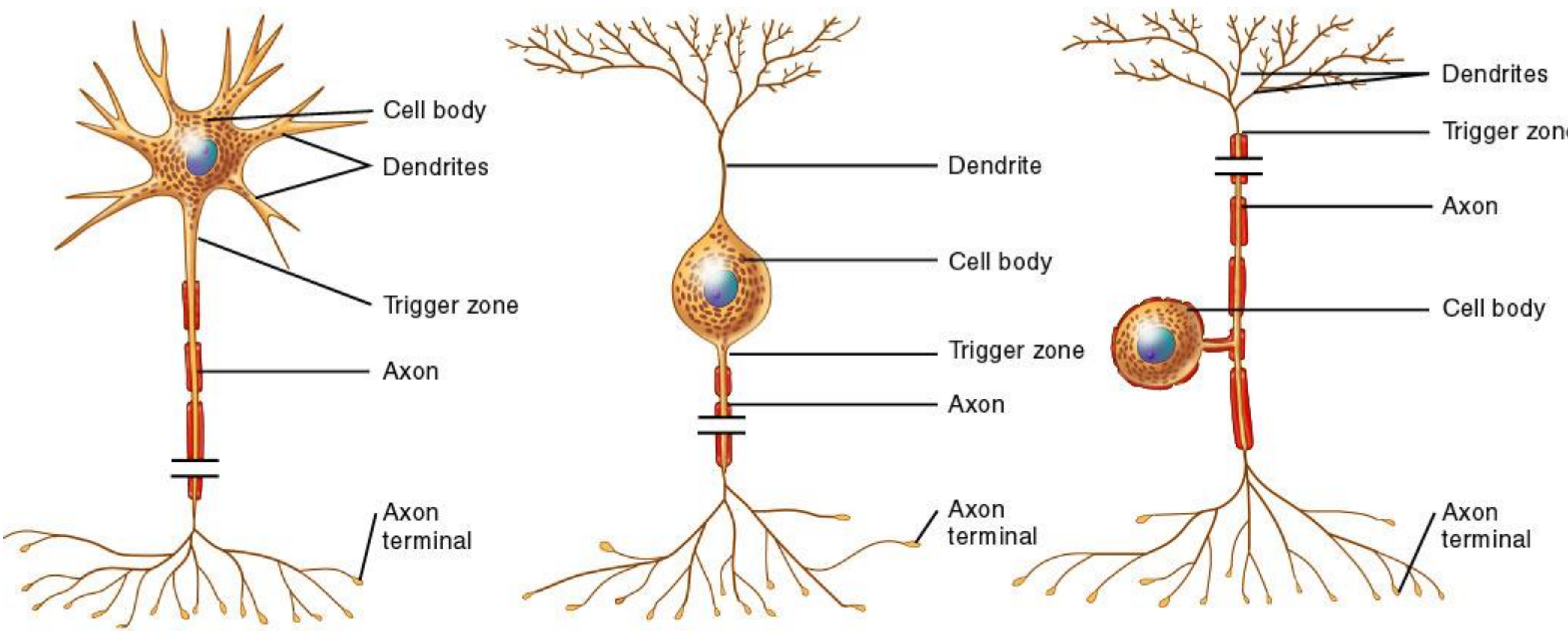
Nerve and Muscle Physiology

Plasma Membranes of Excitable tissues

Ref: Guyton, 12th ed: pp: 57-69. 11th ed: **p57-71**,



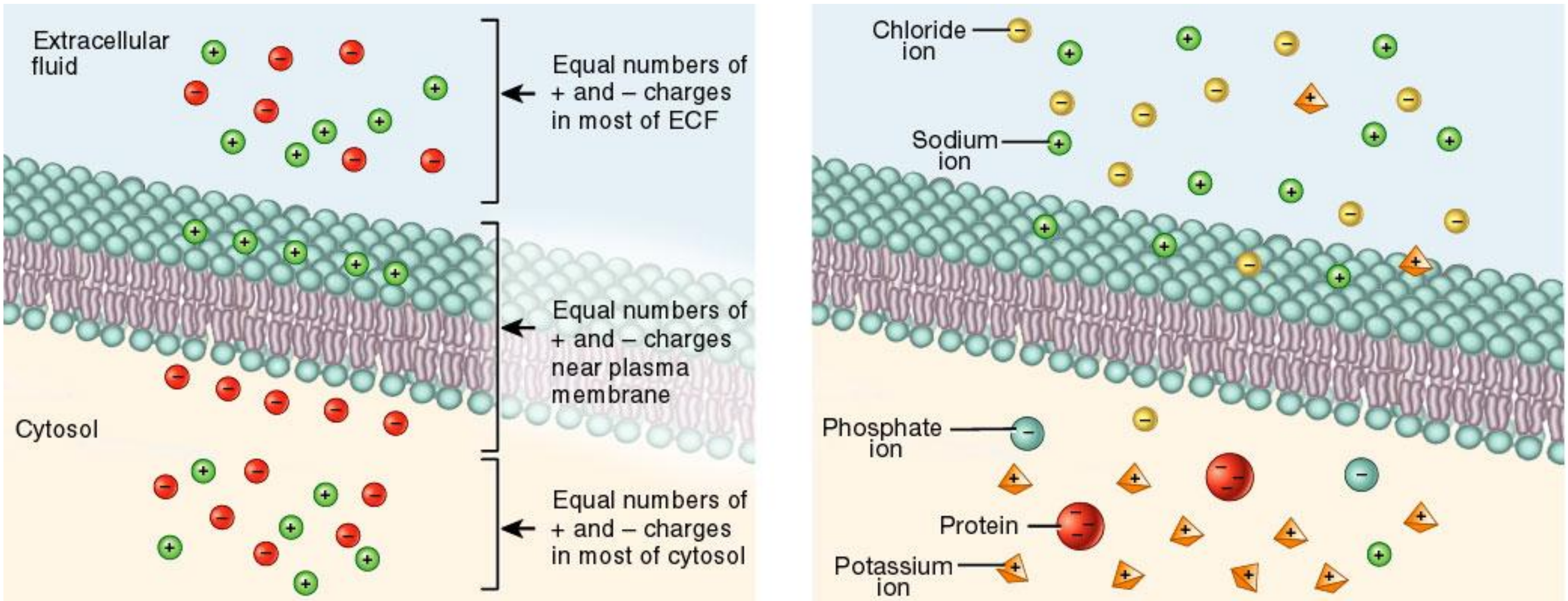
(a) Multipolar neuron

(b) Bipolar neuron

(c) Unipolar neuron

12.04

Fig. 12.09a,b



(a) Distribution of charges

(b) Distribution of ions

12.09ab

Nernest equation

$$E = \frac{RT}{ZF} \ln \frac{[C]out}{[C]in}$$

R (Gas Constant) = 8.314472 (J/K·mol)
T (Absolute Temperature) = t °C + 273.15 (°K)
Z (Valence)
F (Faraday's Constant) = 9.6485309×10^4 (C/mol)
[C]out (Outside Concentration, mM)
[C]in (Inside Concentration, mM)

E_{k+}

$$E_{eq,K^+} = 61.54mV \log \frac{[K^+]_o}{[K^+]_i},$$

E (mV) = - 61.log (Ci/Co)

E = Equilibrium potential for a univalent ion

Ci = conc. inside the cell.

Co = conc. outside the cell.

Goldman Hodgkin Katz equation

$$E_m = \frac{RT}{F} \ln \left(\frac{P_{Na^+}[Na^+]_o + P_{K^+}[K^+]_o + P_{Cl^-}[Cl^-]_i}{P_{Na^+}[Na^+]_i + P_{K^+}[K^+]_i + P_{Cl^-}[Cl^-]_o} \right)$$

Goldman-Hodgkin-Katz equation

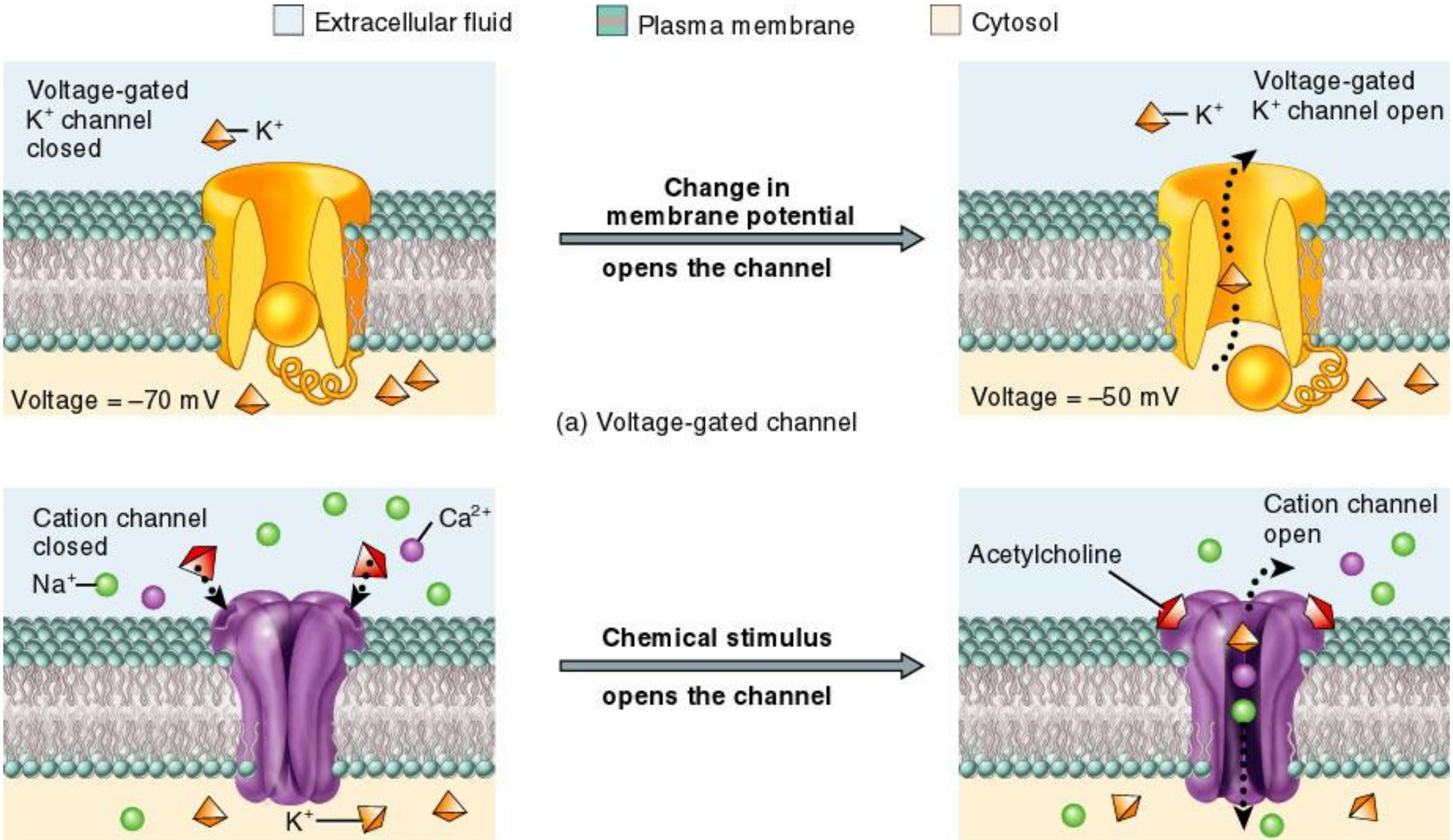
EMF (mV) =

$$- 61.\log \frac{[(C_iNa^+ . P_{Na^+} + C_iK^+ . P_{K^+} + C_oCl^- . P_{Cl^-})}{(C_oNa^+ P_{Na^+} + C_oK^+ P_{K^+} + C_iCl^- P_{Cl^-})]}$$

Ci = Conc. inside

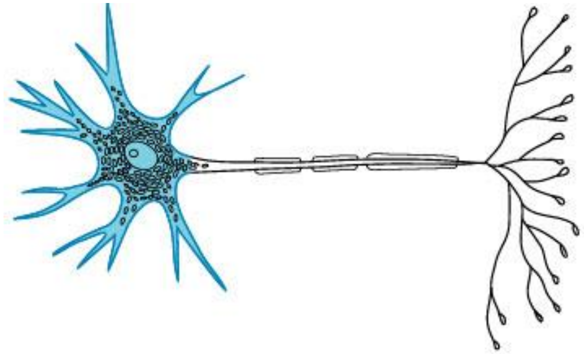
Co = Conc. outside

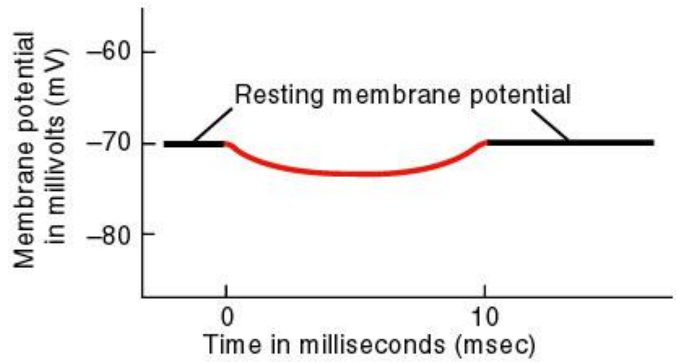
P = permeability of the membrane to that ion.



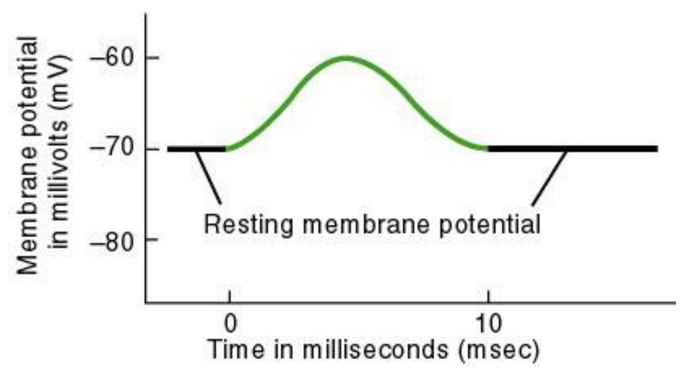
(b) Ligand-gated channel

12.08



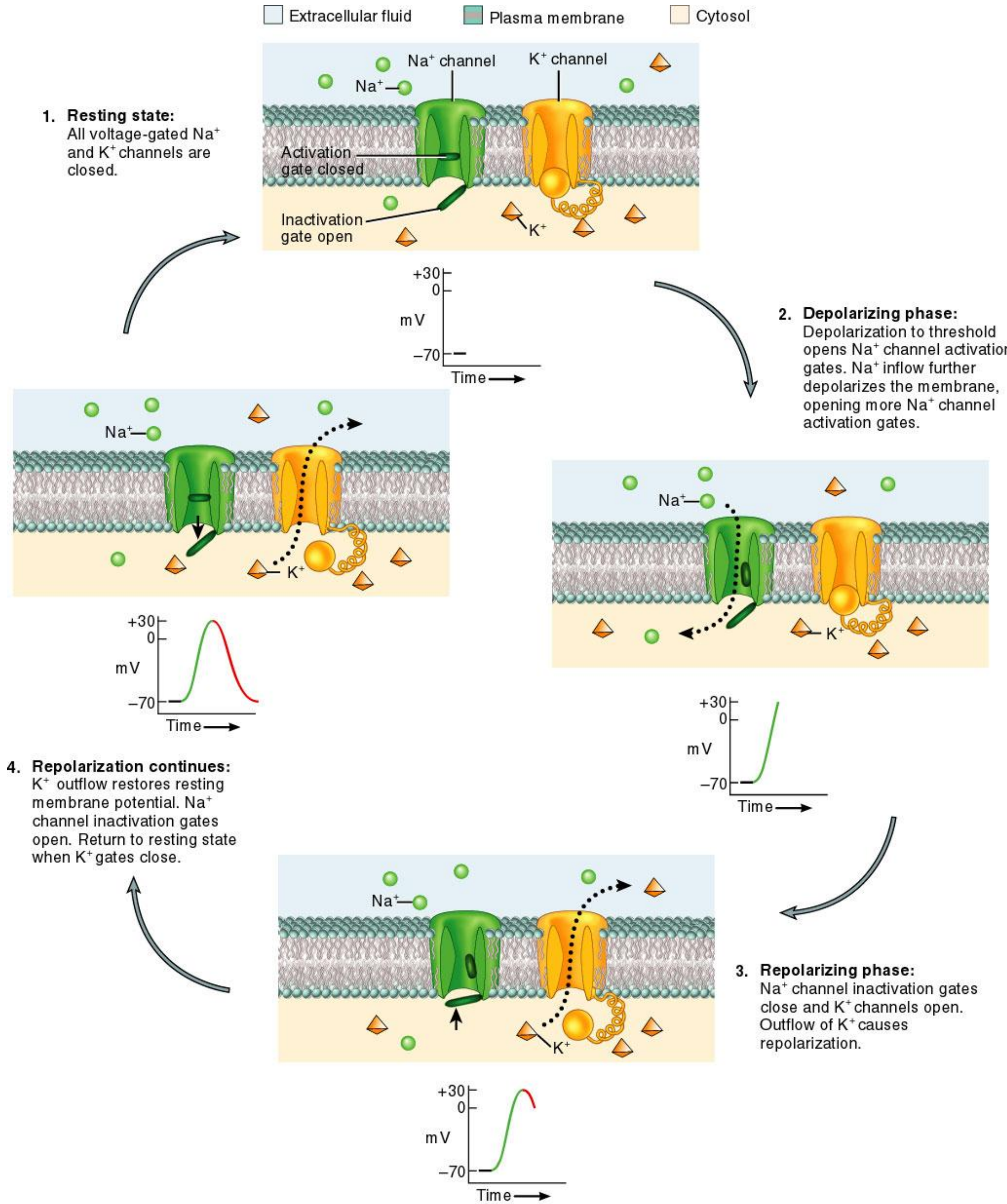


(a) Hyperpolarizing graded potential



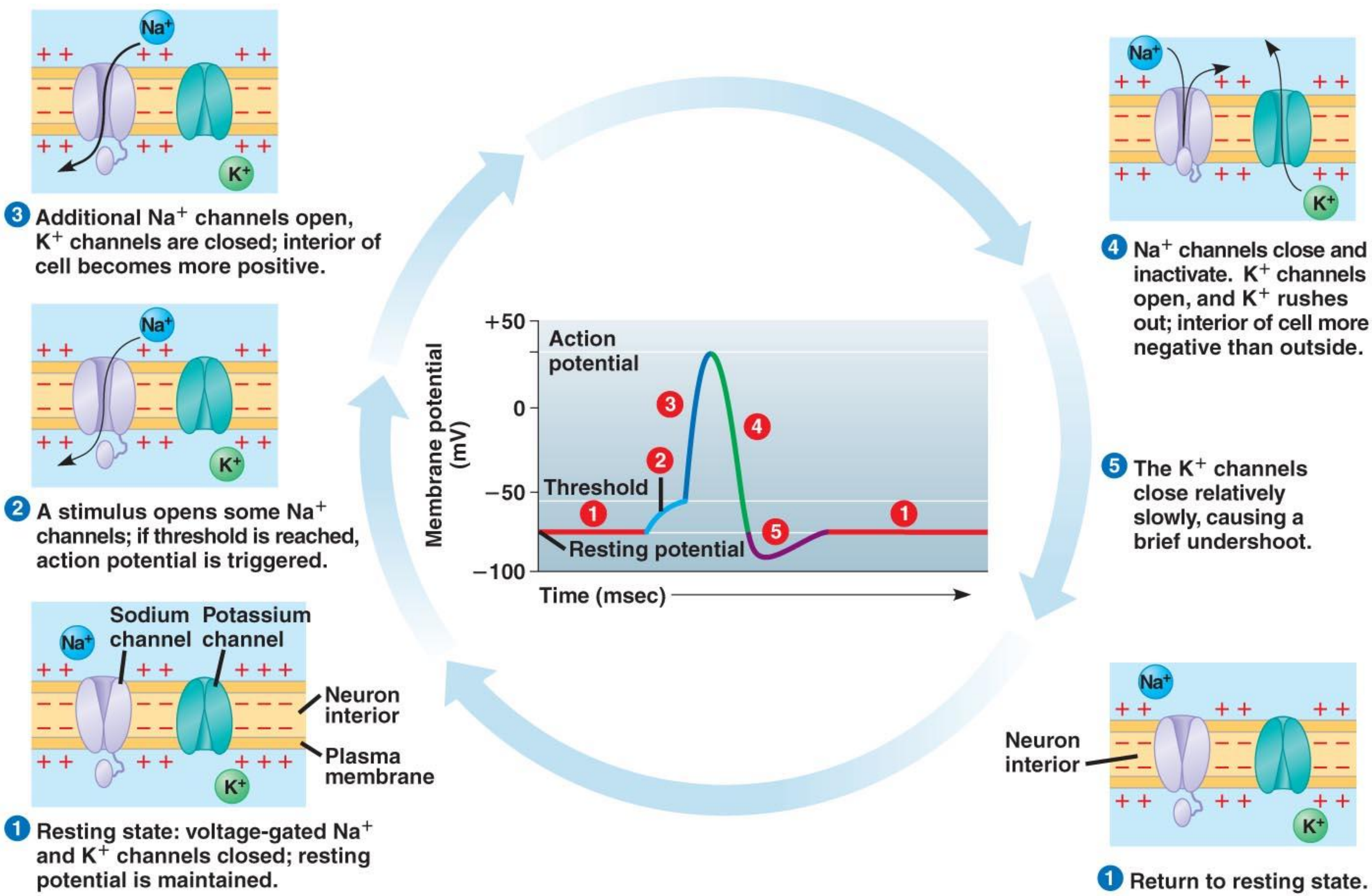
(b) Depolarizing graded potential

12.10

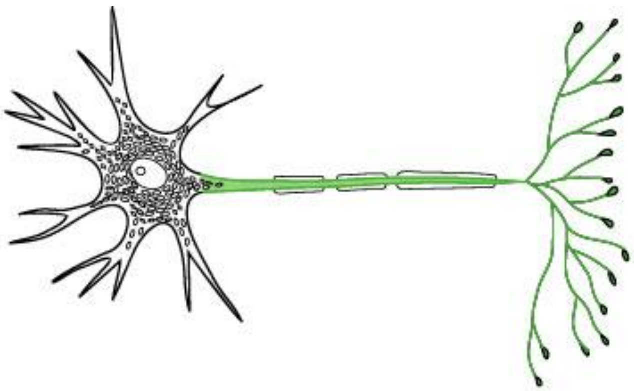


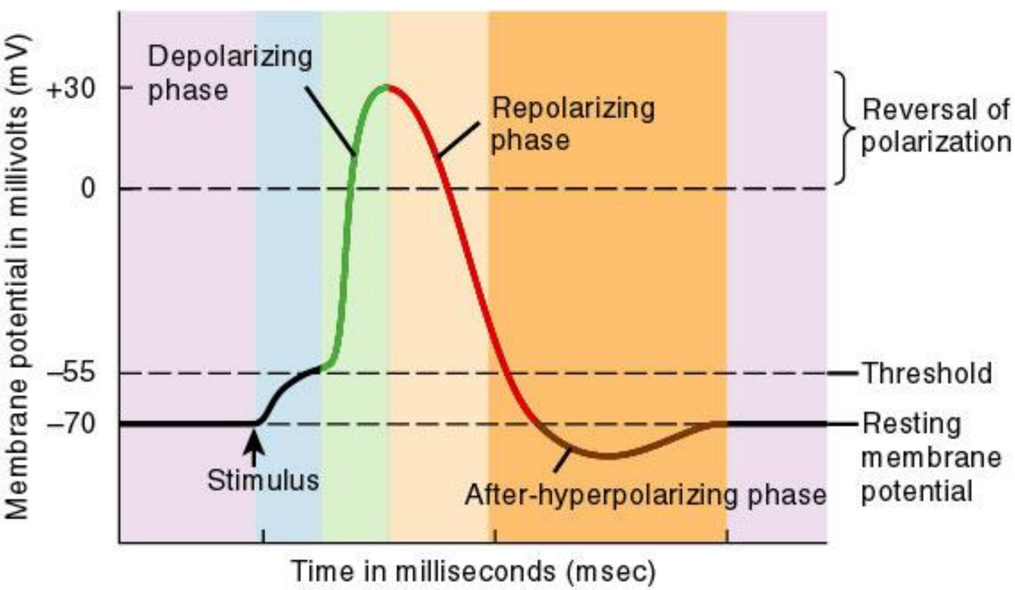
Extracellular fluid
Plasma membrane
Cytosol
Na⁺ channel
K⁺ channel
Na⁺
Activation gate closed
Inactivation gate open
K⁺
1. Resting state:
All voltage-gated Na⁺ and K⁺ channels are closed.
+30
0
mV
–70
Time
2. Depolarizing phase:
Depolarization to threshold opens Na⁺ channel activation gates. Na⁺ inflow further depolarizes the membrane, opening more Na⁺ channel activation gates.
3. Repolarizing phase:
Na⁺ channel inactivation gates close and K⁺ channels open. Outflow of K⁺ causes repolarization.
4. Repolarization continues:
K⁺ outflow restores resting membrane potential. Na⁺ channel inactivation gates open. Return to resting state when K⁺ gates close.

12.12



Na+
K+
3 Additional Na+ channels open, K+ channels are closed; interior of cell becomes more positive.
2 A stimulus opens some Na+ channels; if threshold is reached, action potential is triggered.
Sodium channel
Potassium channel
Neuron interior
Plasma membrane
1 Resting state: voltage-gated Na+ and K+ channels closed; resting potential is maintained.
4 Na+ channels close and inactivate. K+ channels open, and K+ rushes out; interior of cell more negative than outside.
5 The K+ channels close relatively slowly, causing a brief undershoot.
1 Return to resting state.
Neuron interior
+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
Time (msec)





Key:

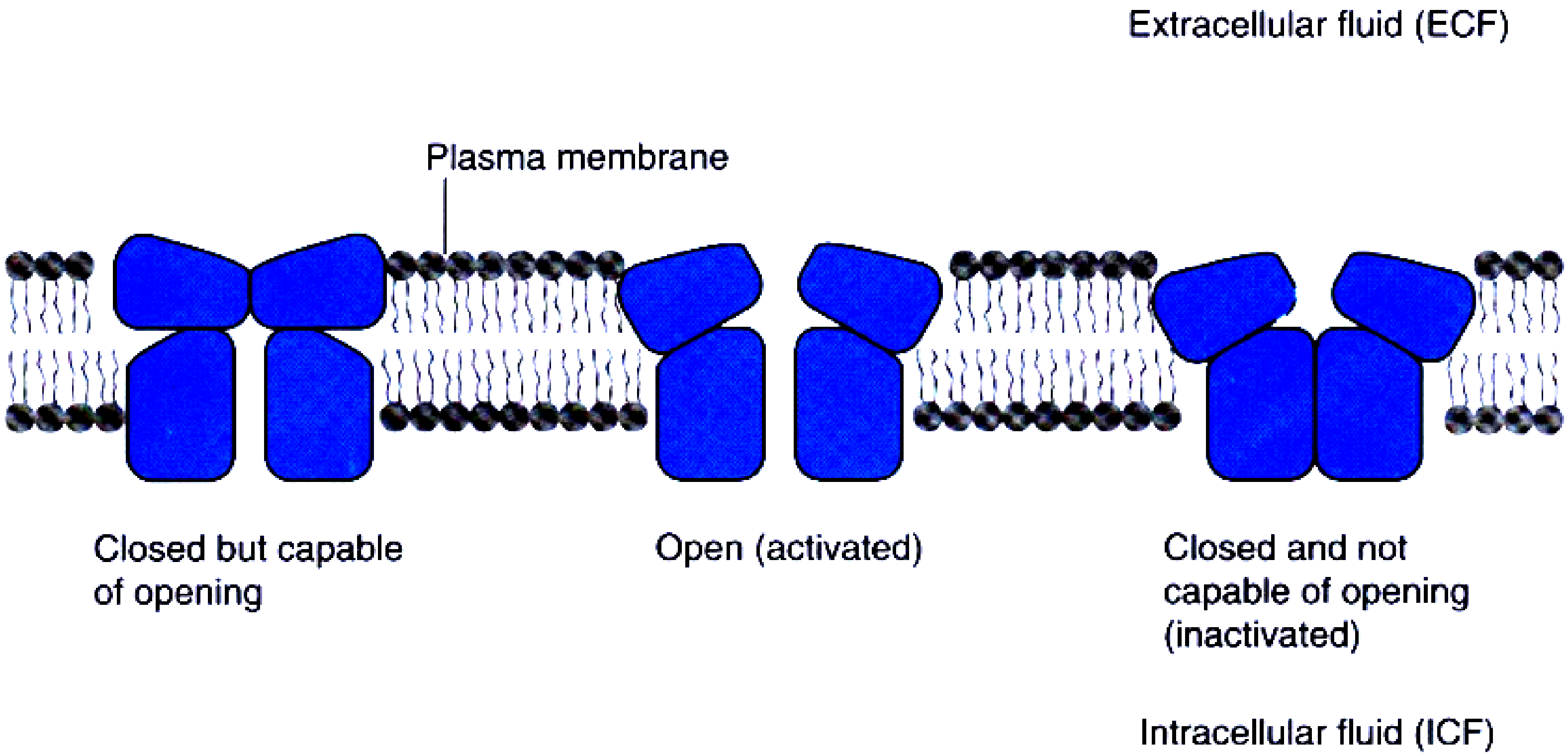
- Resting membrane potential: Voltage-gated Na^+ channels are in the resting state and voltage-gated K^+ channels are closed
- Stimulus causes depolarization to threshold
- Voltage-gated Na^+ channel activation gates are open
- Voltage-gated K^+ channels are open; Na^+ channels are inactivating
- Voltage-gated K^+ channels are still open; Na^+ channels are in the resting state

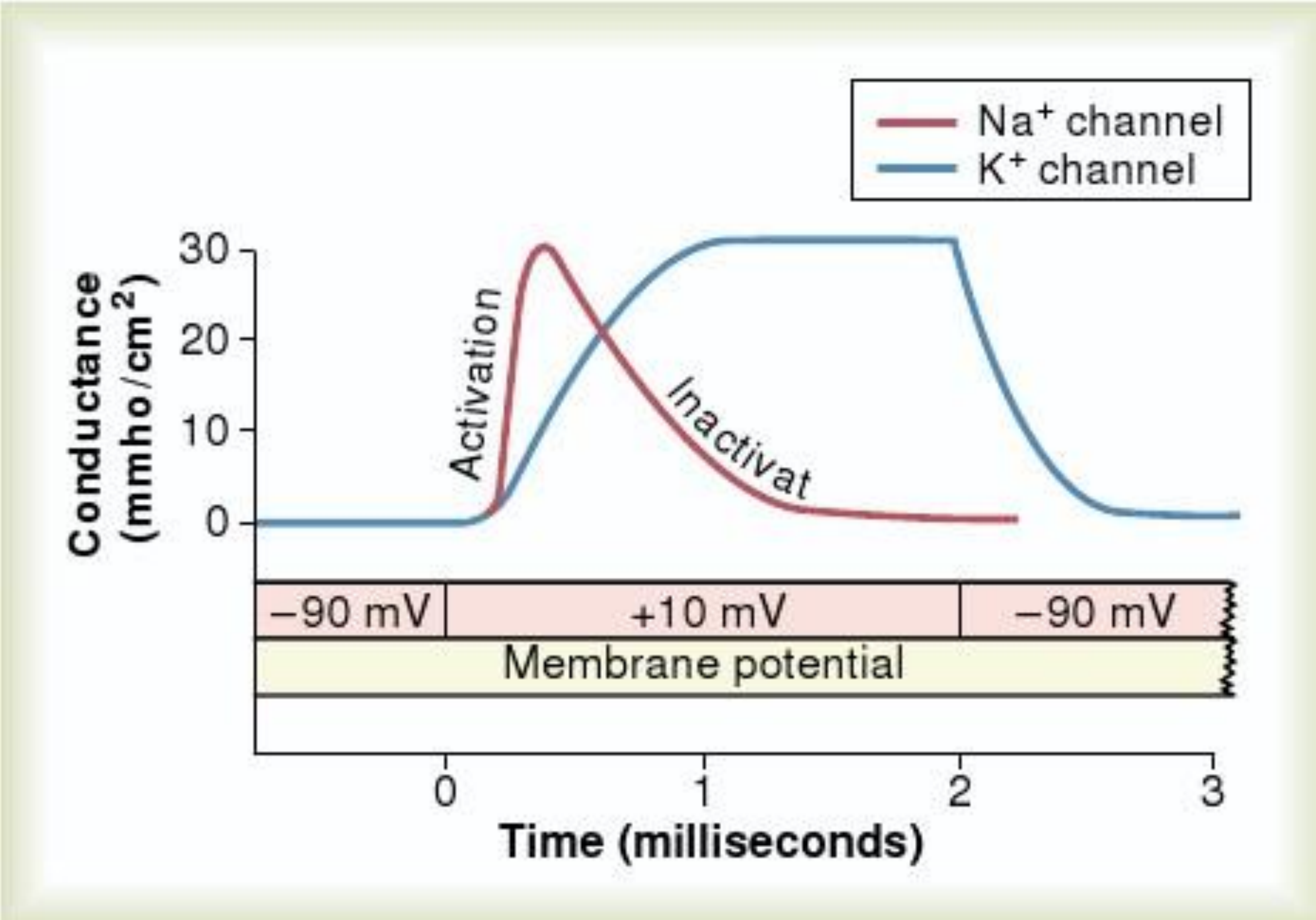
Absolute refractory period (the third and fourth key items)

Relative refractory period (the last key item)

12.11

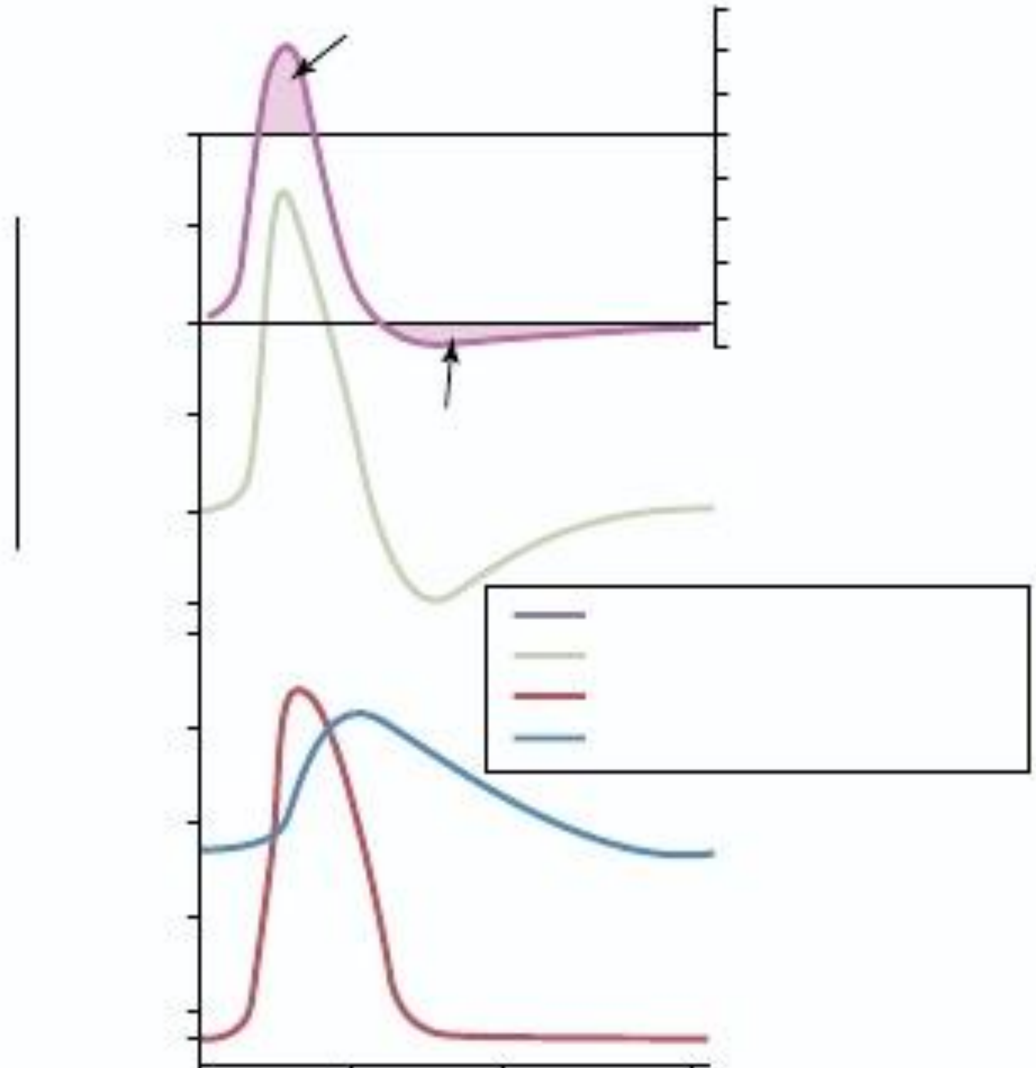
Conformations of Voltage–Gated Na+ Channels

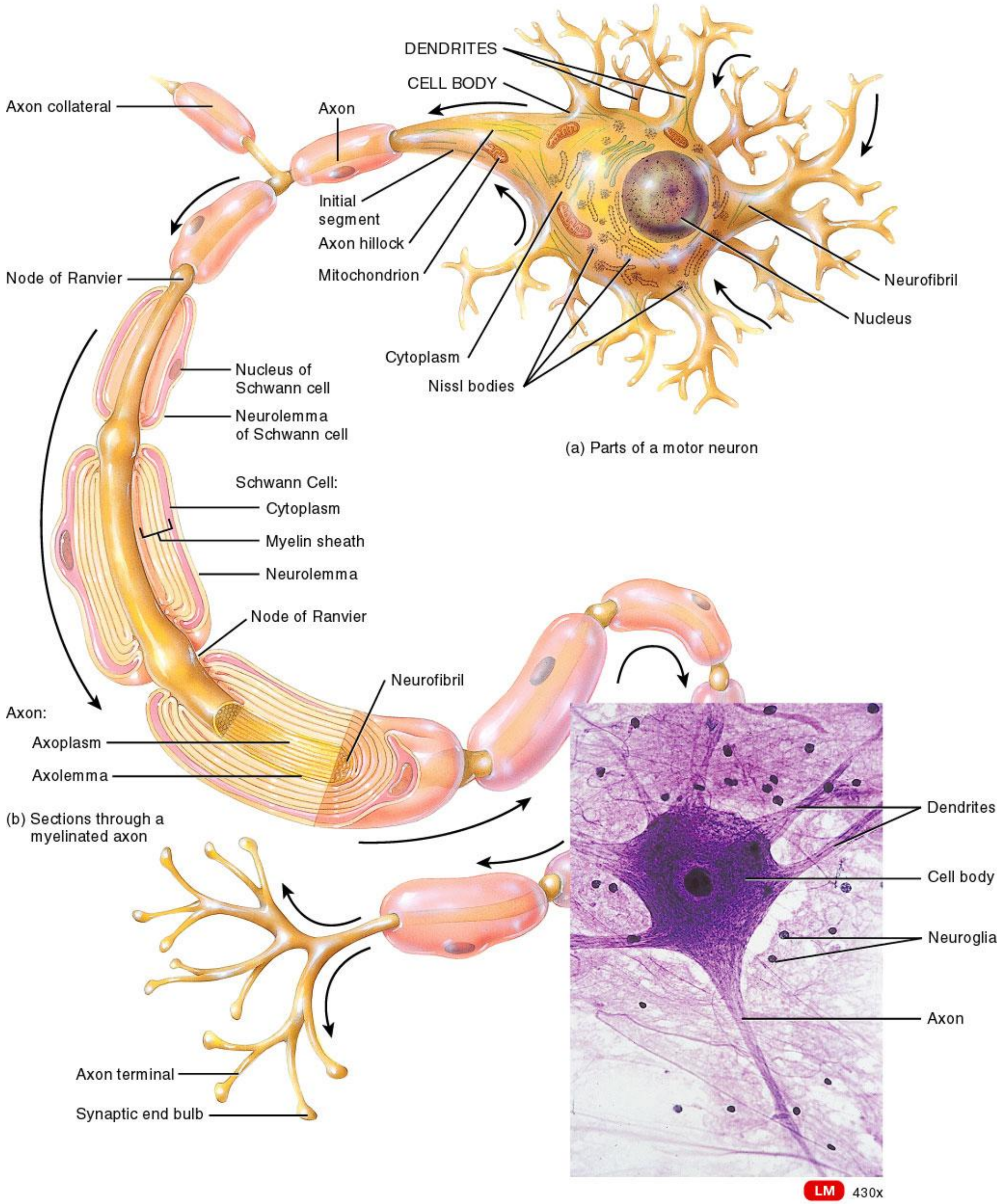




Na+ channel
K+ channel
Conductance (mmho/cm2)
30
20
10
0
Activation
Inactivat
−90 mV
+10 mV
−90 mV
Membrane potential
0
1
2
3
Time (milliseconds)

Figure 5–9

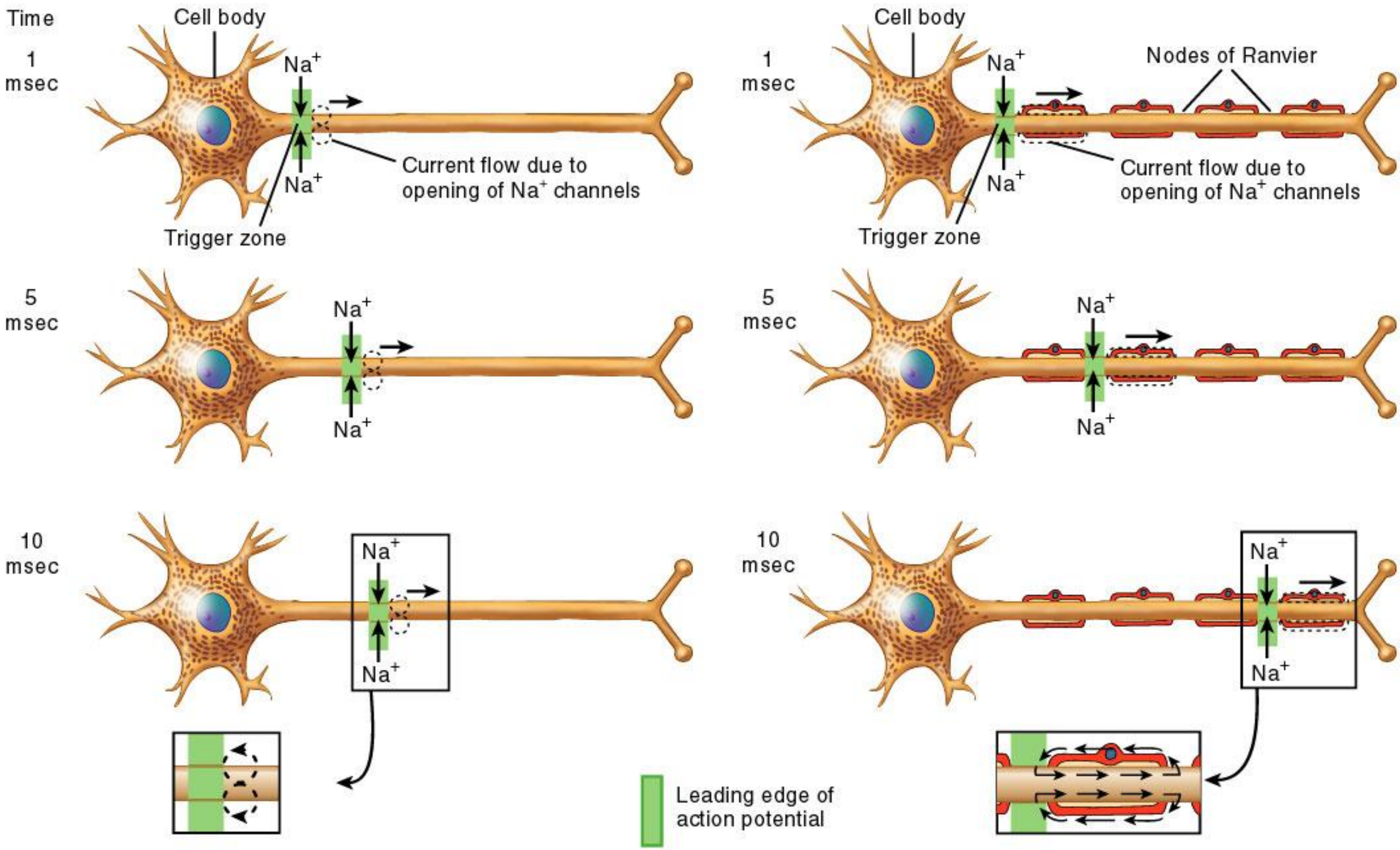




(a) Parts of a motor neuron

(b) Sections through a myelinated axon

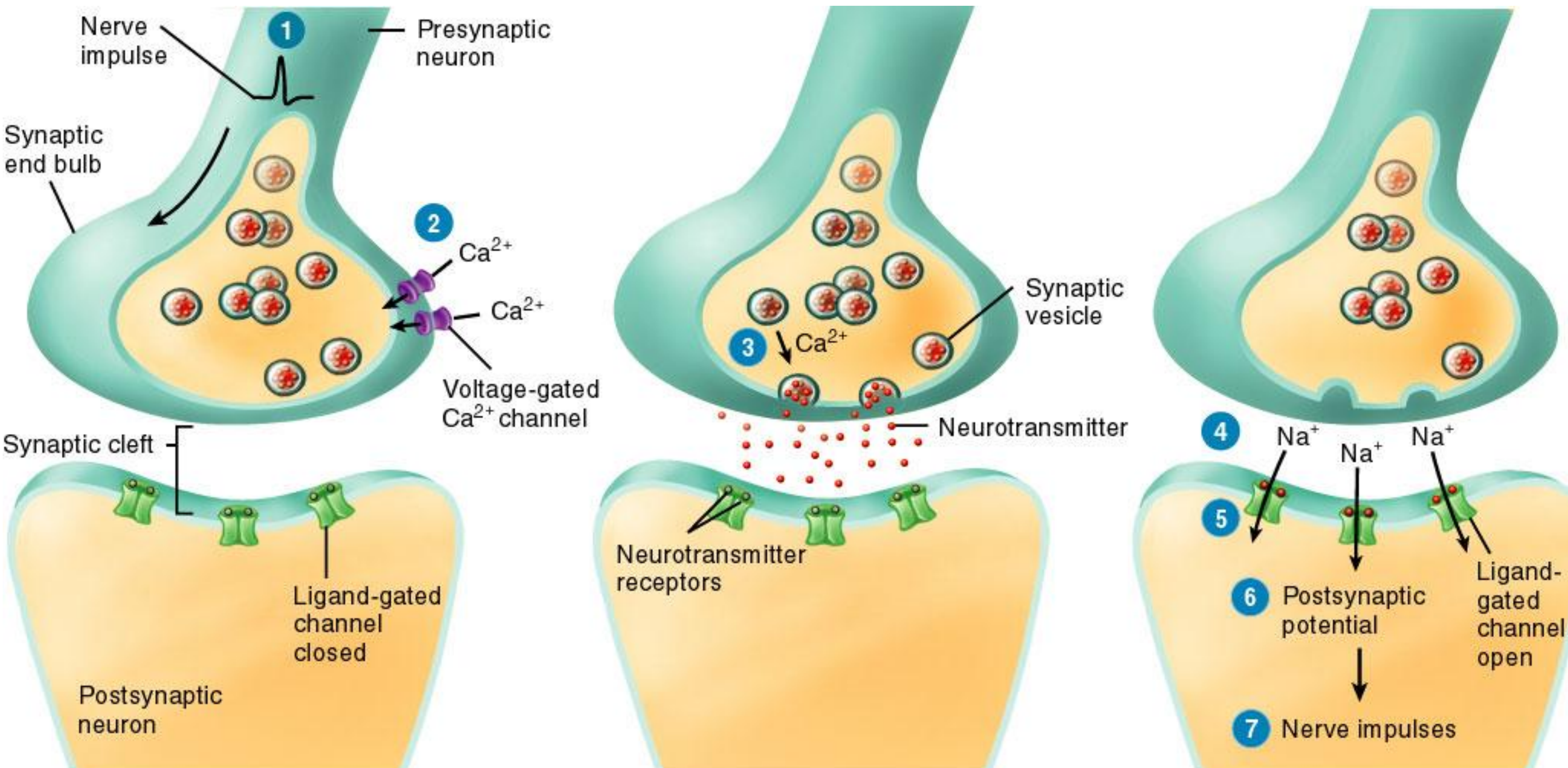
(c) Motor neuron



(a) Continuous conduction

(b) Saltatory conduction

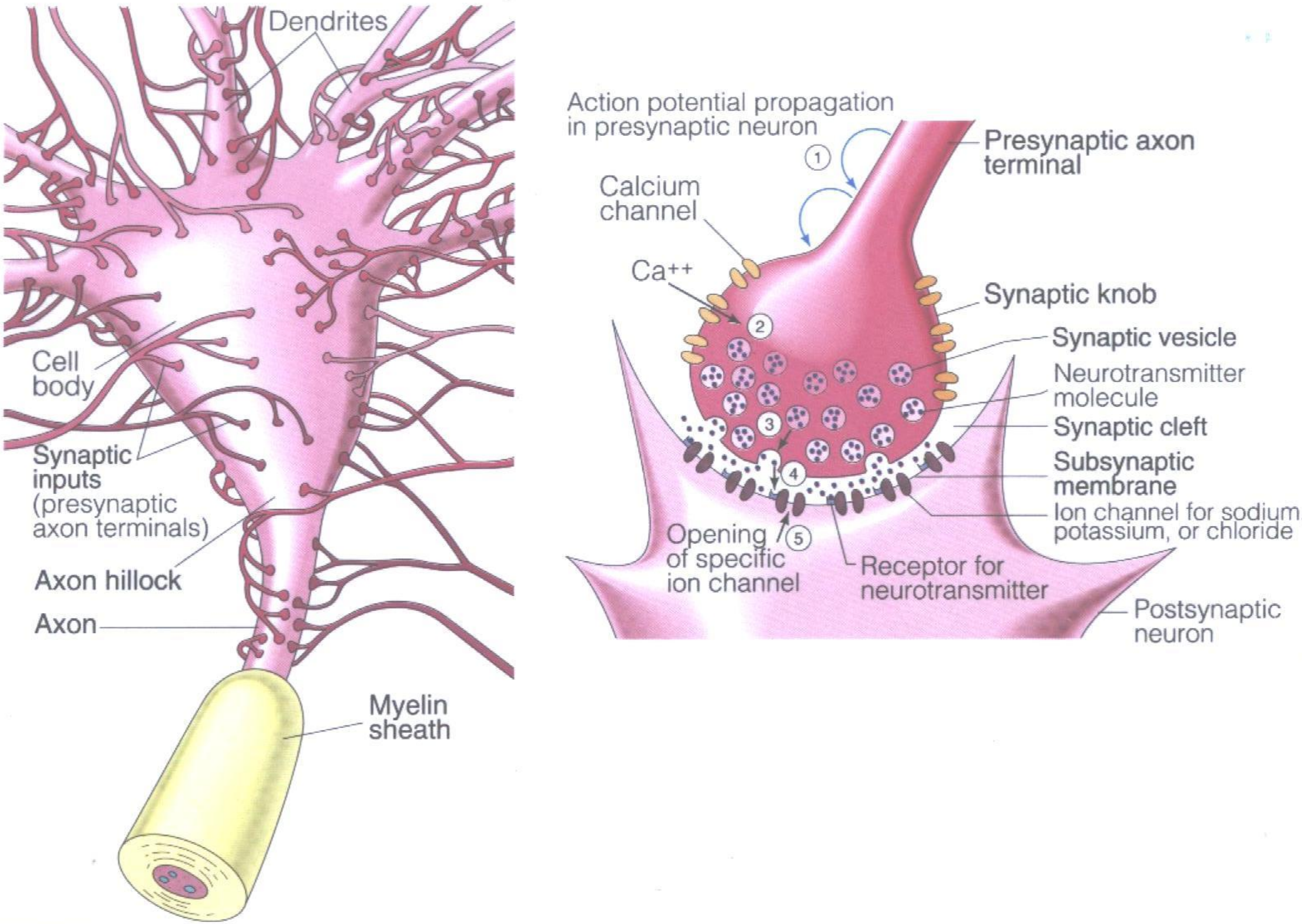
12.13

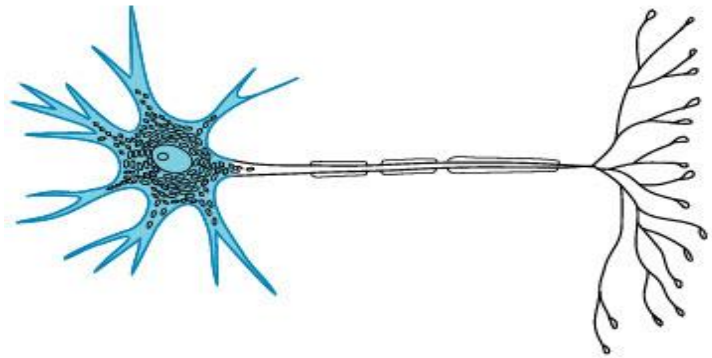


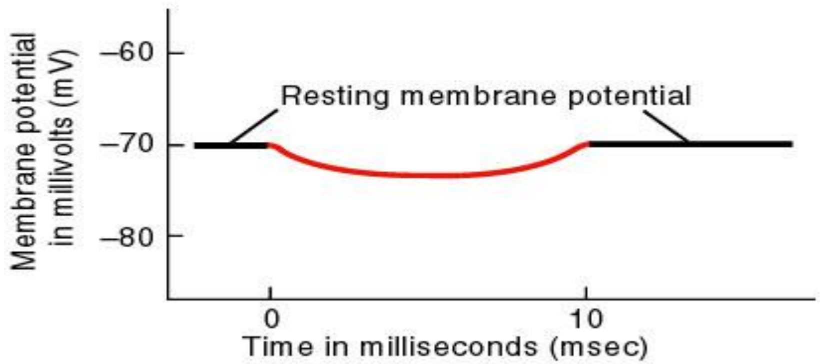
1
Nerve impulse
Presynaptic neuron
Synaptic end bulb
2
Ca^{2+}
Ca^{2+}
Voltage-gated Ca^{2+} channel
Synaptic cleft
Ligand-gated channel closed
Postsynaptic neuron
3
Ca^{2+}
Synaptic vesicle
Neurotransmitter
Neurotransmitter receptors
4
Na^{+}
Na^{+}
Na^{+}
5
6 Postsynaptic potential
7 Nerve impulses
Ligand-gated channel open

12.14

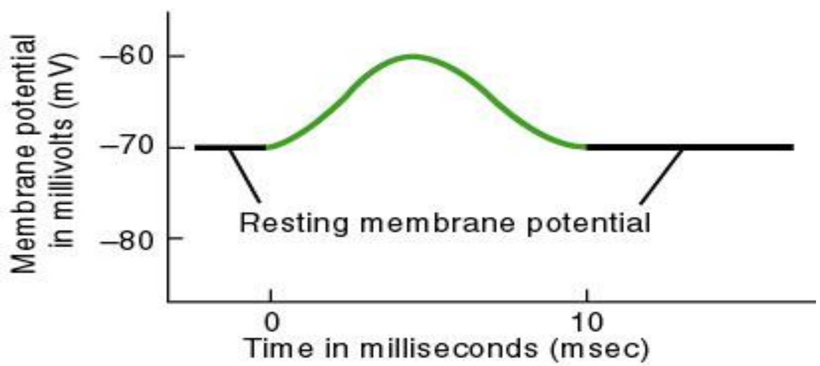
Synaptic Structure and Function





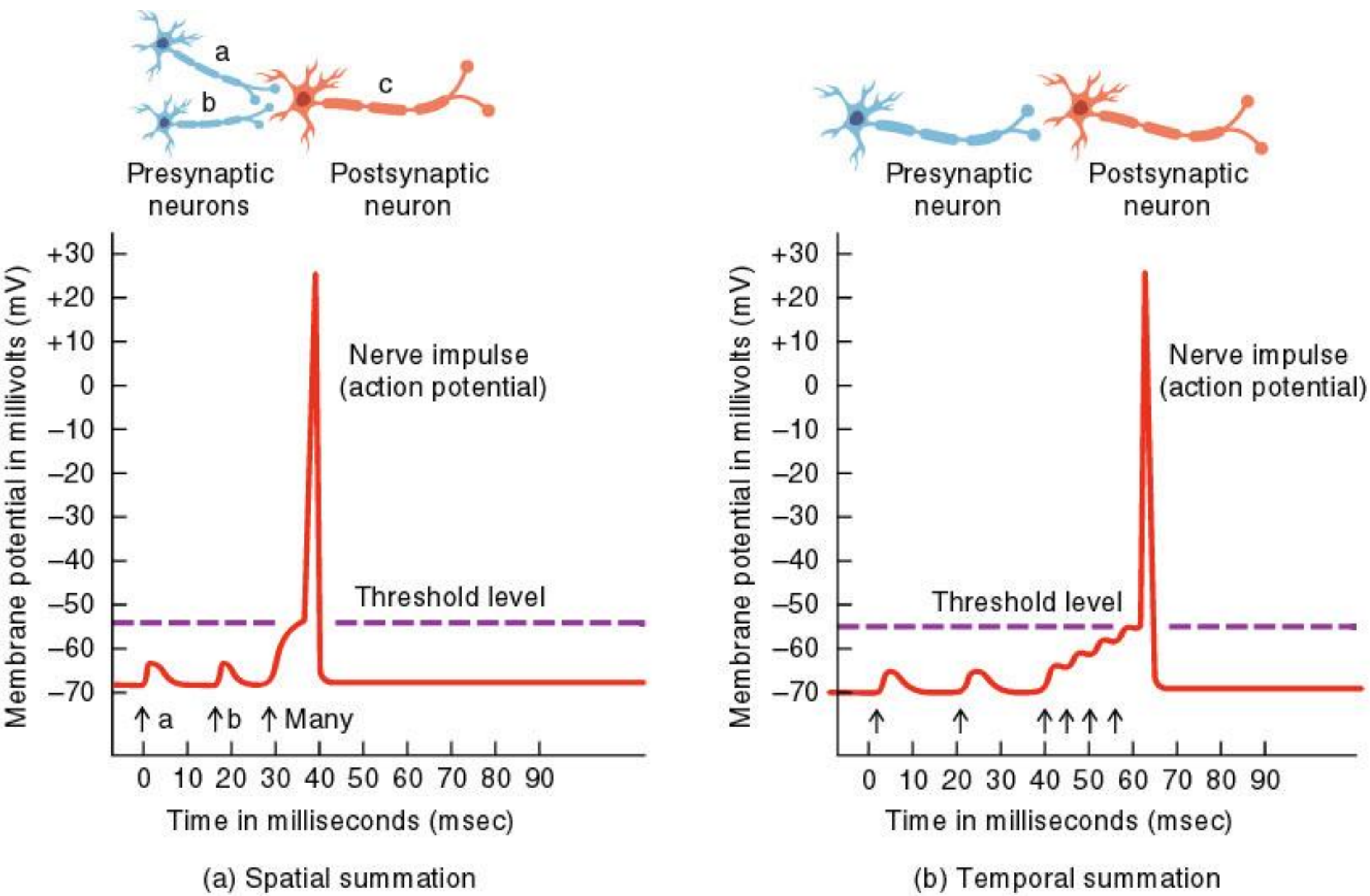


(a) Hyperpolarizing graded potential



(b) Depolarizing graded potential

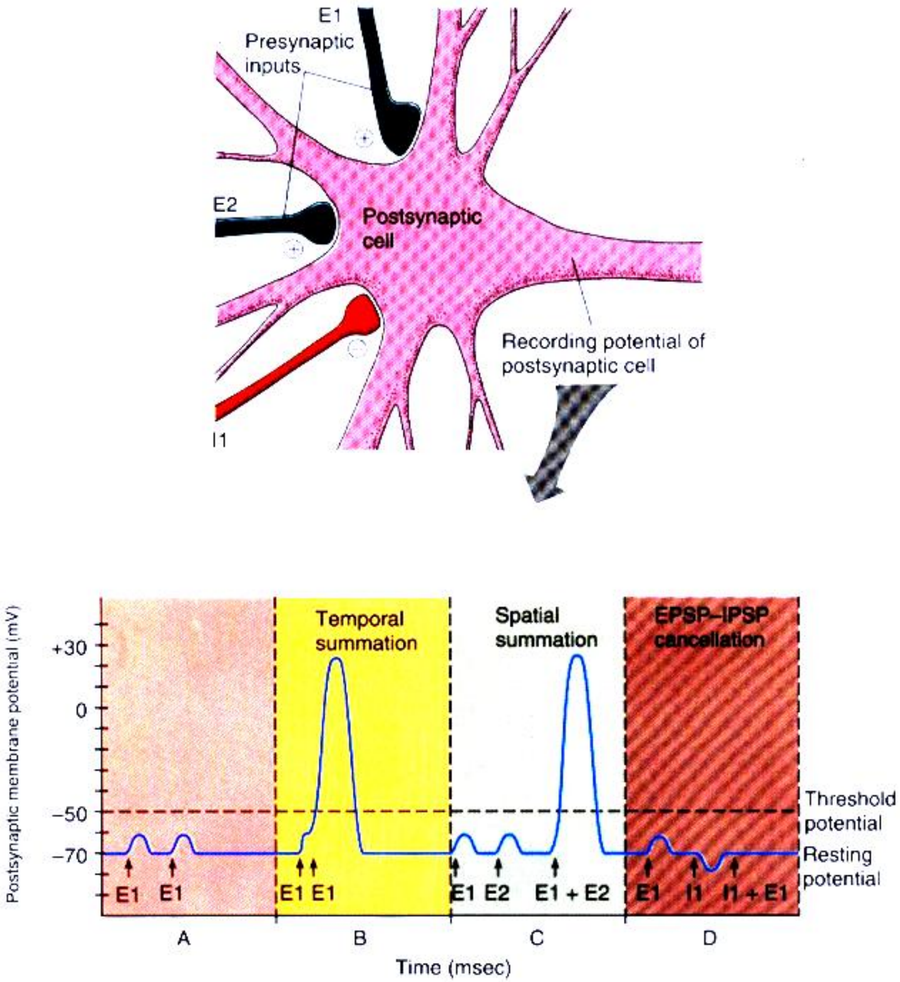
12.10



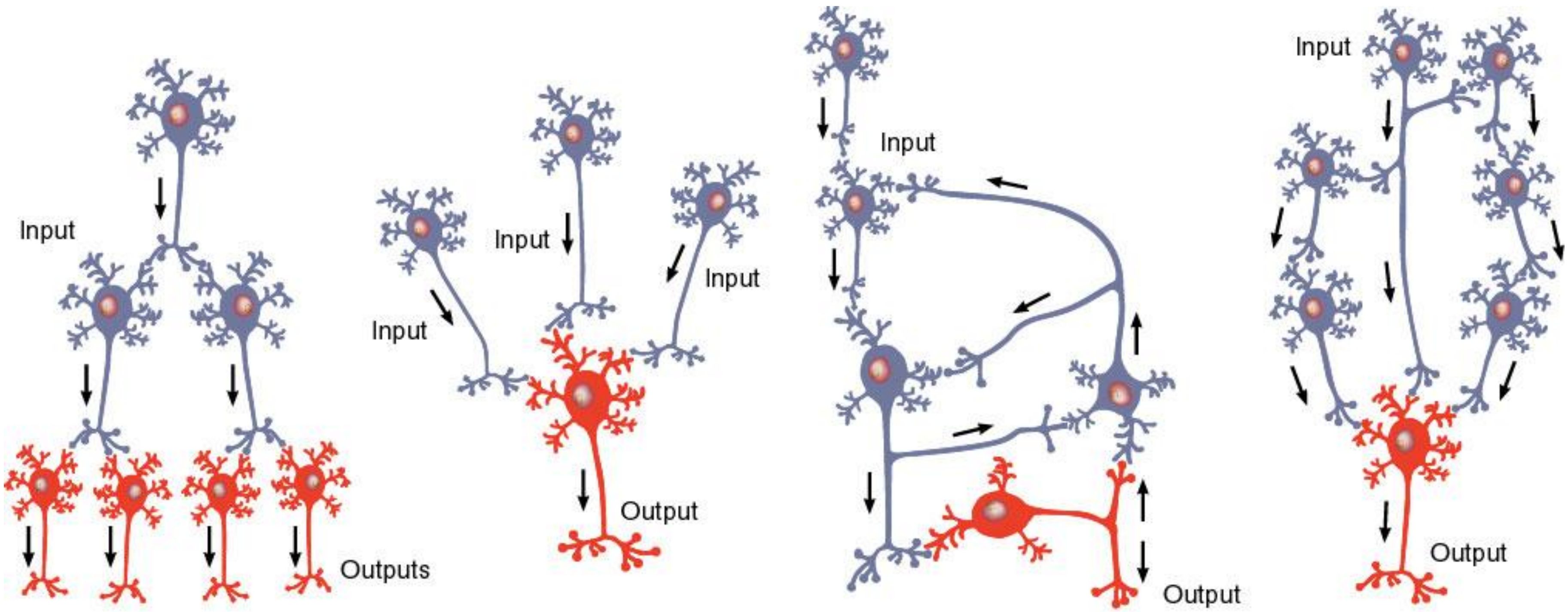
a
b
c
Presynaptic neurons
Postsynaptic neuron
Membrane potential in millivolts (mV)
+30
+20
+10
0
−10
−20
−30
−40
−50
−60
−70
Nerve impulse (action potential)
Threshold level
↑a
↑b
↑Many
0 10 20 30 40 50 60 70 80 90
Time in milliseconds (msec)
(a) Spatial summation
Presynaptic neuron
Postsynaptic neuron
Membrane potential in millivolts (mV)
+30
+20
+10
0
−10
−20
−30
−40
−50
−60
−70
Nerve impulse (action potential)
Threshold level
0 10 20 30 40 50 60 70 80 90
Time in milliseconds (msec)
(b) Temporal summation

12.15

Determination of Grand Postsynaptic Potential



Acetate 28 (Figure 4-18)



(a) Diverging circuit (b) Converging circuit (c) Reverberating circuit (d) Parallel after-discharge circuit

12.16