UNIT – 3

BIOPOTENTIAL ELECTRODES

& CONFIGURATION

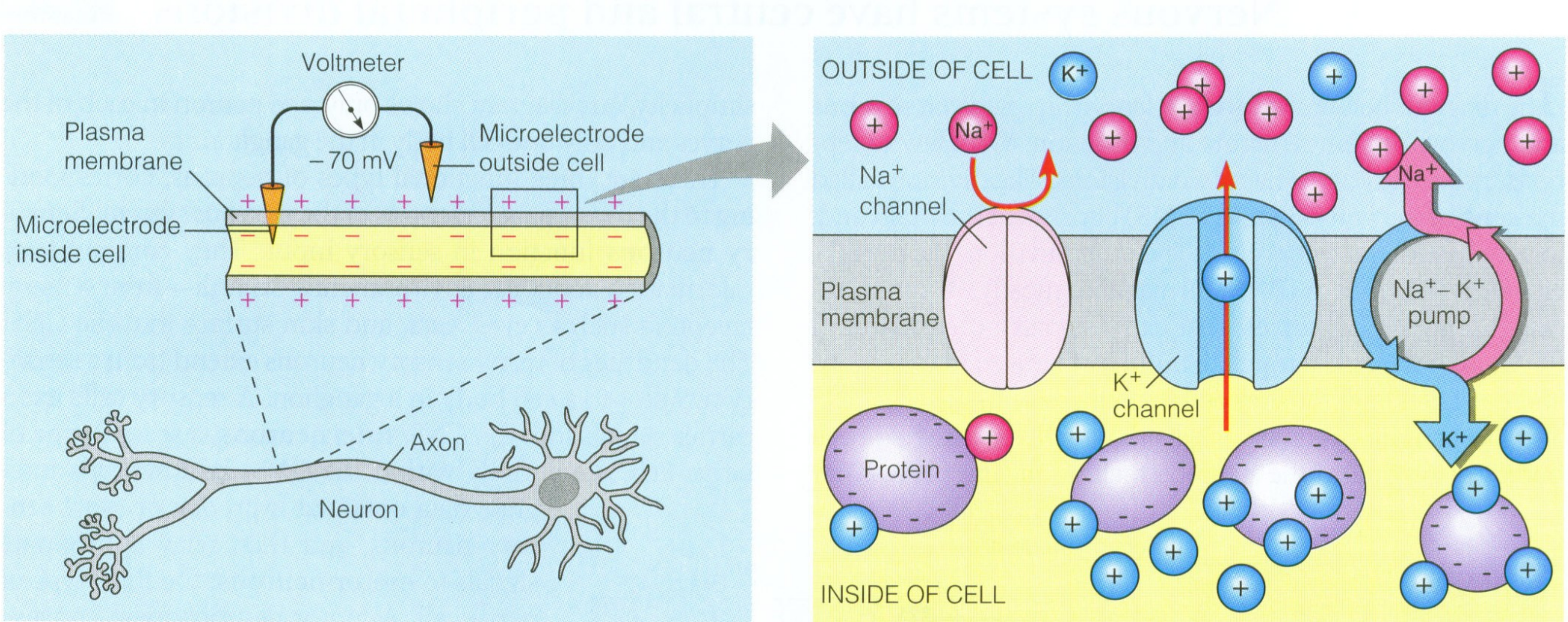
Goldman-Hodgkin-Katz Eq.

Bioelectricity

- Provides basis for “irritability” or “excitability
- Fundamental property of all living cells
- Related to minute differences in the electrical potential across a cell

‘resting potential’

- Resting potential values can range from 20 to 100 mv, with inside of membrane negative to outside
- Any stimulus which evokes a response in a cell is associated with a change in this potential



A. Measuring a neuron's resting potential

B. How the resting potential is generated

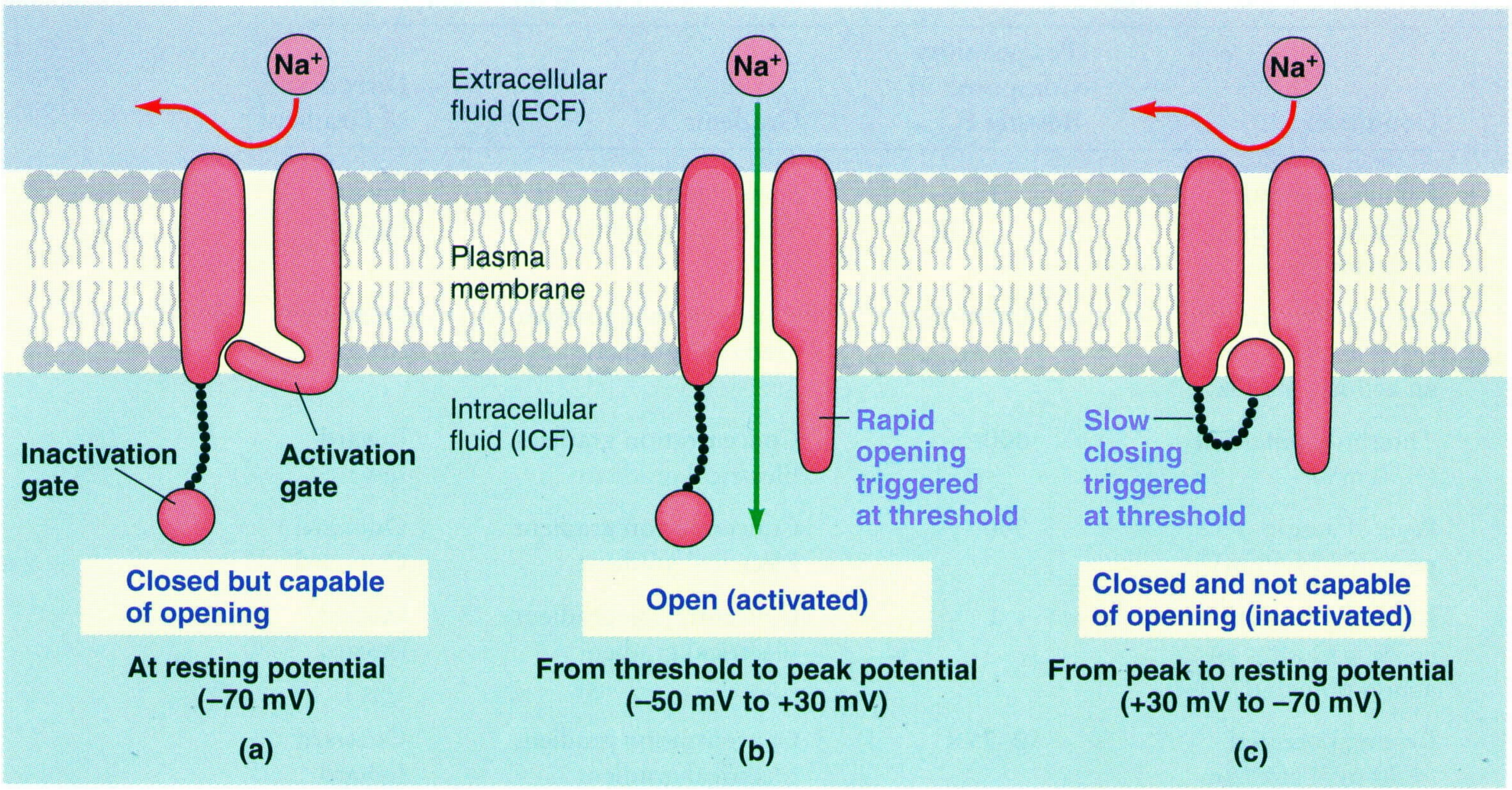
Membrane Channels:

Leak Channels

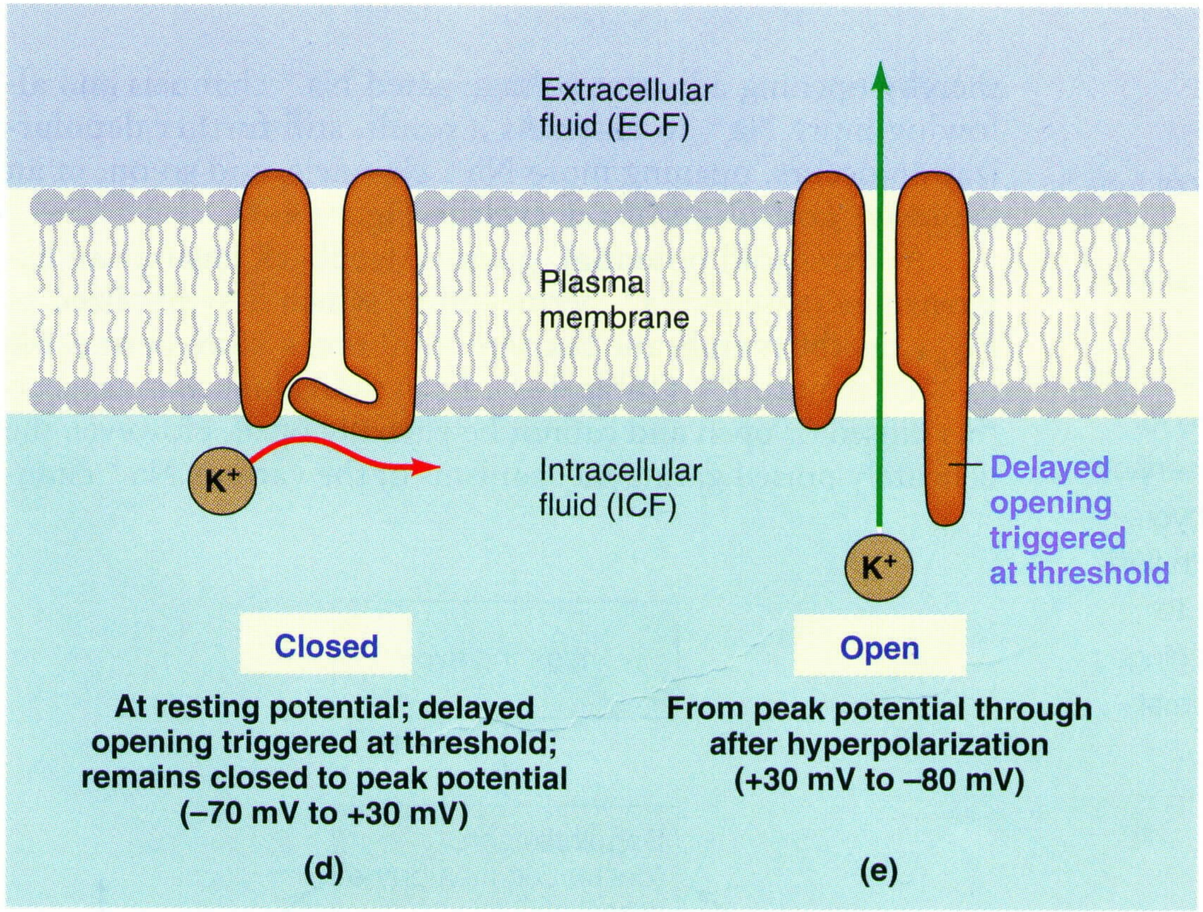
Gated Channels

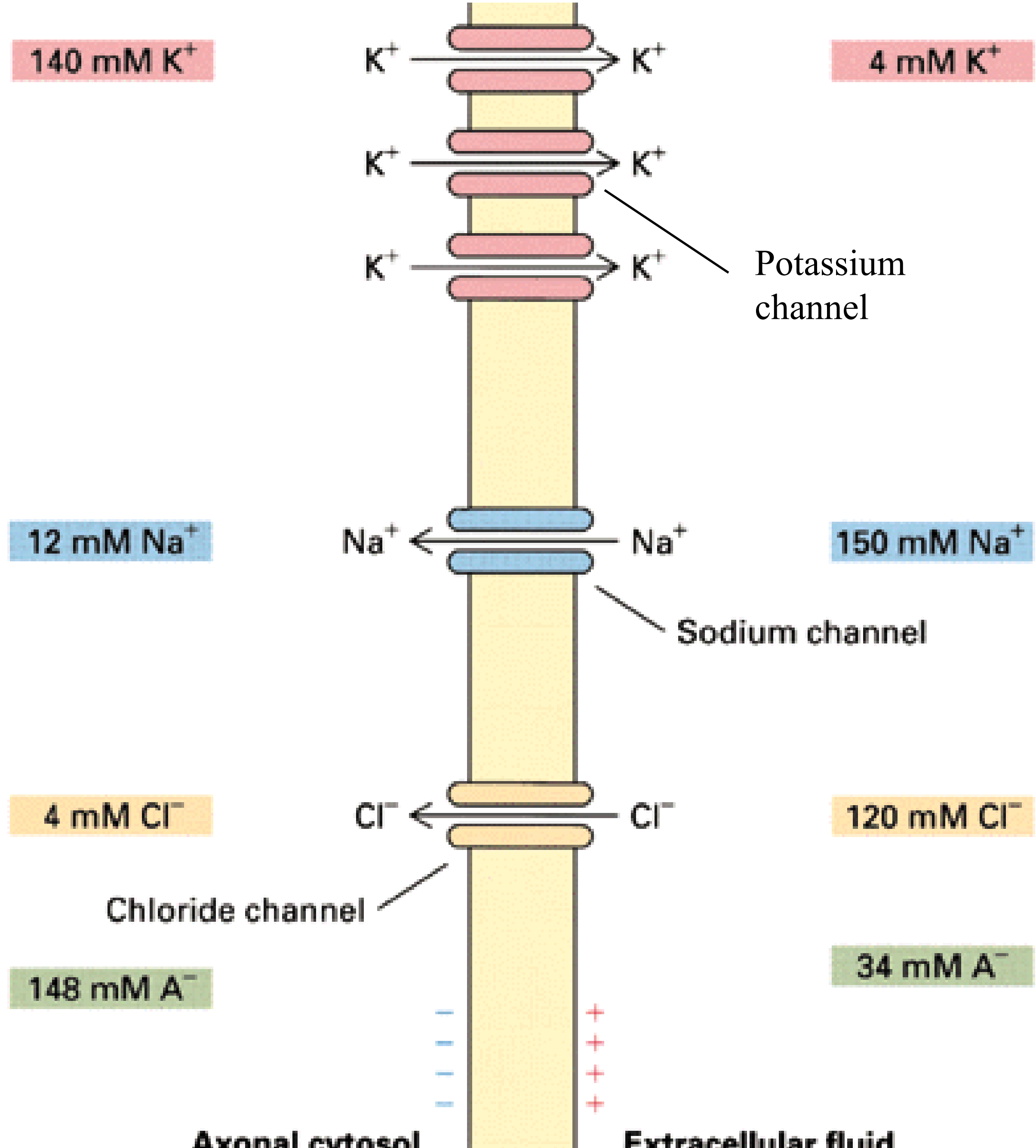
- Chemical (Ligand)
- Voltage
- Mechanical

Voltage-Gated Sodium Channel

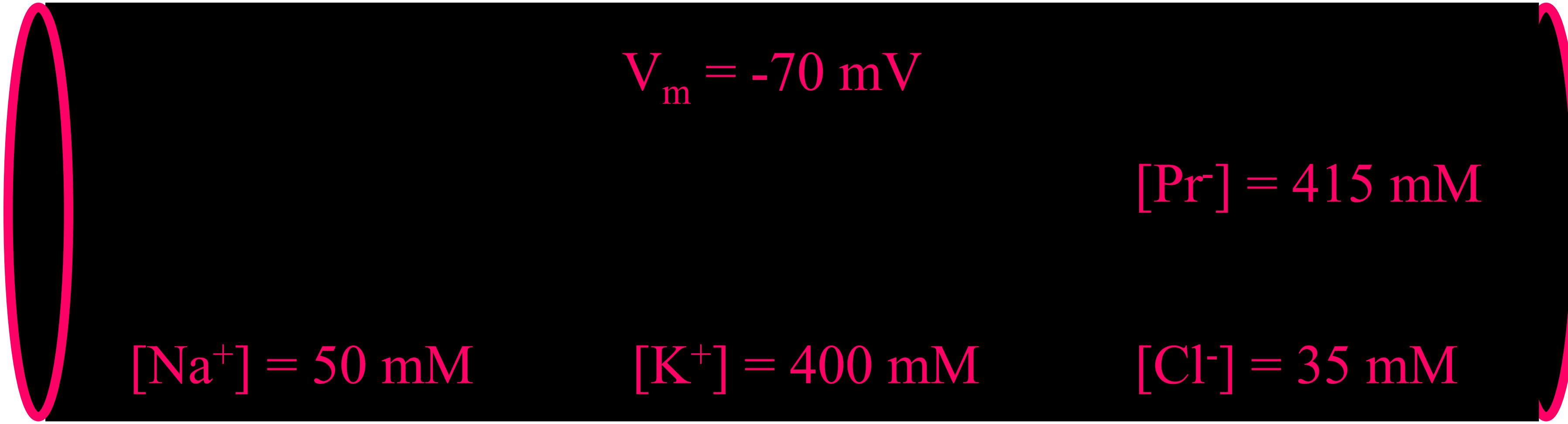


Voltage-Gated Potassium Channel




140 mM K+
K+
K+
4 mM K+
Potassium channel
12 mM Na+
Na+
Na+
150 mM Na+
Sodium channel
4 mM Cl−
Cl−
Cl−
120 mM Cl−
Chloride channel
148 mM A−
34 mM A−
Axonal cytosol
Extracellular fluid

Look at squid giant axon:



$[Na^+]$ = 440 mM $[K^+]$ = 20 mM $[Cl^-]$ = 560 mM

$$E_{Na} = \frac{+25\text{mV}}{+1} \ln \frac{440}{50} = +54.4 \text{ mV}$$

$$E_K = -74.9 \text{ mV}$$

$$E_{Cl} = -69.3 \text{ mV}$$

What determines the value of the membrane voltage?

Goldman-Hodgkin-Katz Eq.

$$V_m = +\,25\text{ mV} \bullet \ln \frac{P_{Na}\,[Na^+]_o + P_K\,[K^+]_o + P_{Cl}\,[Cl^-]_i}{P_{Na}\,[Na^+]_i + P_K\,[K^+]_i + P_{Cl}\,[Cl^-]_o}$$

If the membrane were only permeable to Na:

$$V_m = +\,25\text{ mV} \bullet \ln \frac{\cancel{P}_{Na}\,[Na^+]_o}{\cancel{P}_{Na}\,[Na^+]_i} = E_{Na} = +\,54.4\text{ mV}$$

Goldman-Hodgkin-Katz Eq.

$$V_m = + 25 \text{ mV} \bullet \ln \frac{P_{Na} [Na^+]_o + P_K [K^+]_o + P_{Cl} [Cl^-]_i}{P_{Na} [Na^+]_i + P_K [K^+]_i + P_{Cl} [Cl^-]_o}$$

If the membrane were only permeable to K:

$$V_m = + 25 \text{ mV} \bullet \ln \frac{\cancel{P}_K [K^+]_o}{\cancel{P}_K [K^+]_i} = E_K = - 74.9 \text{ mV}$$

If the membrane were only permeable to Cl:

$$V_m = +\,25\text{ mV} \bullet \ln \frac{\cancel{P}_{Cl}\,[Cl^-]_i}{\cancel{P}_{Cl}\,[Cl^-]_o} = E_{Cl} = -\,69.3\text{ mV}$$

Thus, the GHK eq. is a sum of the Nernst eqs. weighted by permeability!

In the resting neuron, P_K & P_{Cl} >> P_{Na}

(~ 20-50 x)

Therefore, Vm is close to E_K & E_{Cl}

with very little contribution from E_{Na}

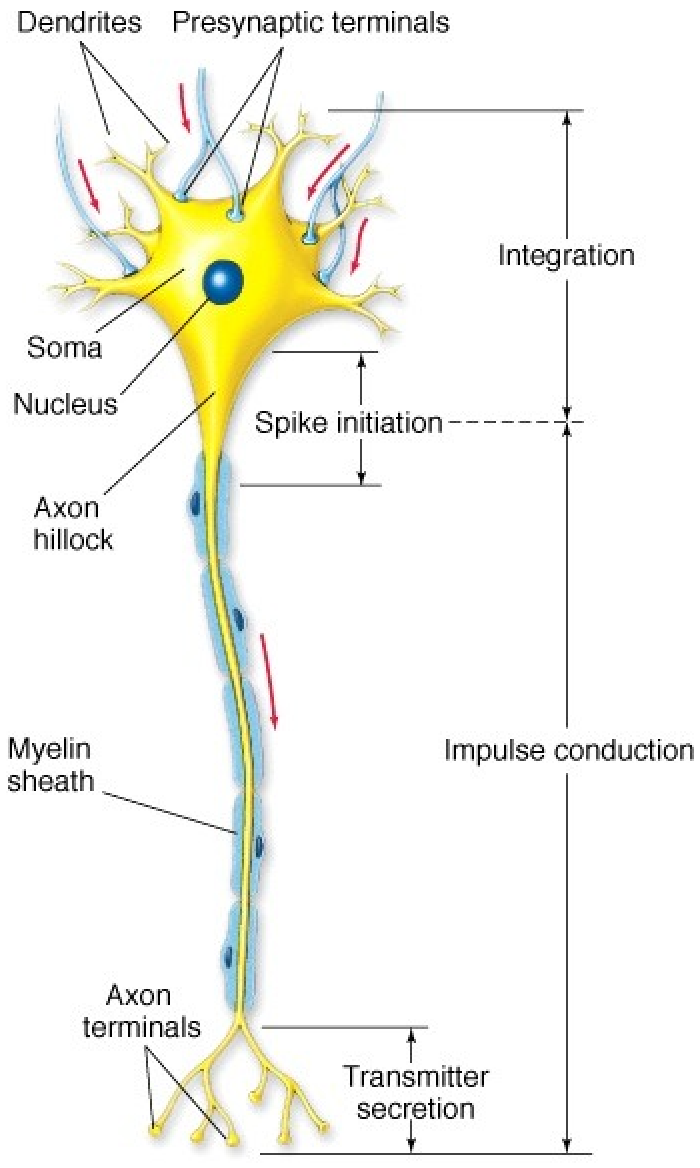
Neuronal Physiology

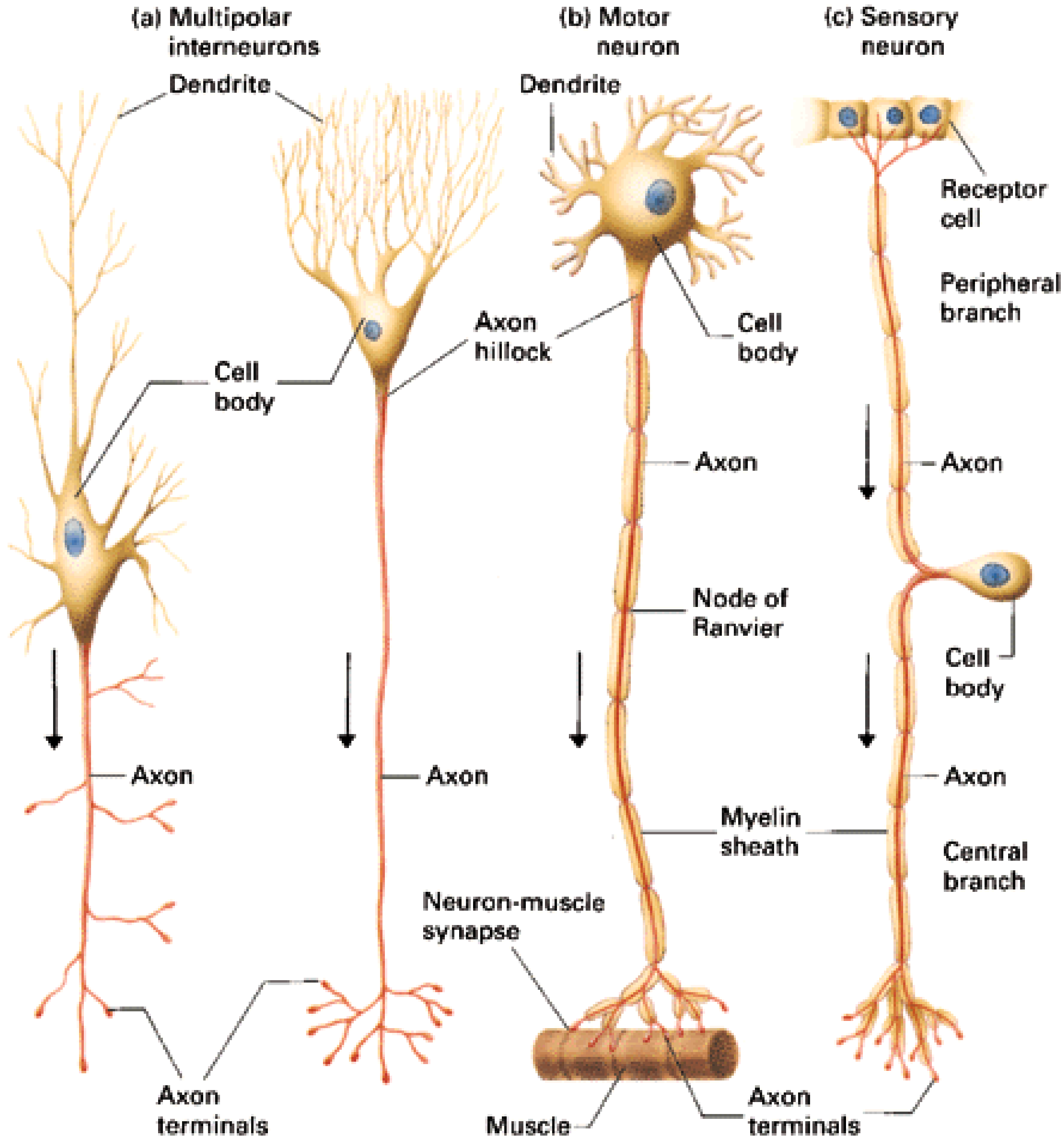
Neurons = nerve cells; fundamental unit of nervous system

Surrounded by plasma membrane that possesses an electrical potential (resting potential = -70 mv)

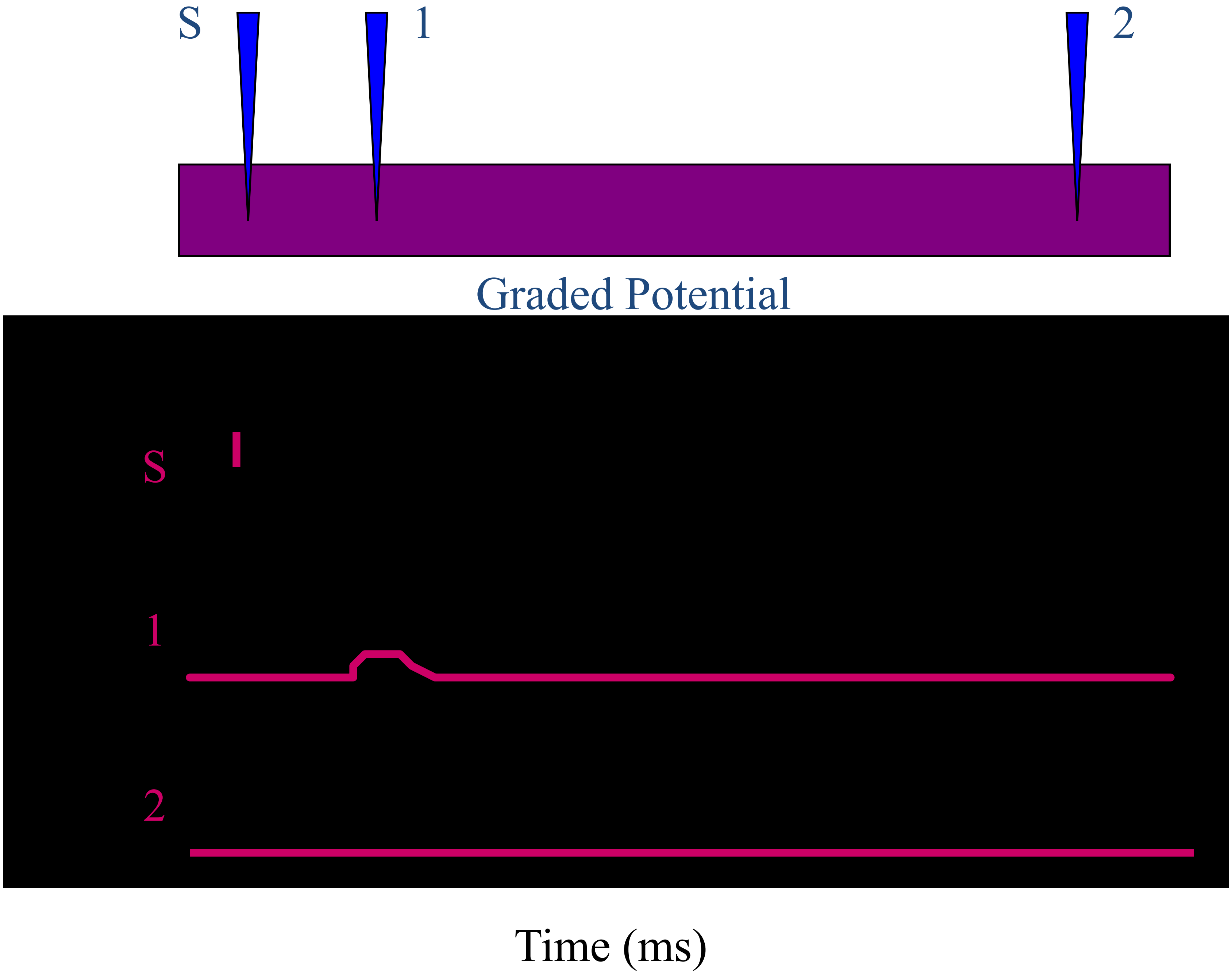
Membrane potential due to uneven distribution of ions on either side of membrane

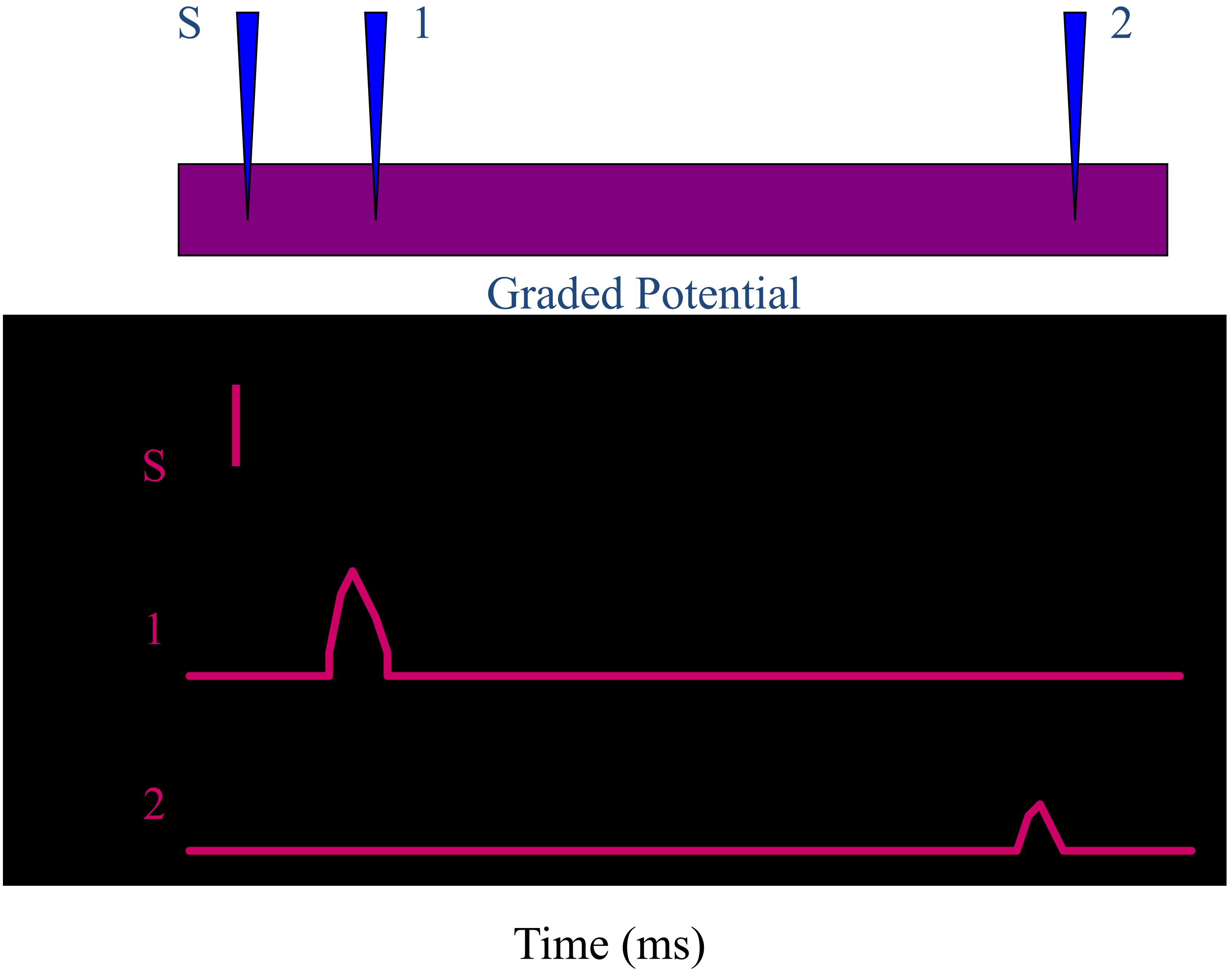
Nerve (and muscle) cells can make special use of this potential (i.e., excitable tissues) – use changes in the potential to create signals and hence transmit information or bring about contractions

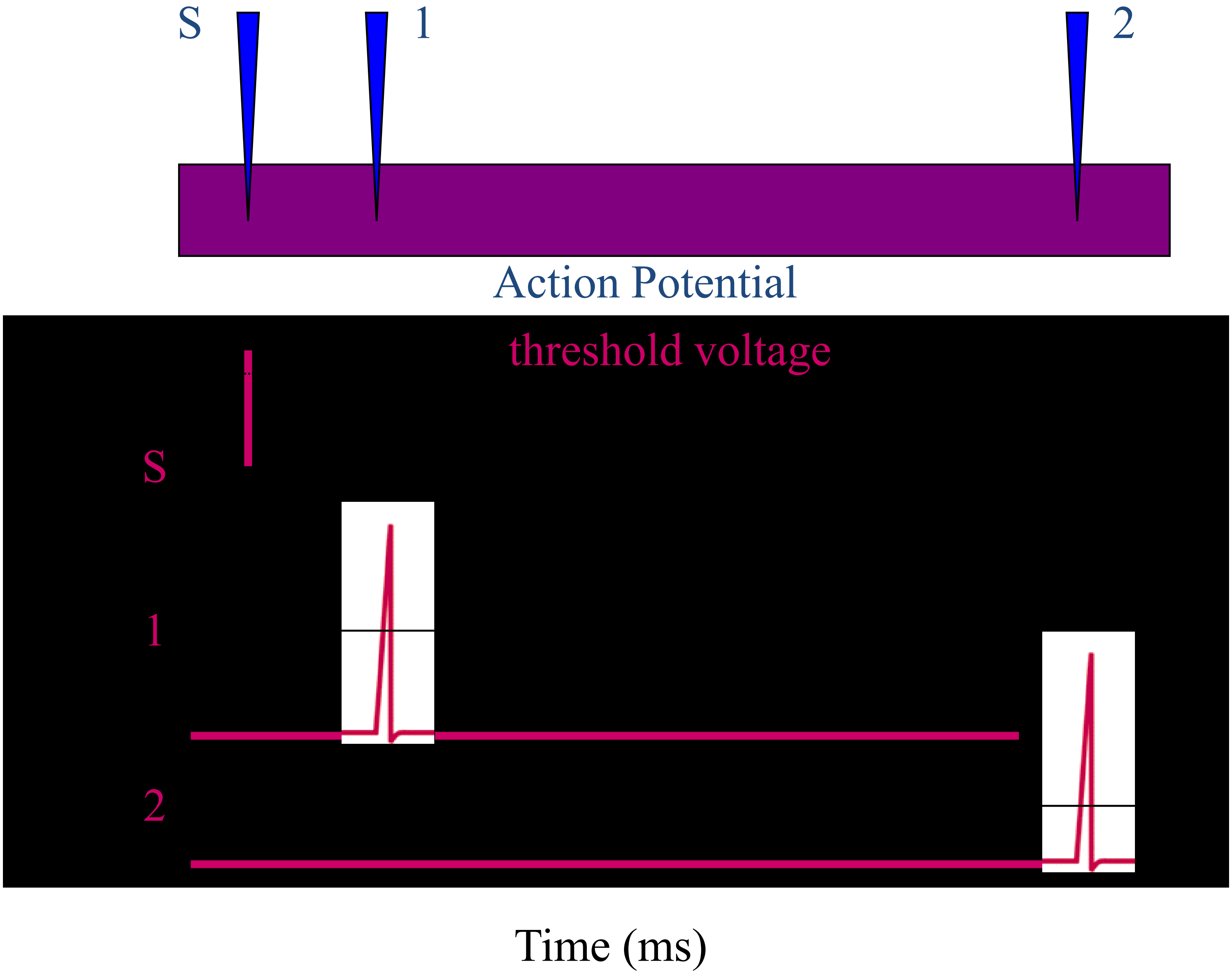

Dendrites
Presynaptic terminals
Integration
Soma
Nucleus
Spike initiation
Axon hillock
Myelin sheath
Impulse conduction
Axon terminals
Transmitter secretion

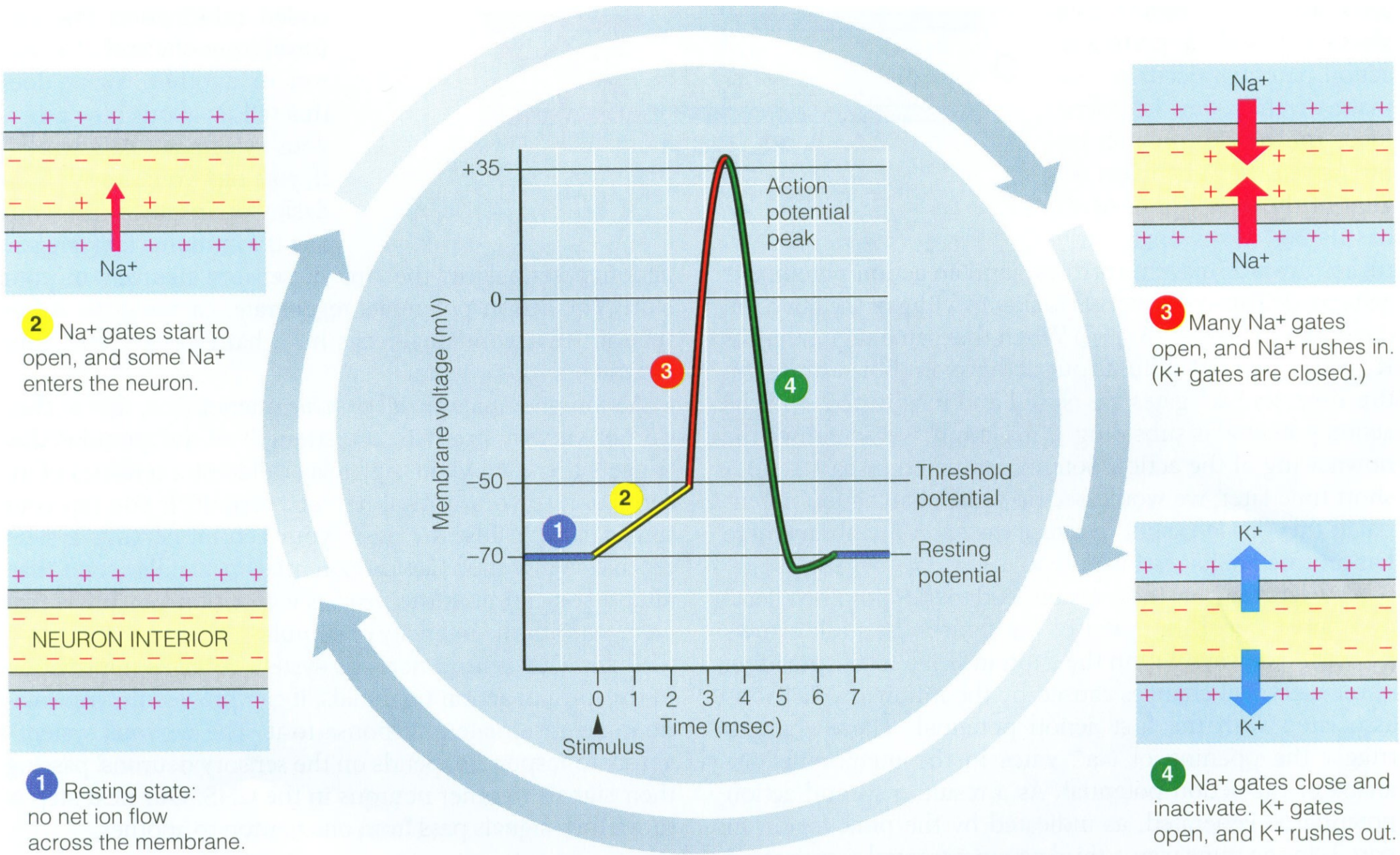


(a) Multipolar interneurons
(b) Motor neuron
(c) Sensory neuron
Dendrite
Dendrite
Receptor cell
Peripheral branch
Cell body
Axon hillock
Cell body
Axon
Axon
Node of Ranvier
Cell body
Axon
Axon
Axon
Myelin sheath
Central branch
Neuron-muscle synapse
Axon terminals
Muscle
Axon terminals


S
1
2
Graded Potential
S
1
2
Time (ms)


S
1
2
Graded Potential
S
1
2
Time (ms)


S
1
2
Action Potential
threshold voltage
S
1
2
Time (ms)



Na+
Na+ gates start to open, and some Na+ enters the neuron.
NEURON INTERIOR
Resting state: no net ion flow across the membrane.
+35
0
-50
-70
Membrane voltage (mV)
Action potential peak
Threshold potential
Resting potential
0 1 2 3 4 5 6 7
Stimulus
Time (msec)
Many Na+ gates open, and Na+ rushes in. (K+ gates are closed.)
K+
Na+ gates close and inactivate. K+ gates open, and K+ rushes out.

No "Resting" Potential for the Weary

Use the Goldman, Hodgkin, Katz equation to calculate the resting potential (V_m) for a cell having the following features:

Na^+ concentration is 150 mM on the outside and 17 mM on the inside

K^+ concentration is 5 mM on the outside and 143 mM on the inside

Cl^- concentration is 165 mM on the outside and 20 mM on the inside

The cell membrane is 25 times more permeable to K^+ and Cl^- than to Na^+