Advanced Cell Biology. Lecture 31

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Outline

Questions and answers

Ion channels

Signaling in nerve cells

Outline

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Ion channels

Signaling in nerve cells

Previous final question: the answer

Are transporters selective?

Previous final question: the answer

Are transporters selective?

- Yes! (Their functioning is based on binding to protein)

Patch-clamp recording

- Remove a piece of membrane
- Change ion concentration and voltage round this piece
- Measure changes

Patch-clamp technique

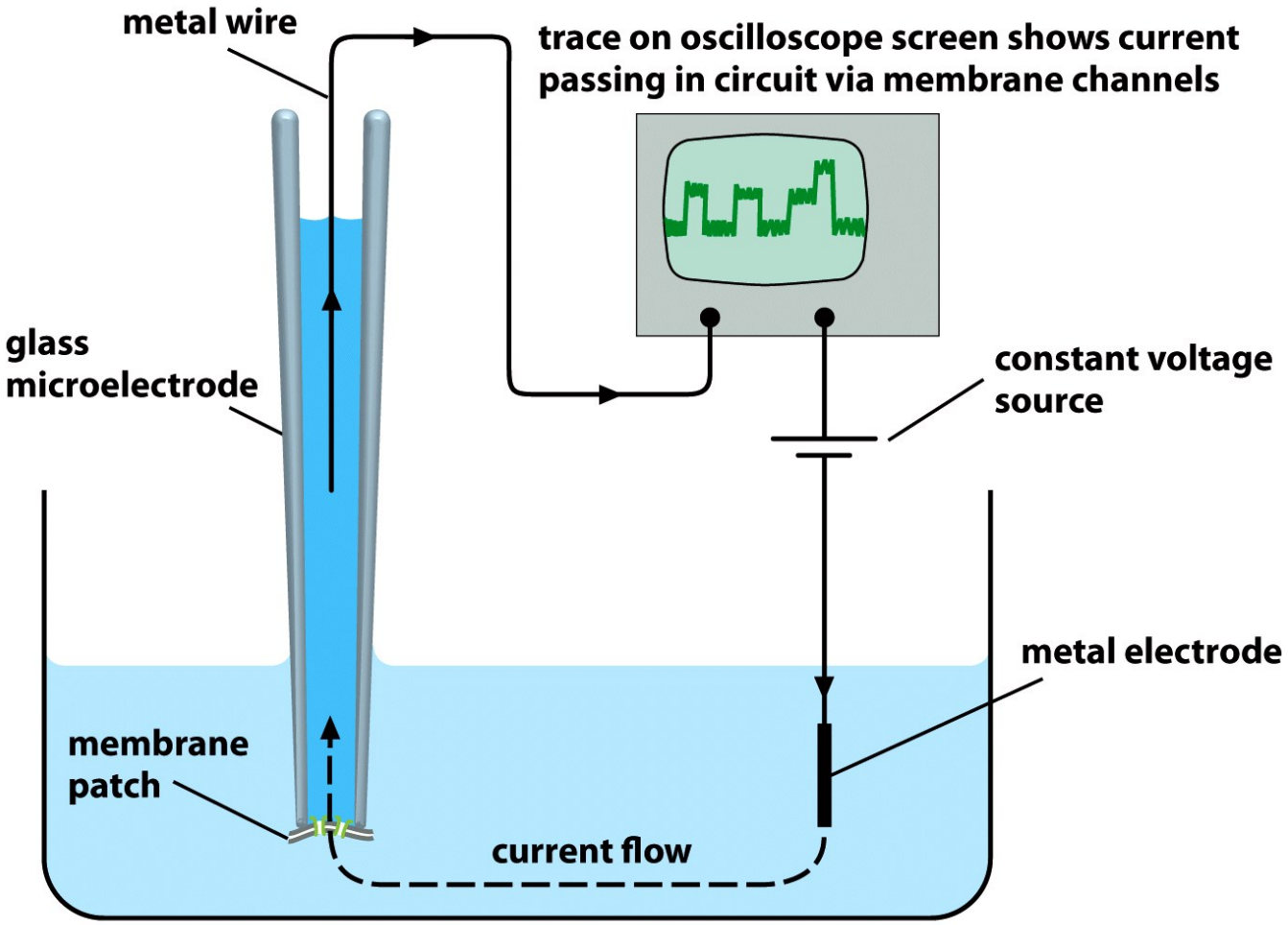
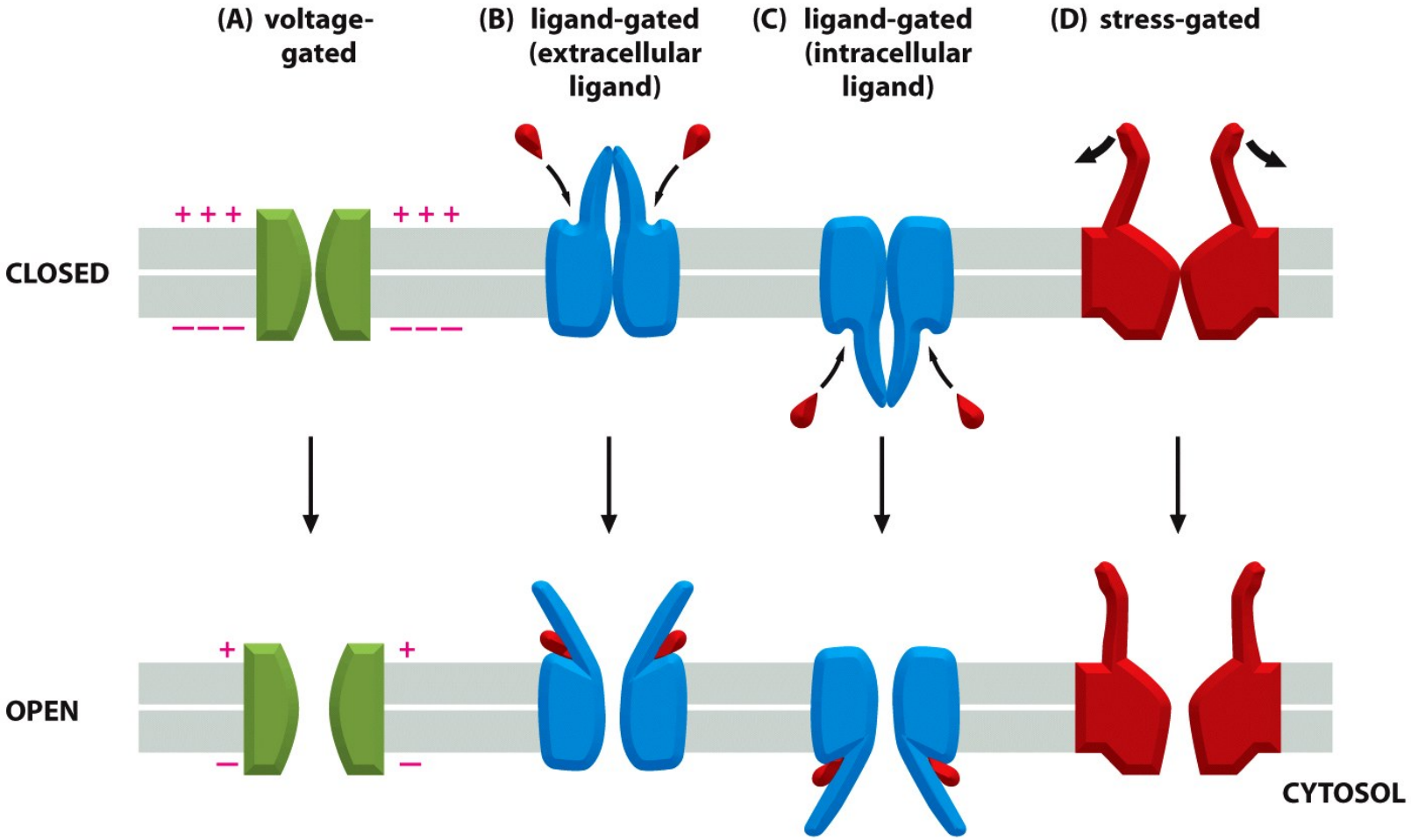


Figure 12-23d Essential Cell Biology 3/e (© Garland Science 2010)

Different types of ion gates

- Voltage-gated
- Ligand-gated
- Stress-gated

Gated channels



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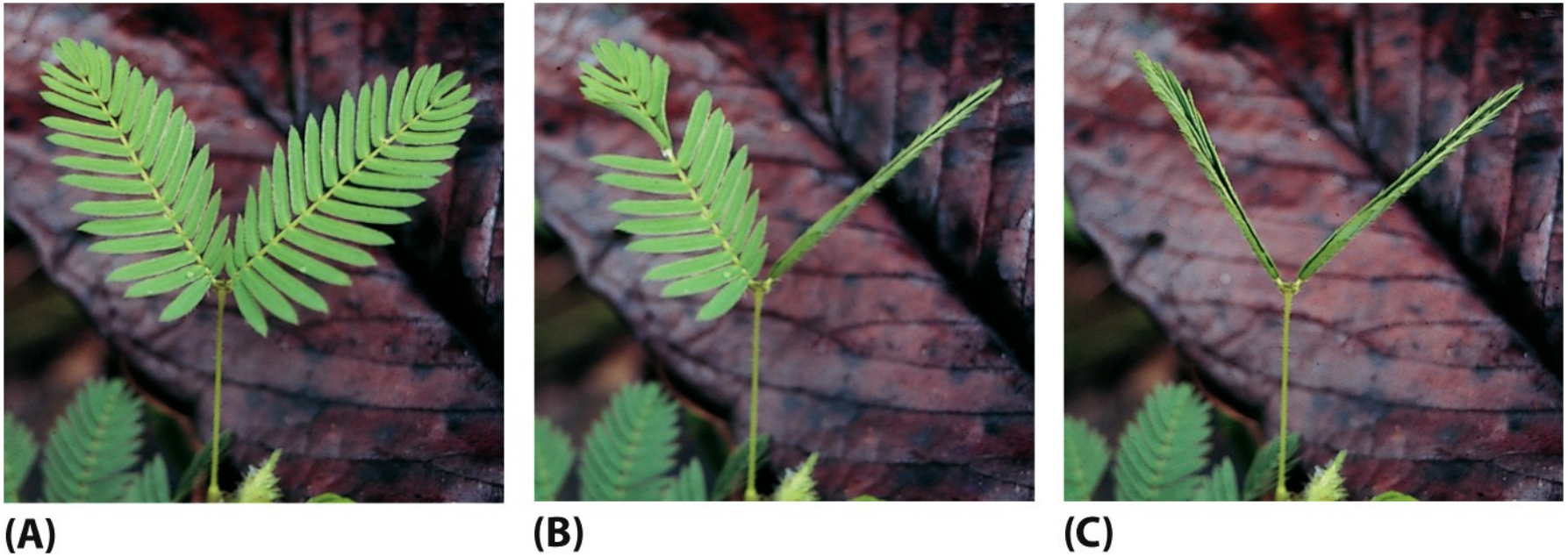
Voltage gates and membrane potential

- Voltage gates will open if electrical (!) membrane potential reaches a given value
- Then, membrane potential changes and channels are closed again
- They are responsible for most cases of sensitivity (except stress)

Mimosa plant



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Stress gates

- Stress gates react to mechanical changes
- Present in inner ear of mammals (go back to the lateral line of fishes)

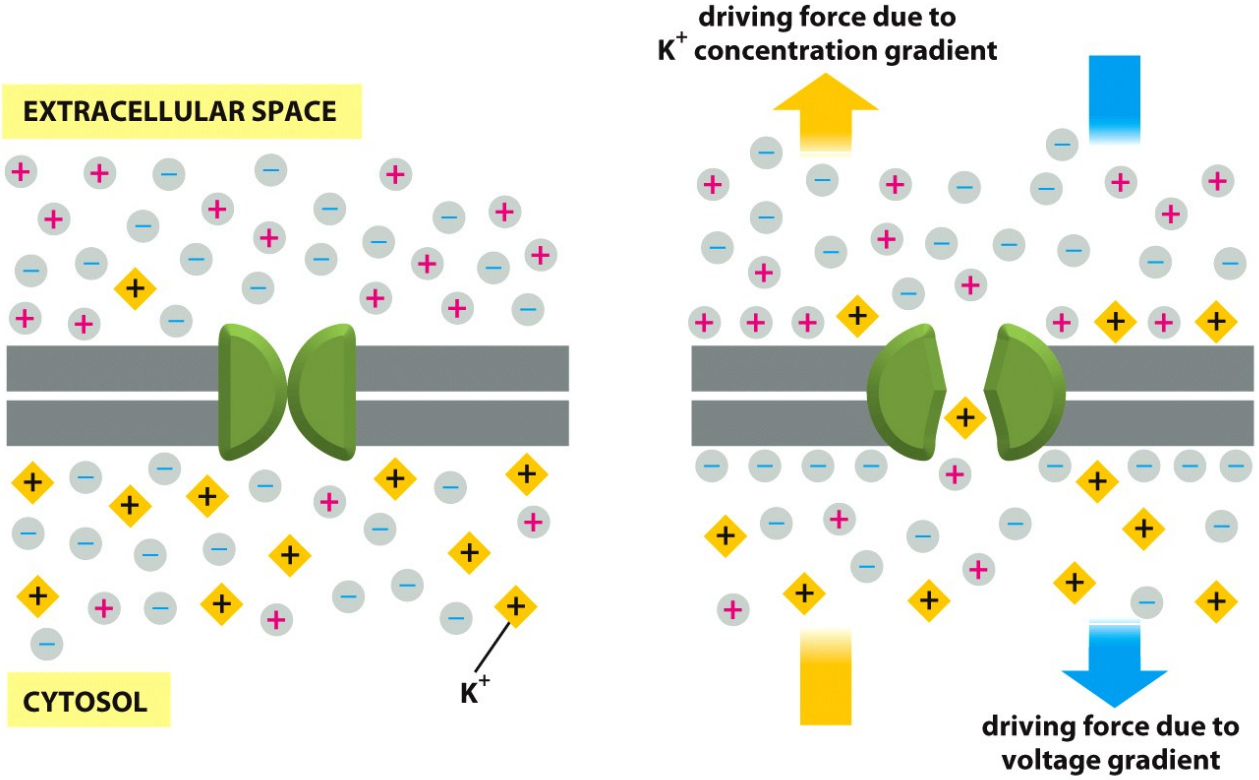
Stress gated channels movie I

Stress gated channels movie II

Origin of membrane potential

- Normally, K^+ leak channels are open randomly and let K^+ to move freely
- However, there are still much more K^+ inside than outside because when it leaks out, electric force will stop this process at some point
- This point is a resting potential, $\approx$–20–200 mV

K^+ channels



(A) K^+ channel closed, membrane potential = 0; more K^+ inside the cell than outside, but zero *net* charge on each side (positive and negative charges balanced exactly)

(B) K^+ channel open; K^+ moves out, leaving negative ions behind, and this charge distribution creates a membrane potential that balances the tendency of K^+ to move out

Figure 12-29 Essential Cell Biology 3/e (© Garland Science 2010)

Nernst equation

- Connects chemical and electrical potentials
- $V = 62 \log_{10}(C_o/C_i)$ [at +37°C]
- V is a membrane electrical potential, C_o and C_i are outside and inside concentrations of ion

Nerve cells

- Neurons
- Axons distribute signals and ends with nerve terminals
- Dendrites are short branches which receive signals

Giant axons of squids

- Atlantic squid, *Loligo pealei* has extremely long and thick axons (up to 10 cm in length and 1 mm diameter)
- This was an excellent model for studying nerve cells and signals
- Alan Hodgkin and Andrew Huxley received 1963 Nobel Prize for their investigations with giant axons

Atlantic squid

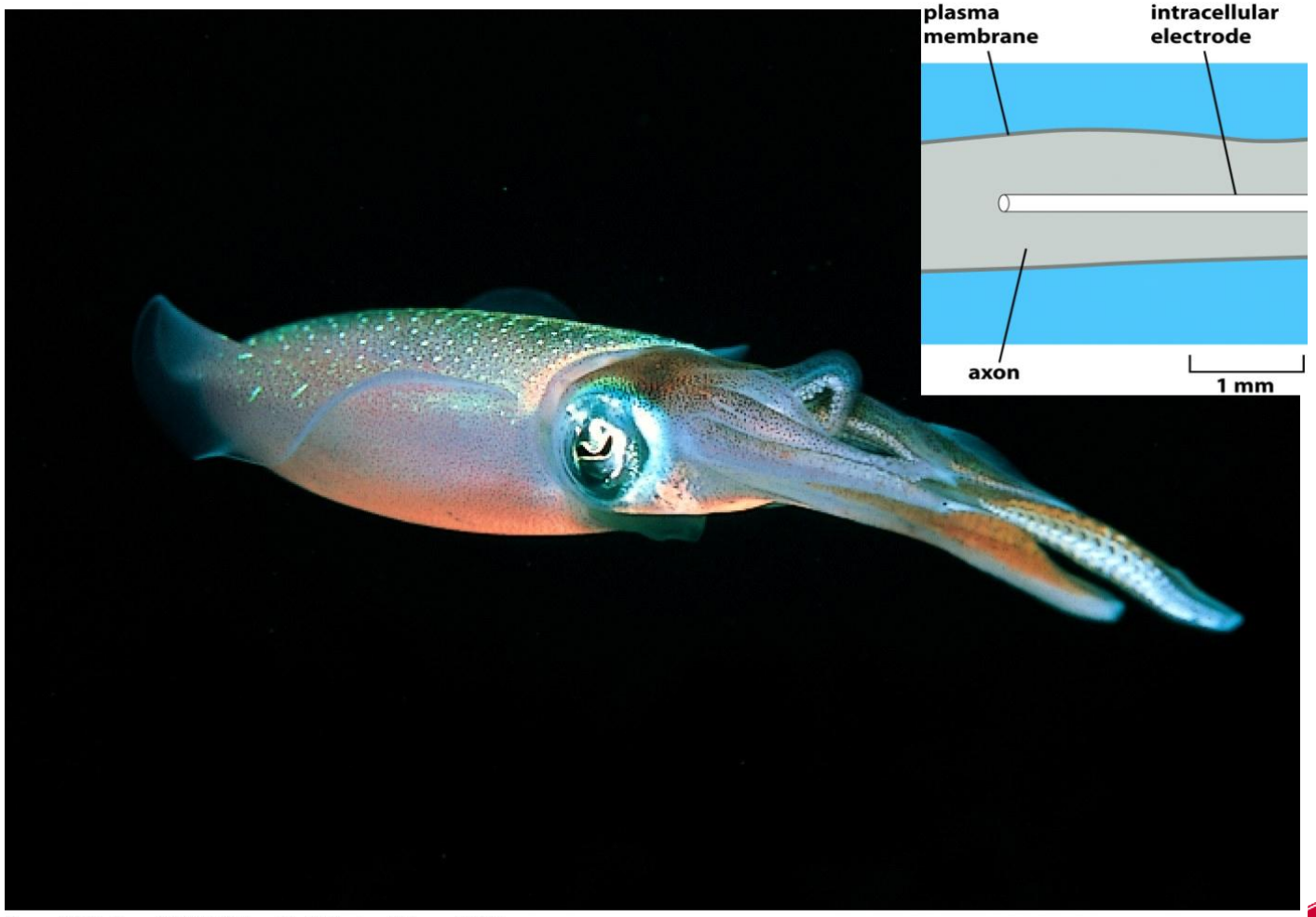
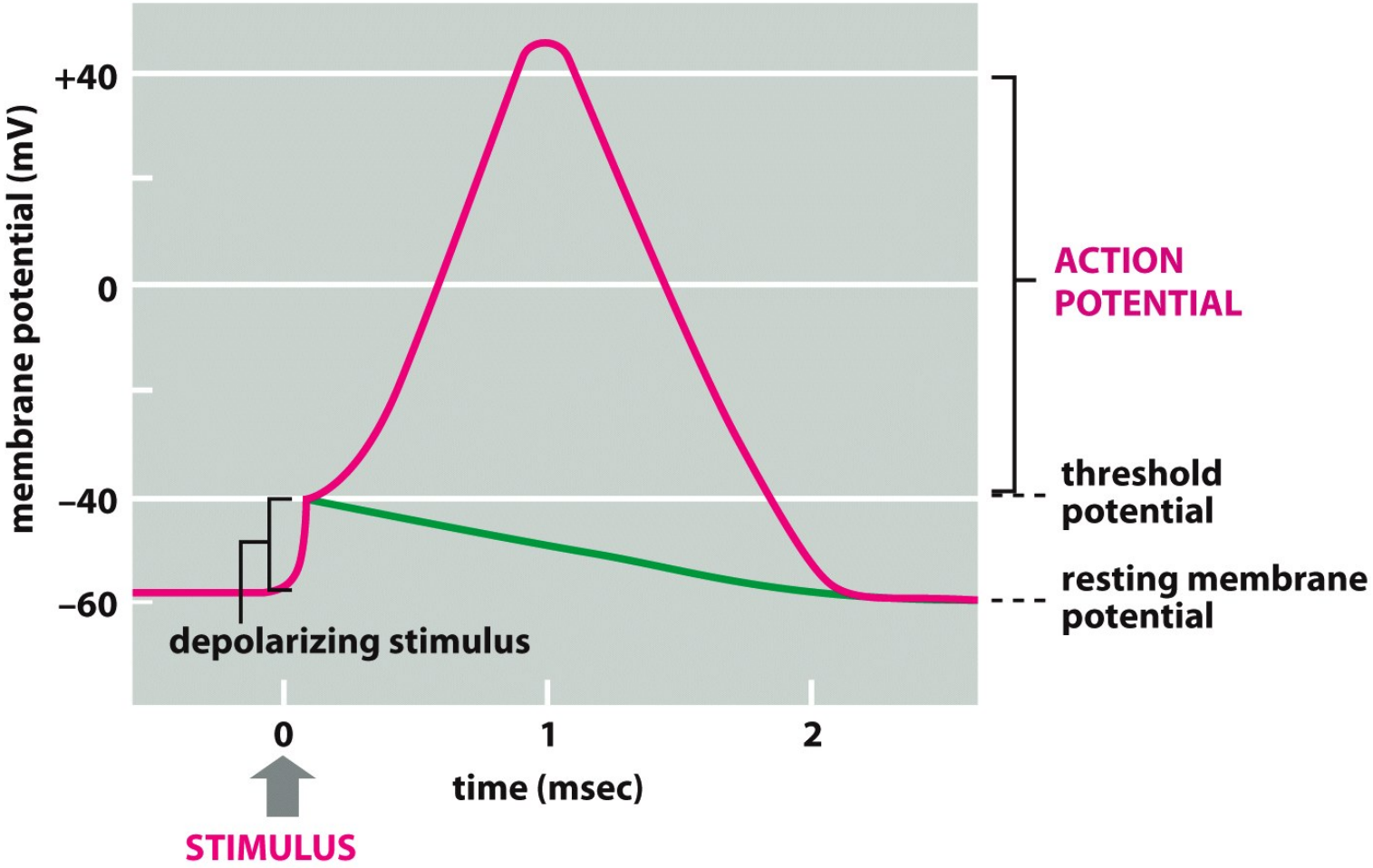


Figure 12-32 Essential Cell Biology 3/e (© Garland Science 2010)

Action potential and Na^+ channels

- Depolarization of neighbor region is a stimulus which opens Na^+ channels and initiate rapid movement of these ions into cell
- Membrane potential changes from ≈–60 to ≈+40 mV and channels inactivate
- Then, voltage-gated K^+ channels are open, K^+ leaks out of cell and potential restores
- Then, Na^+ channels close and Na^+/K^+ pump restore ion concentration to default values

Action potential



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Explanation of action potential

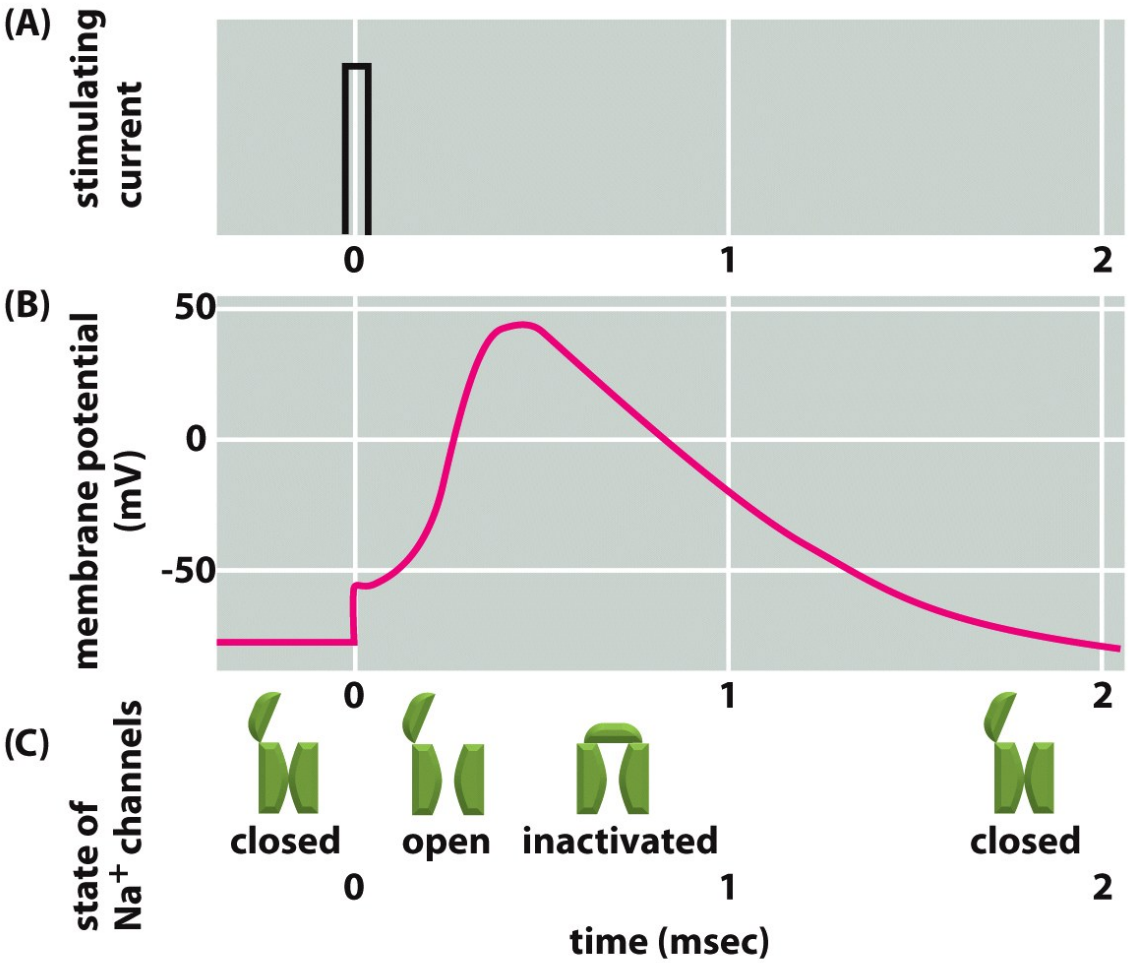

Figure 12-35 Essential Cell Biology 3/e (© Garland Science 2010)

Action potential movie

Propagation of action potential

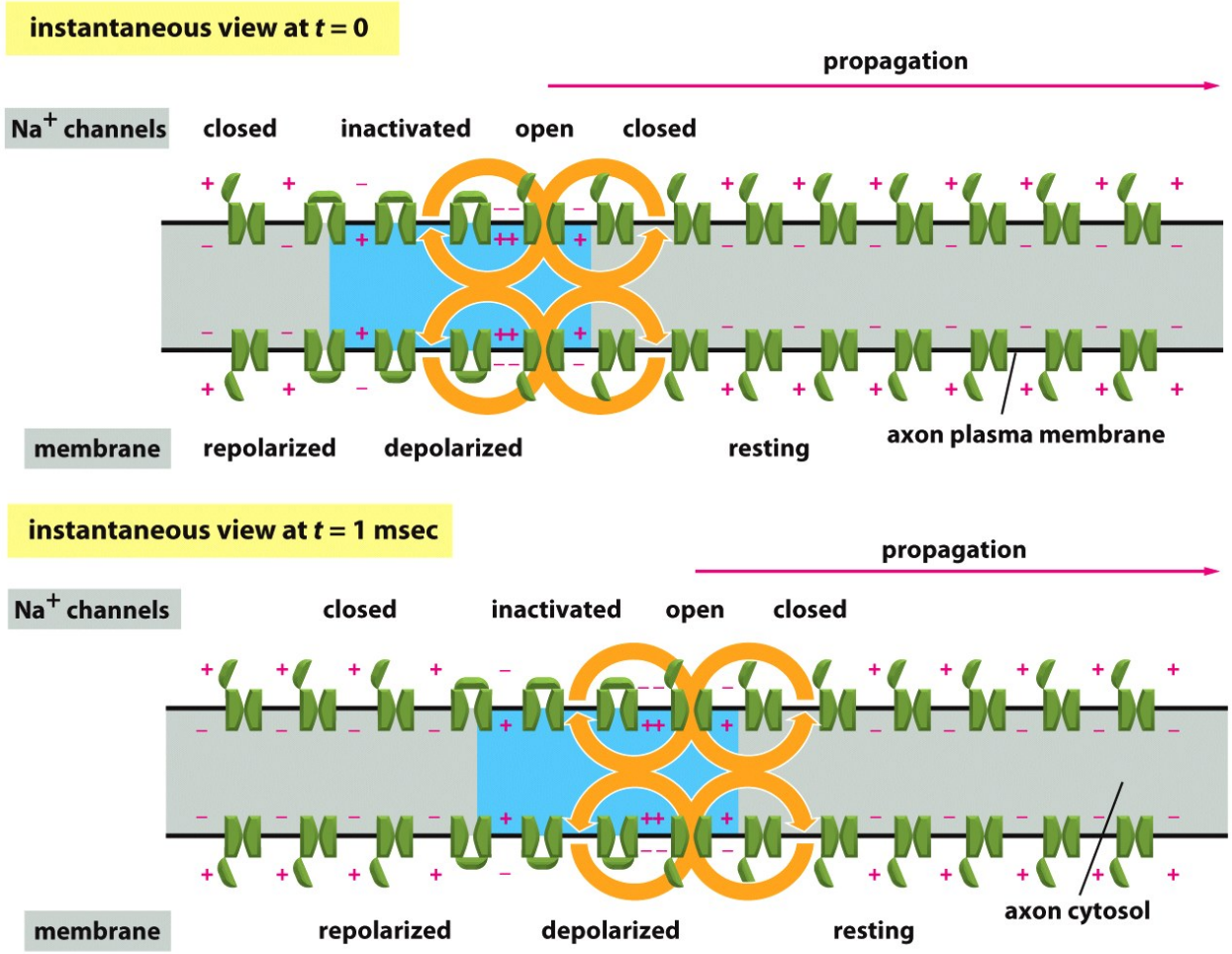

Figure 12-39b Essential Cell Biology 3/e (© Garland Science 2010)

Ca^{2+} channels and synapses

- Synapse converts electrochemical signal to pure chemical
- Depolarization of presynaptic membrane will cause Ca^{2+} channels to open, increase calcium concentration inside cell and initiate fusion of synaptic vesicles to the membrane
- Fusion should be quickly stopped (one of mechanisms is retro-neurotransmitters like endocannabinoids)

Transmitter-gated channels

- Neurotransmitter (small molecule of given configuration) crosses synaptic cleft and binds to ligand-gated receptors
- In synaptic junctions between nerve and muscle cells, acetylcholine neurotransmitter will bind to receprots in postsynaptic muscle cells
- Neurotransmitters need to be quickly destroyed (many poisons like kurare will block this destruction)

Synaptic communication (Part I)

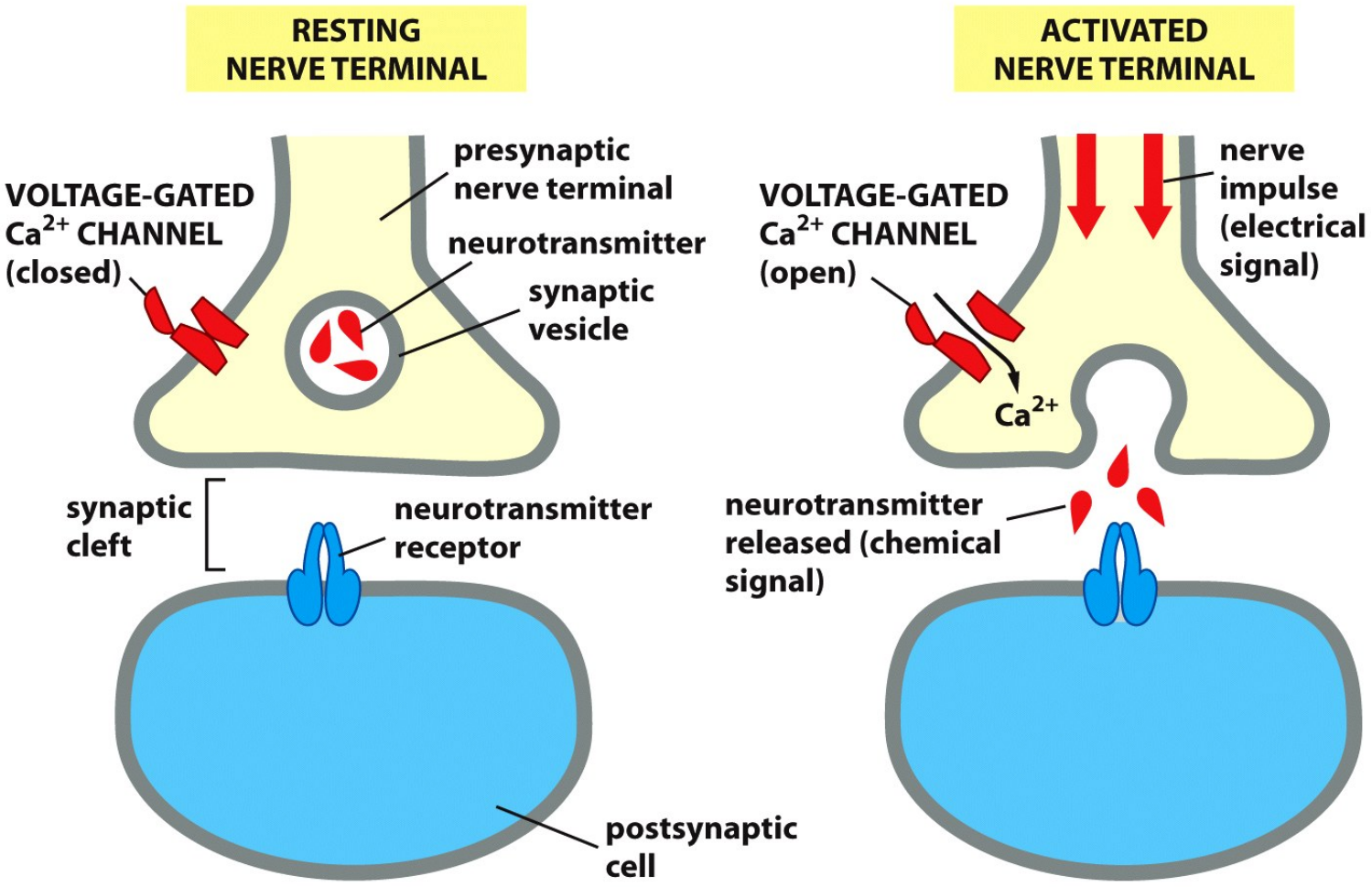

Figure 12-41 Essential Cell Biology 3/e (© Garland Science 2010)

Synaptic communication (Part II)

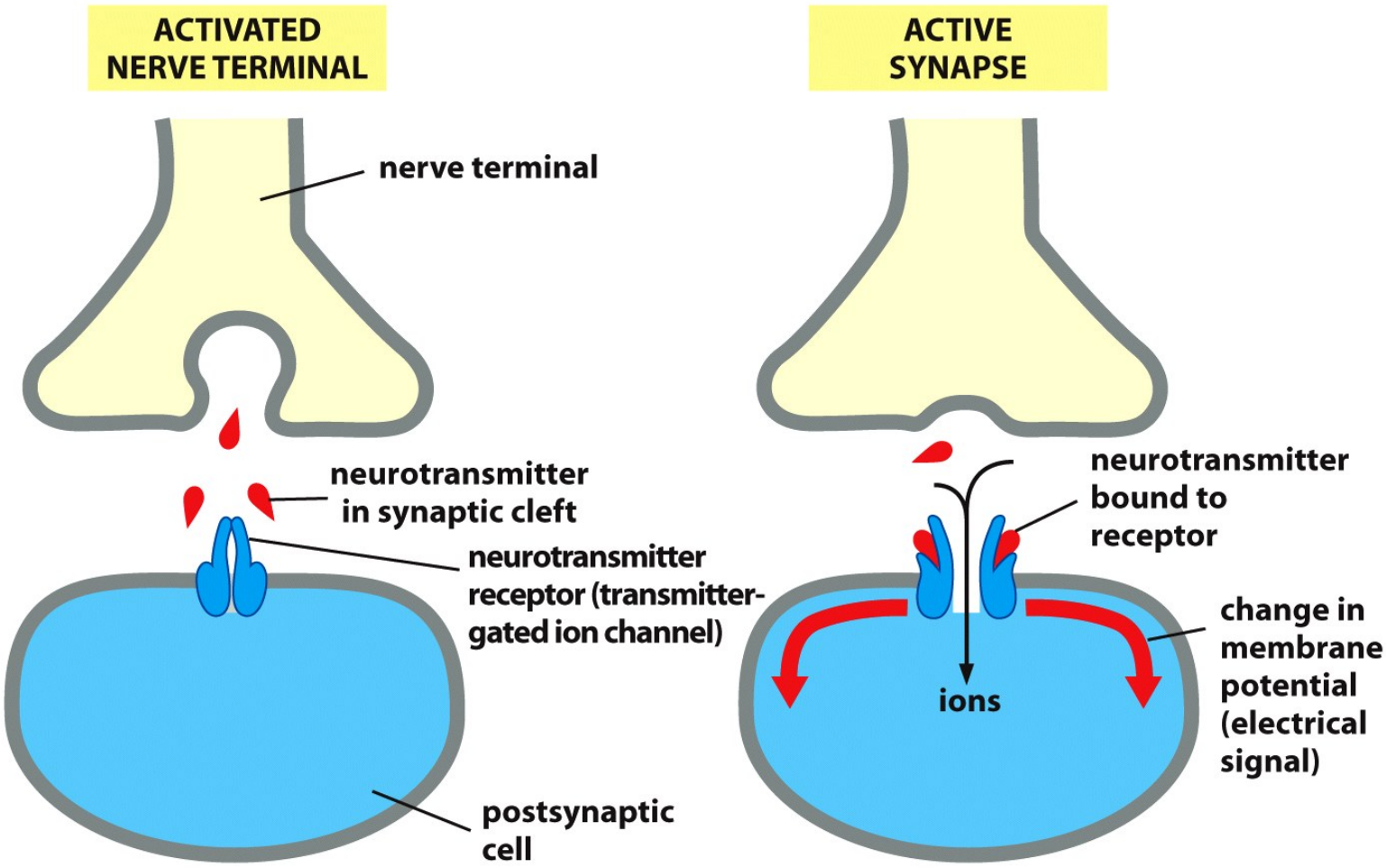

Figure 12-42 Essential Cell Biology 3/e (© Garland Science 2010)

Synaptic communication movie

Final question (2 points)

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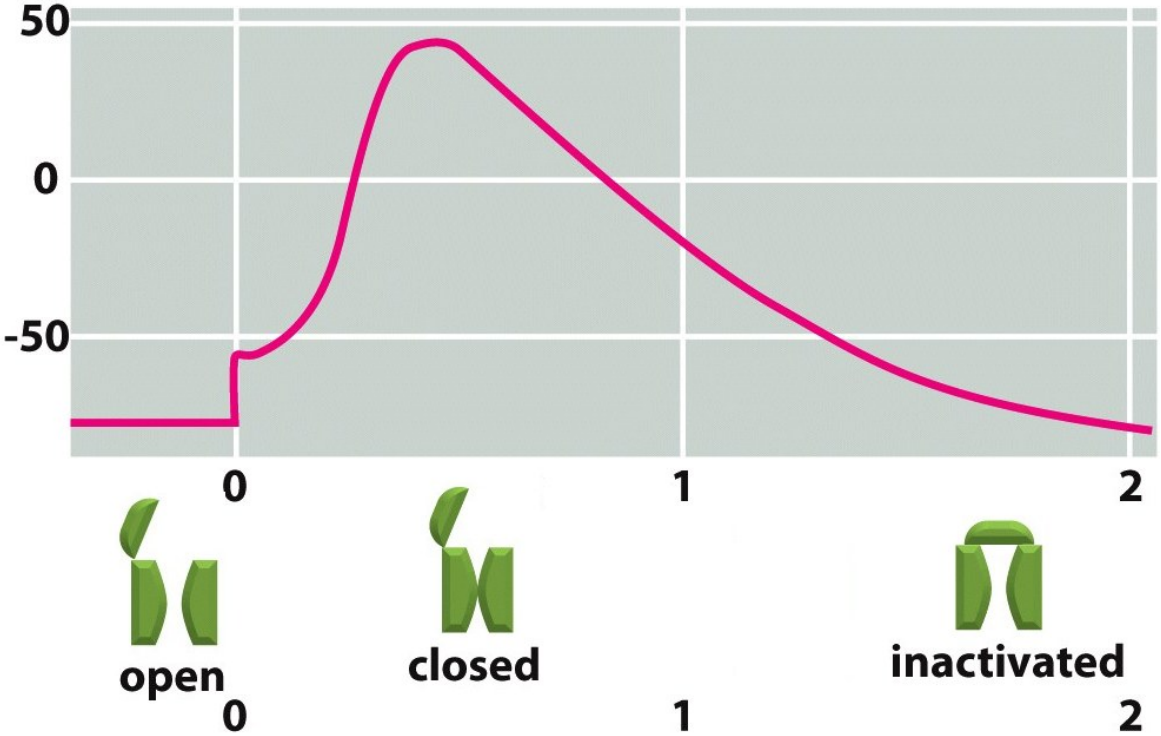
What is wrong in this picture?



Summary

- Most ion channels are gated and tot open continuously
- Membrane potential is a result of unequal distribution of electric charge across a membrane
- Action potential is due to opening, deactivating and closing of Na^+ channels
- Ca^{2+}, Cl^- channels and neurotransmitters are responsible for synaptic communication

For Further Reading

A. Shipunov.
Advanced Cell Biology [Electronic resource].
2011—onwards.
Mode of access: http://ashipunov.info/shipunov/school/biol_250.

B. Alberts et al.
Essential Cell Biology. 3rd edition.
Garland Science, 2009.
Chapter 12.