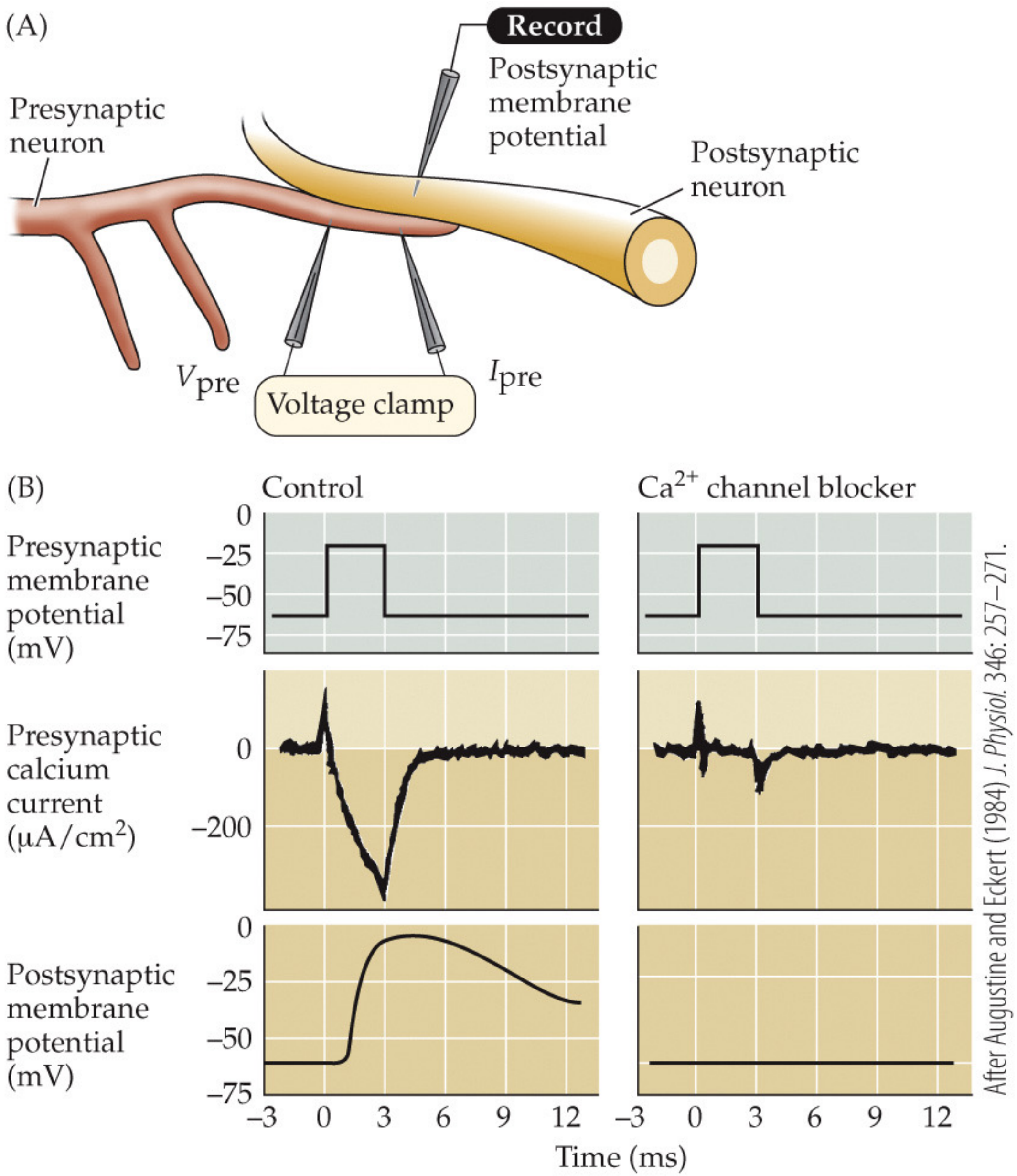
Local recycling of synaptic vesicles in presynaptic terminals



After Heuser and Reese (1973).

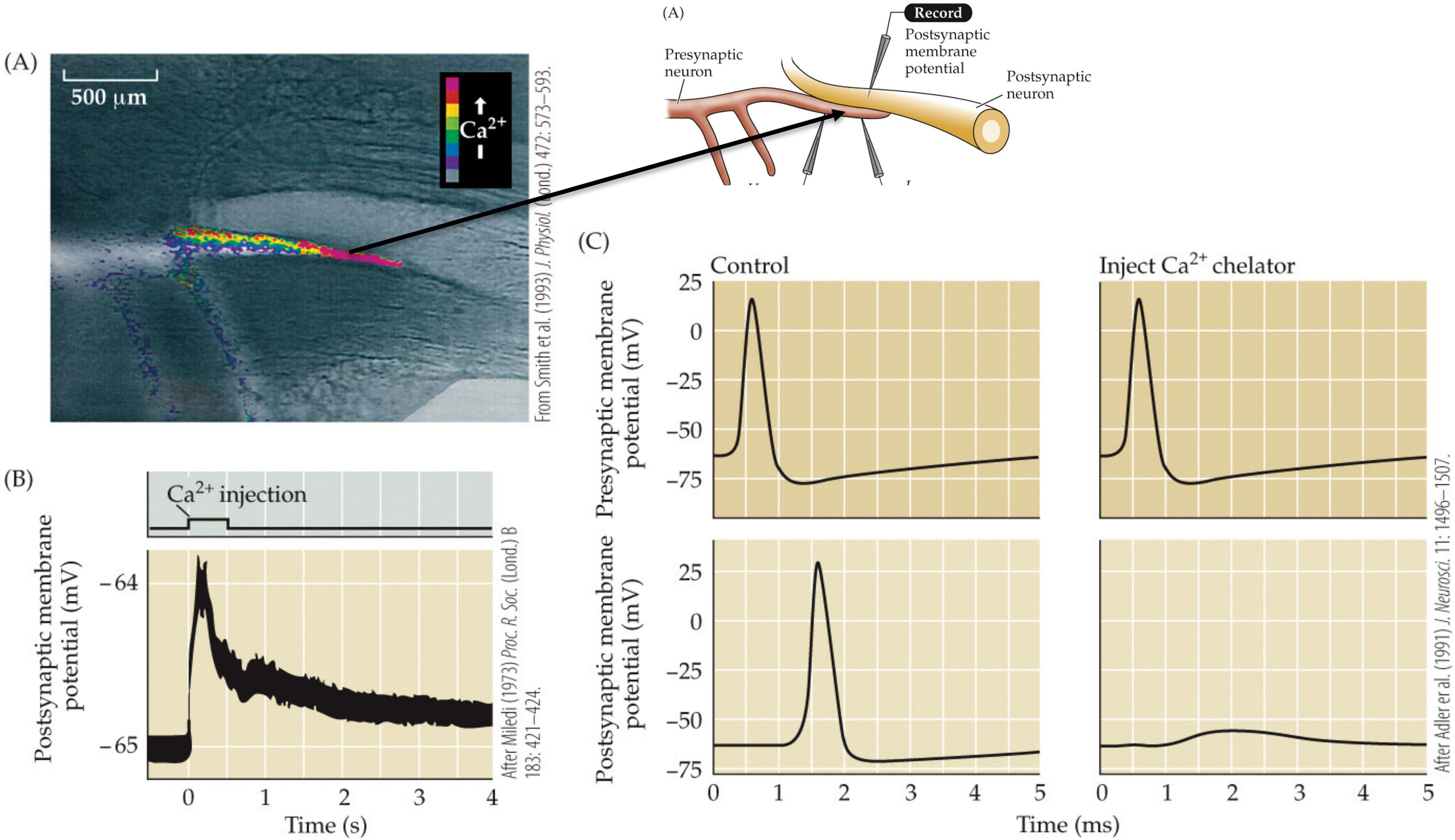
NEUROSCIENCE 6e, Figure 5.8

Entry of Ca^{2+} through presynaptic voltage-gated calcium channels causes transmitter release



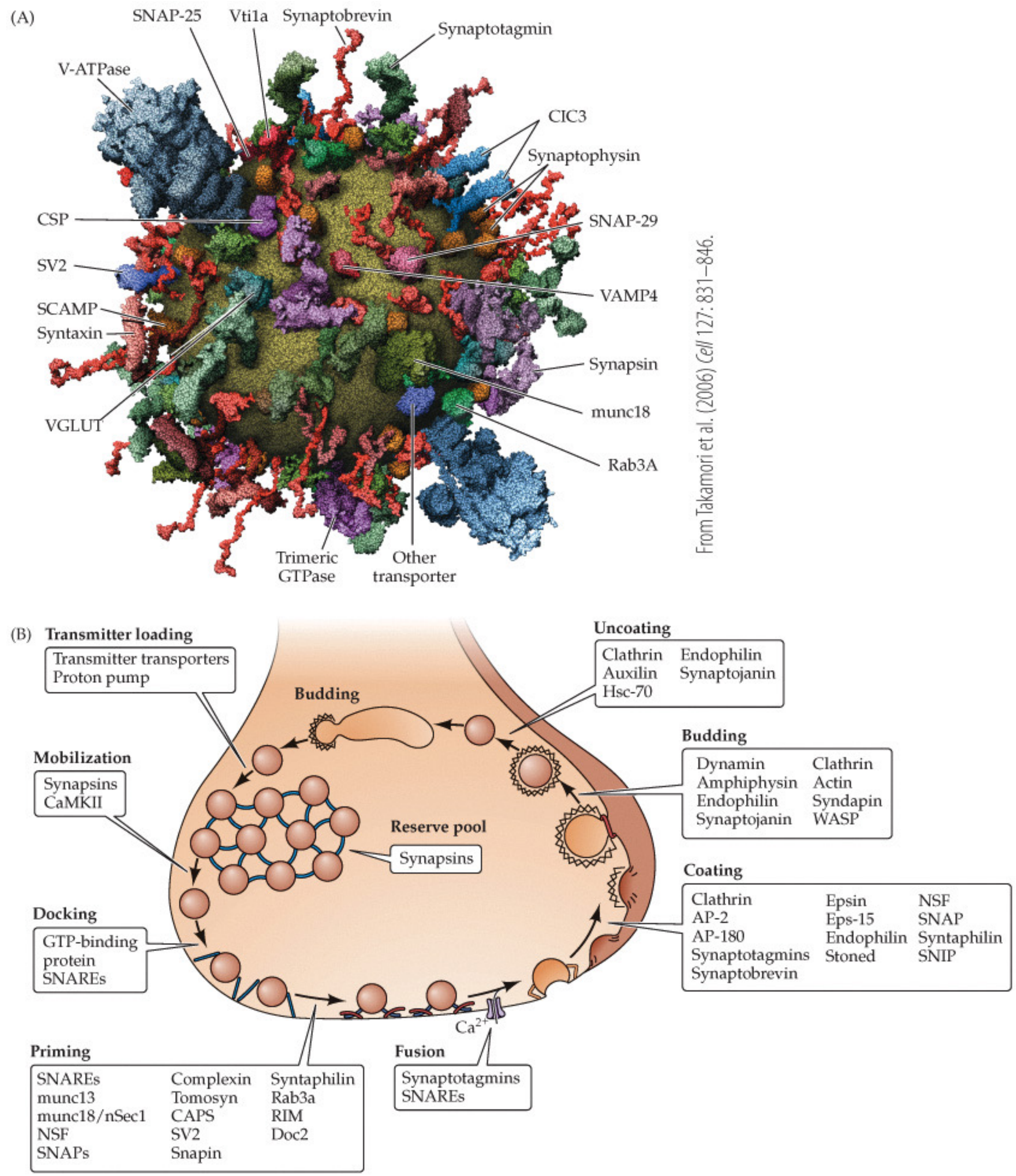
NEUROSCIENCE 6e, Figure 5.9

Evidence that a rise in presynaptic Ca^{2+} concentration triggers transmitter release from presynaptic terminals



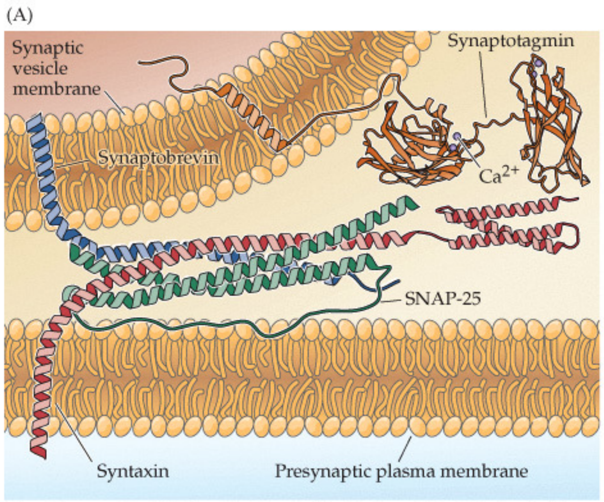
NEUROSCIENCE 6e, Figure 5.10

Presynaptic proteins and their roles in synaptic vesicle cycling

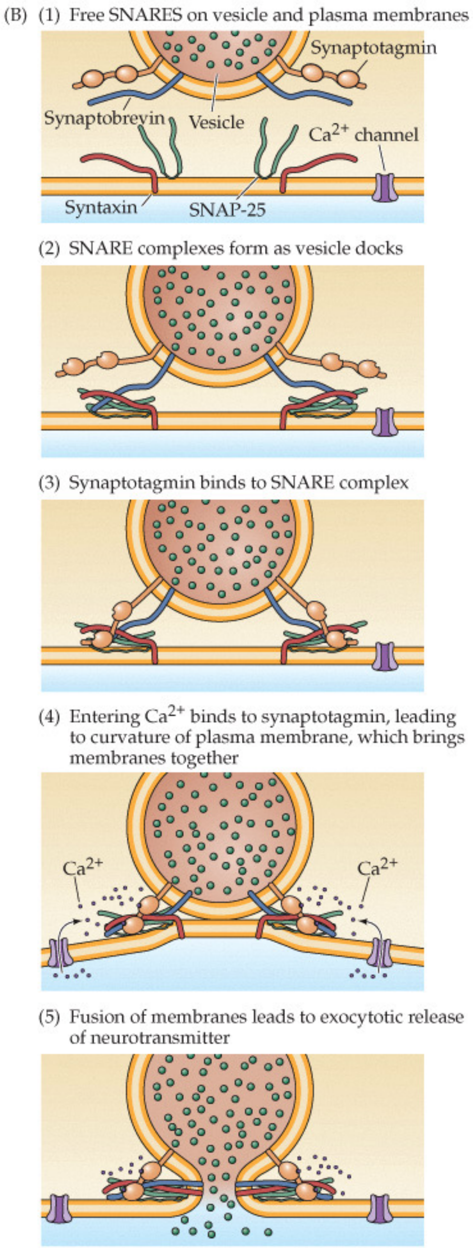


NEUROSCIENCE 6e, Figure 5.11

Molecular mechanisms of exocytosis during neurotransmitter release

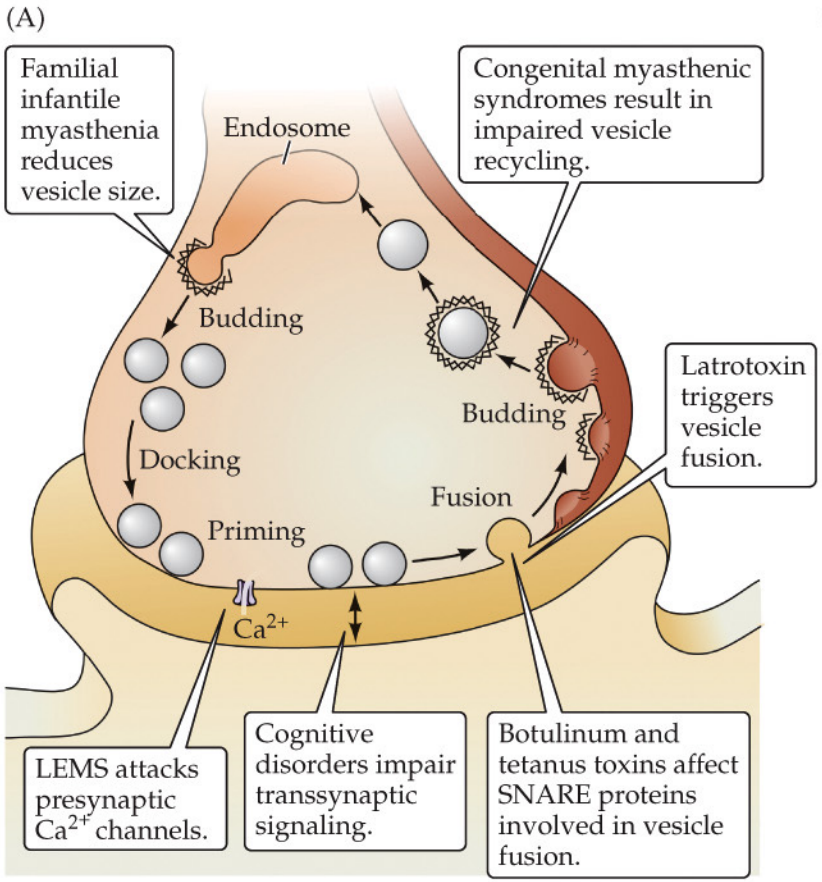


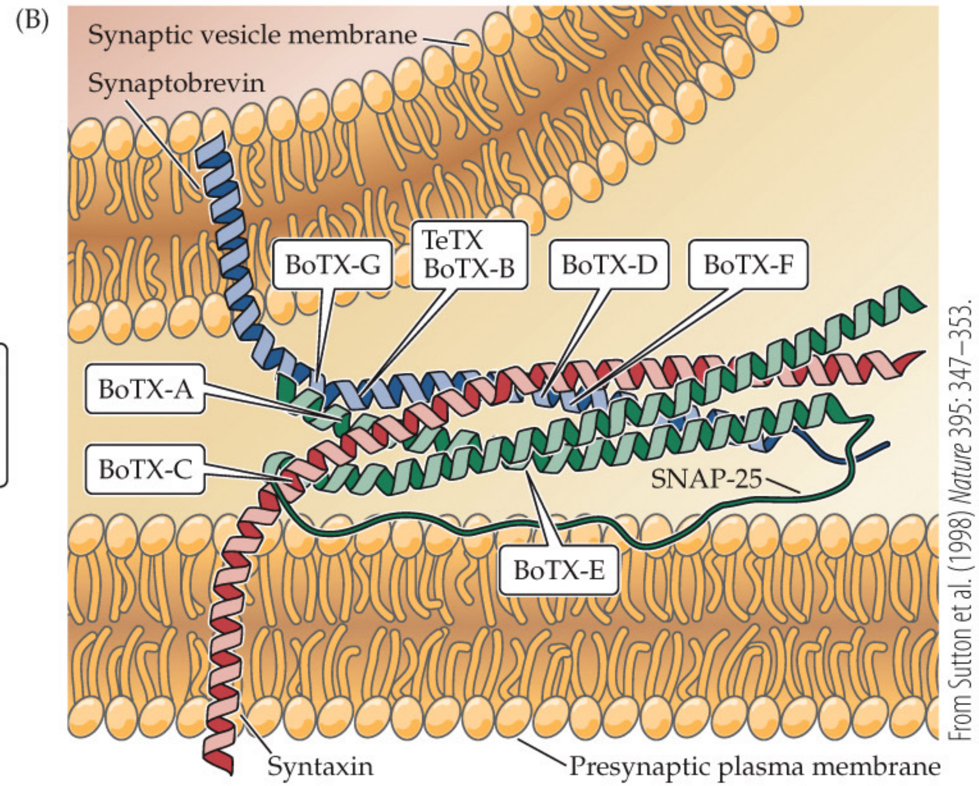
A from Sutton et al. (1998) *Nature* 395: 347–35. Also Madej et al. (2014) *Nucleic Acids Res.* D297–303. B after Zhou et al. (2015) *Nature* 525: 62–67.



NEUROSCIENCE 6e, Figure 5.12

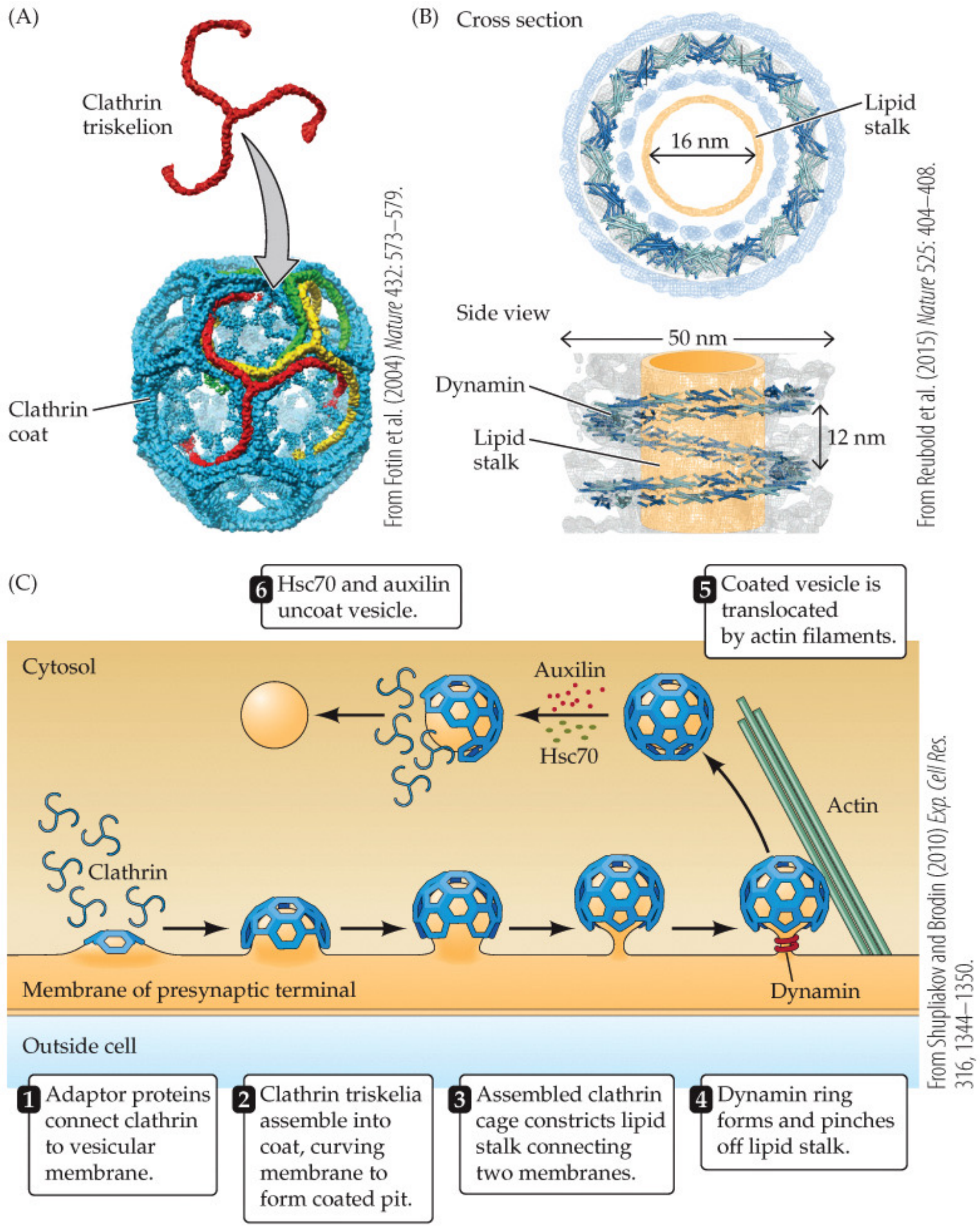
CLINICAL APPLICATIONS Disorders That Affect the Presynaptic Terminal





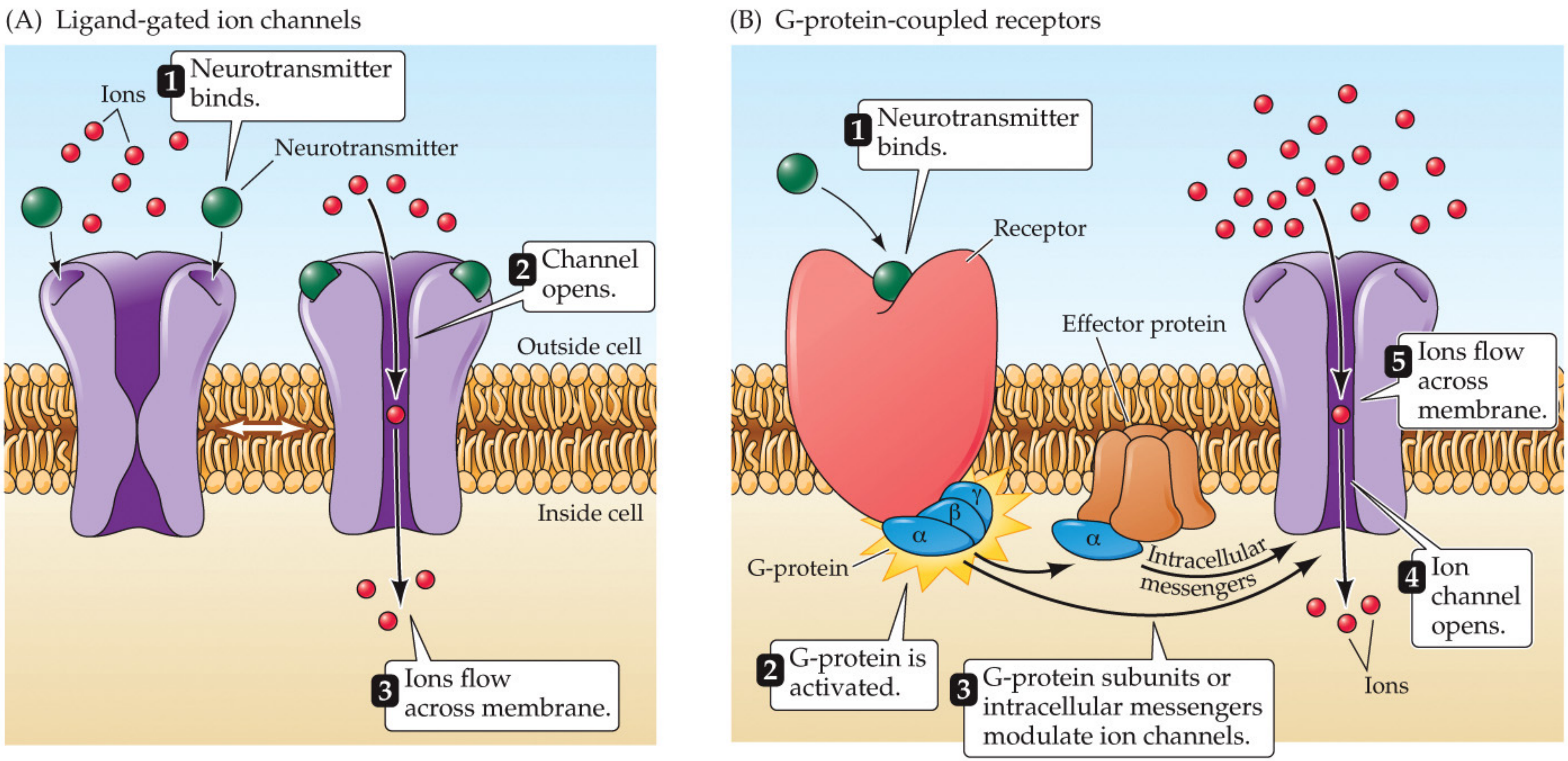
NEUROSCIENCE 6e, Clinical Applications 5

Molecular mechanisms of endocytosis following neurotransmitter release



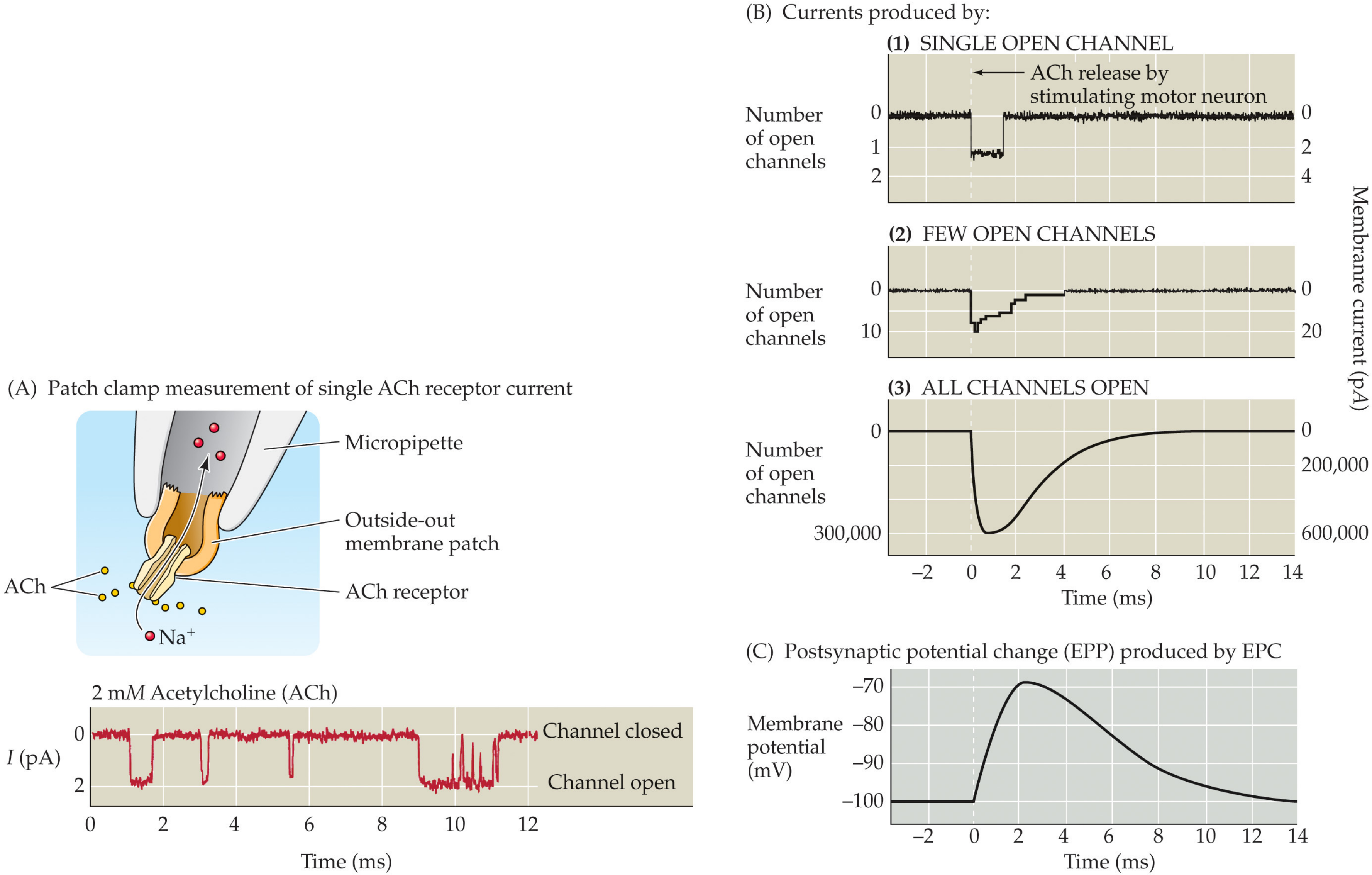
NEUROSCIENCE 6e, Figure 5.13

Two different types of neurotransmitter receptors



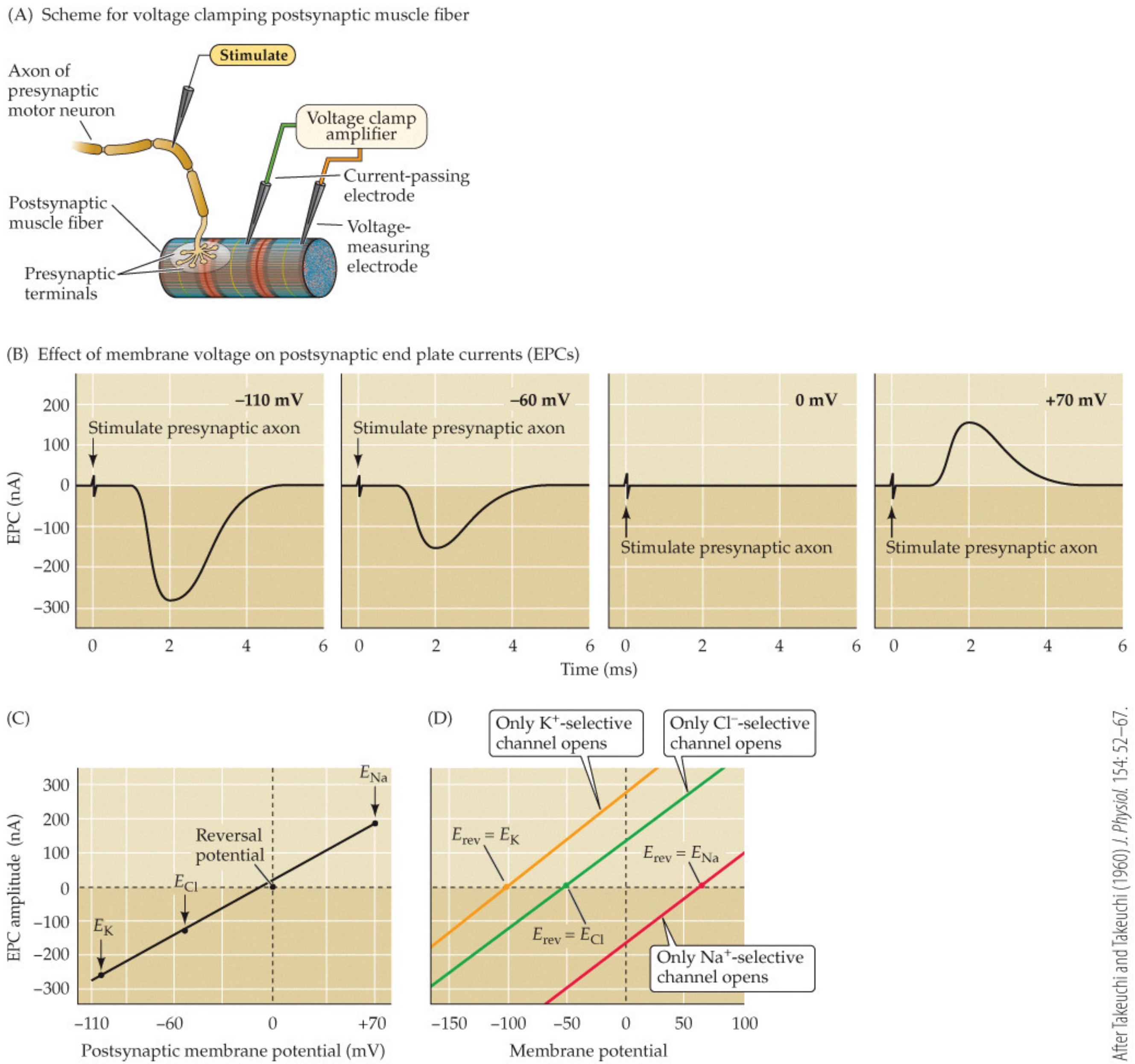
NEUROSCIENCE 6e, Figure 5.14

Activation of ACh receptors at neuromuscular synapses



NEUROSCIENCE 6e, Figure 5.15

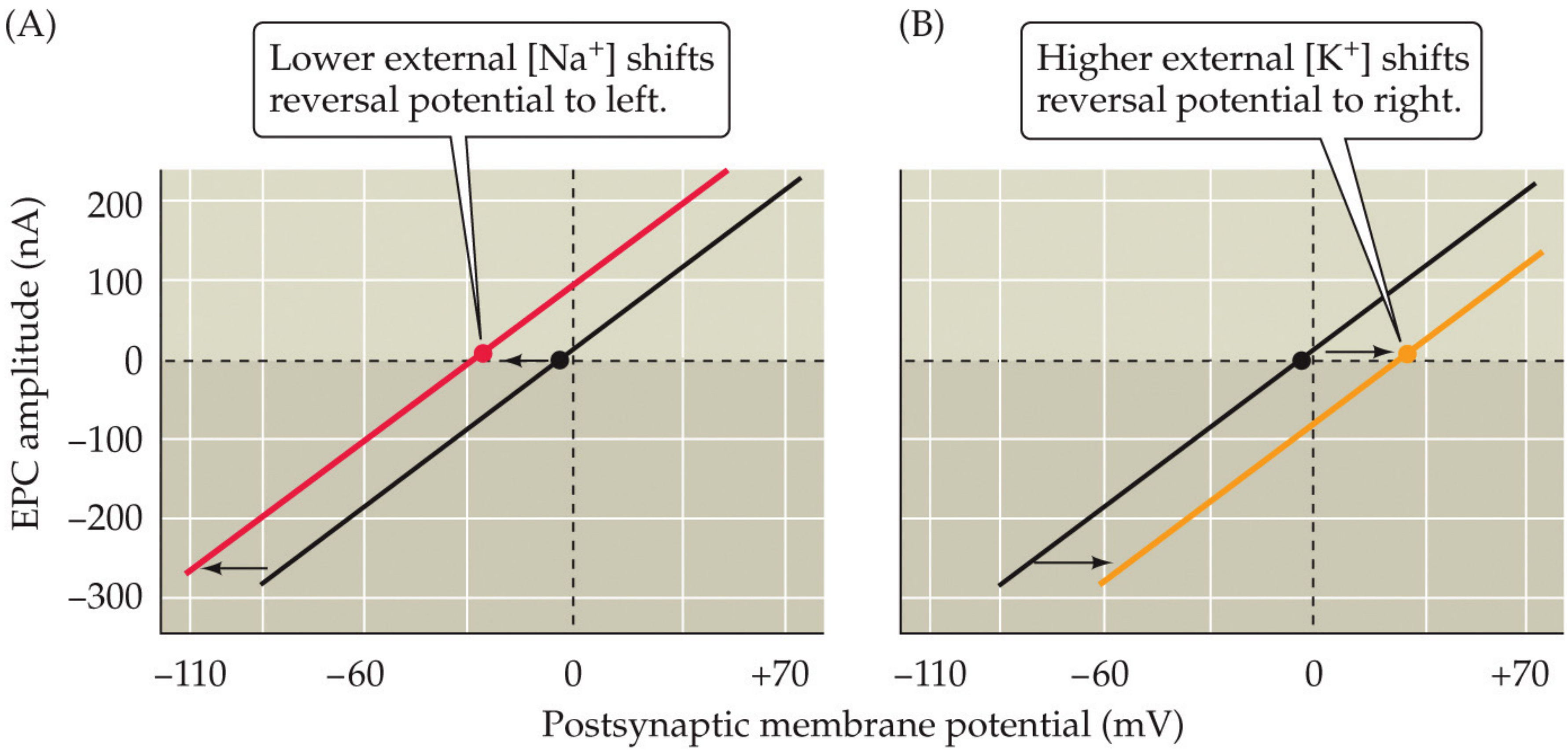
Influence of the postsynaptic membrane potential on end plate currents



After Takeuchi and Takeuchi (1960) *J. Physiol.* 154: 52–67.

***NEUROSCIENCE 6e*, Figure 5.16**

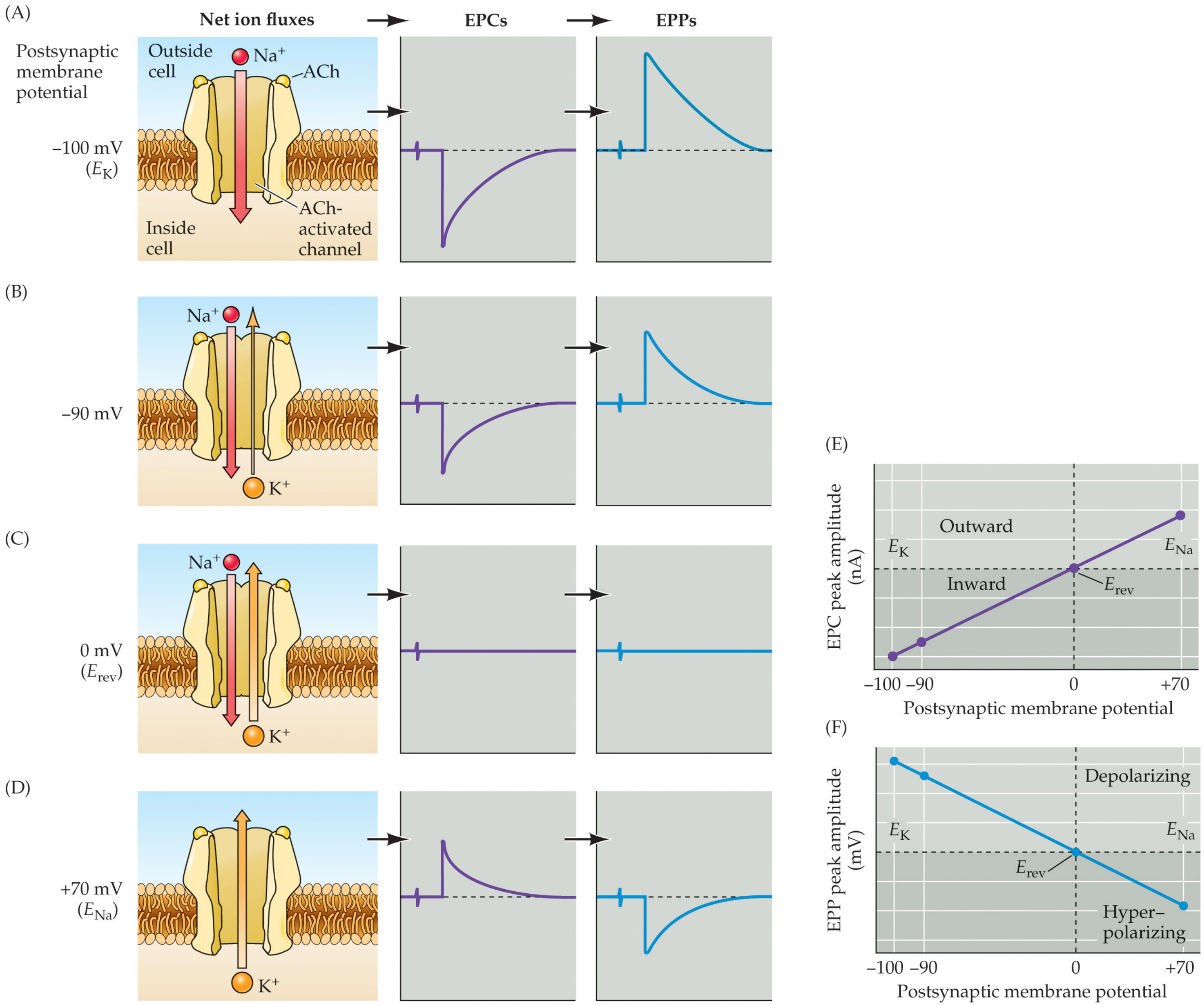
Reversal potential of the end plate current changes when ion gradients change



After Takeuchi and Takeuchi (1960) *J. Physiol.* 154: 52–67.

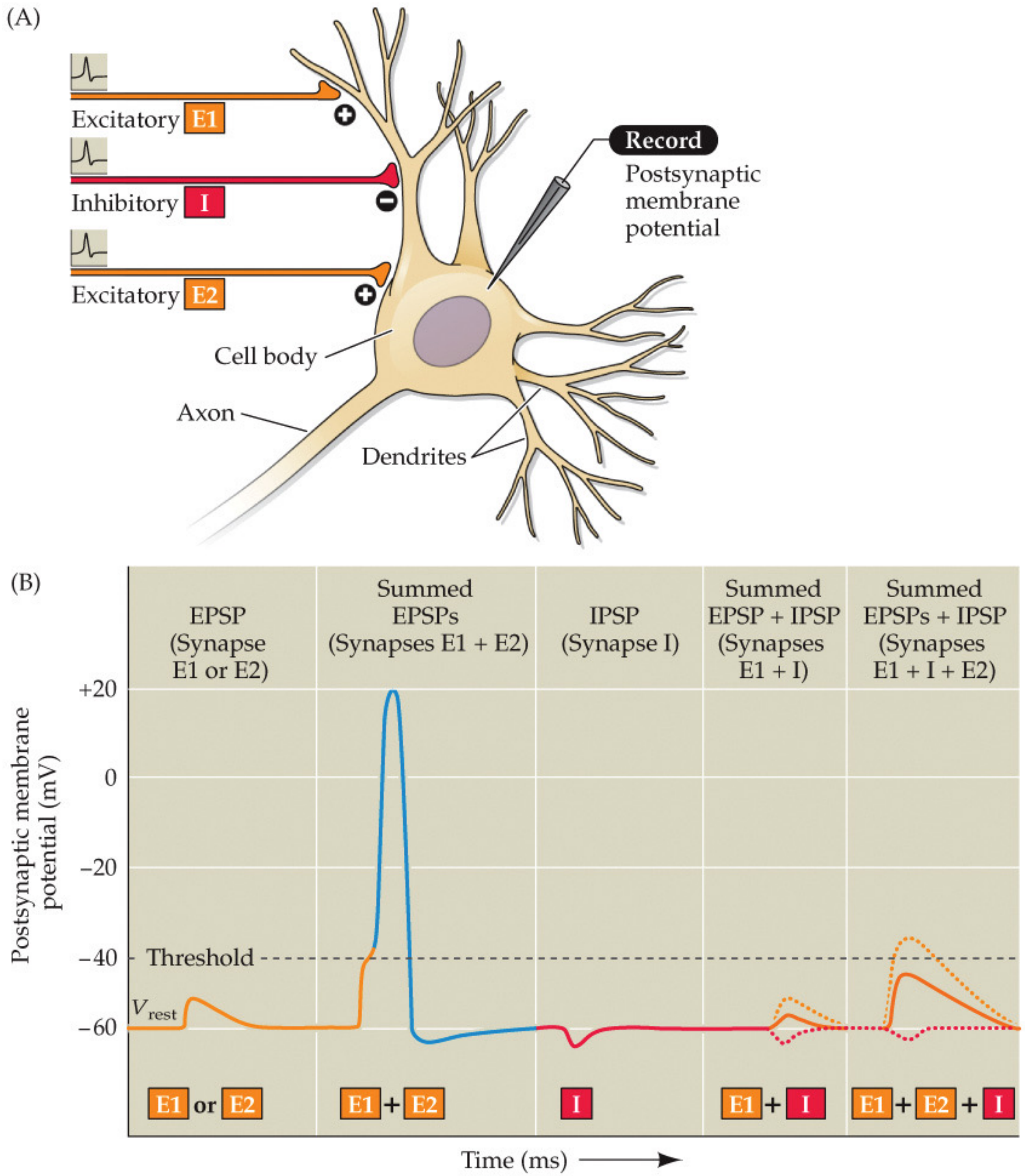
***NEUROSCIENCE 6e*, Figure 5.17**

Na⁺ and K⁺ movements during EPCs and EPPs



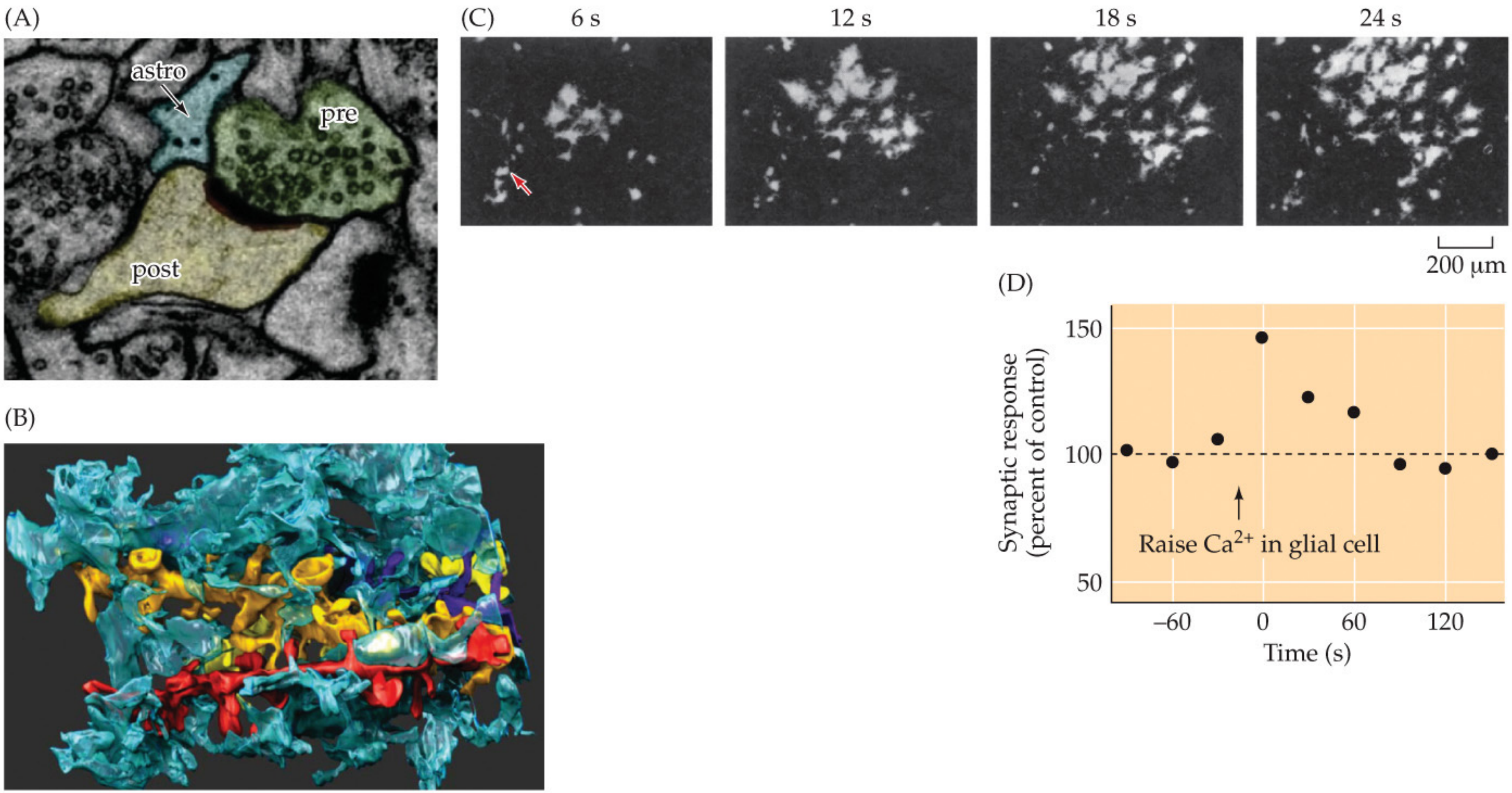
NEUROSCIENCE 6e, Figure 5.18

Summation of postsynaptic potentials



NEUROSCIENCE 6e, Figure 5.20

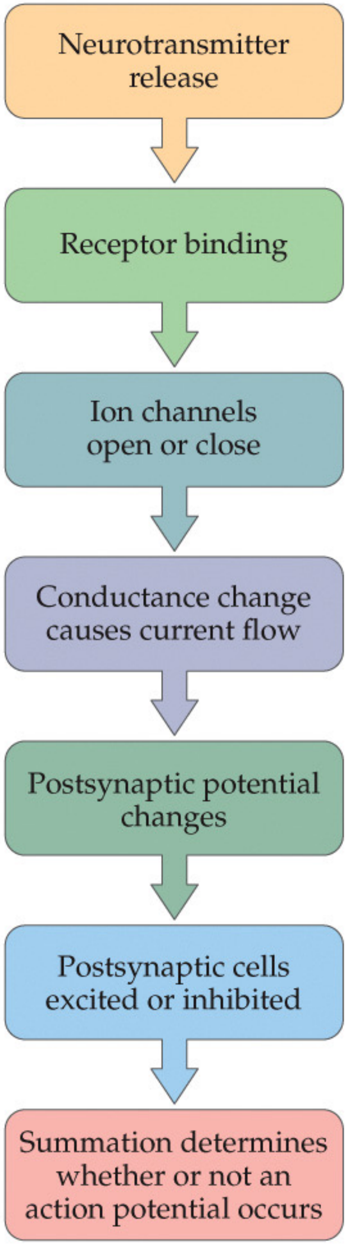
The Tripartite Synapse



A,B from Witcher et al.(2007) *Glia* 55: 13–24. C from Cornell-Bell et al. (1990) *Science* 247: 470-473. D from Perea and Araque (2007) Science 317: 1083–1086.

***NEUROSCIENCE 6e*, Box 5A**

Overview of postsynaptic signaling



NEUROSCIENCE 6e, Figure 5.21