

Bio 112 Handout for Physiology 1

This handout contains:

- Today's iClicker Questions
- Handouts for today's lecture

iClicker Question #21A - before lecture

Which of the following are true?

- (A) All animals have a nervous system.
- (B) All animals have a brain.
- (C) Nerve transmission works the same in all animals that have nerves.
- (D) More than one of the above.
- (E) None of the above.

iClicker Question #21B - after lecture

Which of the following correctly describes the direction of information flow in a neuron?

- (A) cell body \Rightarrow dendrite \Rightarrow axon \Rightarrow terminus
- (B) cell body \Rightarrow axon \Rightarrow dendrite \Rightarrow terminus
- (C) dendrite \Rightarrow cell body \Rightarrow axon \Rightarrow terminus
- (D) terminus \Rightarrow cell body \Rightarrow axon \Rightarrow dendrite
- (E) none of the above

Beaming in your answers

1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should re-send it until you get a green "STATUS" light.

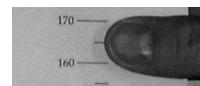
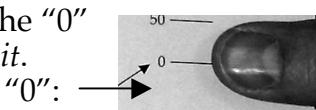
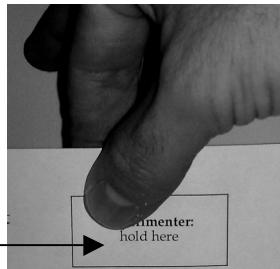
Reaction Time Measurement

Experimenter:
hold here

How to measure the Subject's Reaction Time:

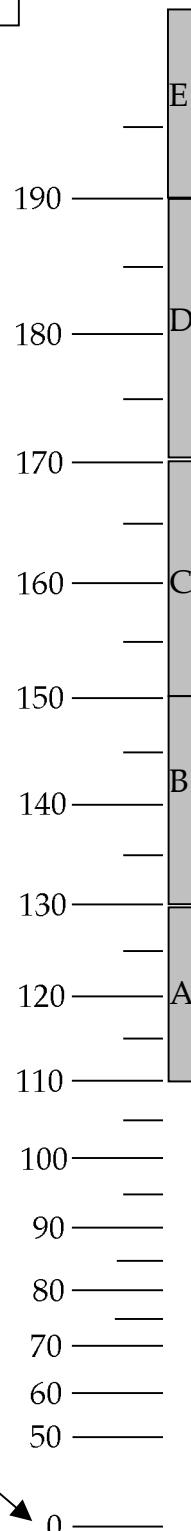
You will measure the time it takes the **Subject** to catch the paper after it has been dropped by the **Experimenter**.

- 1) **Experimenter** holds the paper by the spot indicated. Let the paper hang down freely.
- 2) **Subject** holds her finger and thumb right near the "0" as close to the paper as she can *without touching it*. Line up the middle of your thumb nail with the "0":
- 3) *Without telling the Subject*, the **Experimenter** drops the paper.
- 4) As soon as the **Subject** sees the paper start to drop, she closes her finger and thumb to catch the paper as it falls.
- 5) The longer it takes for the **Subject** to catch the paper, the farther it falls*.
- 6) You can then read the **Subject**'s reaction time by looking at the position of their thumb on the scale to the right. The example shown indicates a reaction time of about 165 ms (in between the 160 and 170 marks).



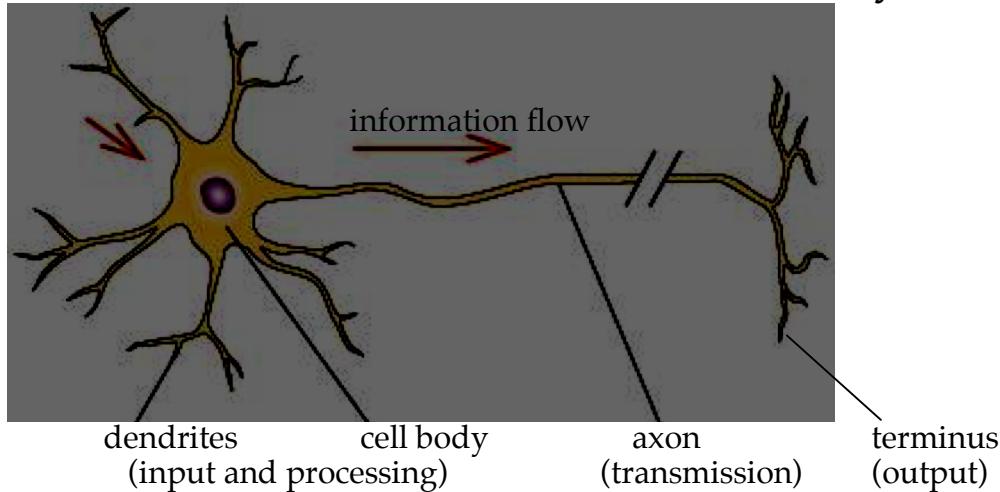
Subject:

- Start here (finger and thumb close to, *but not touching*, the paper).
- Line up the middle of your thumb nail with the "0" line.
- Catch it when the experimenter drops it.

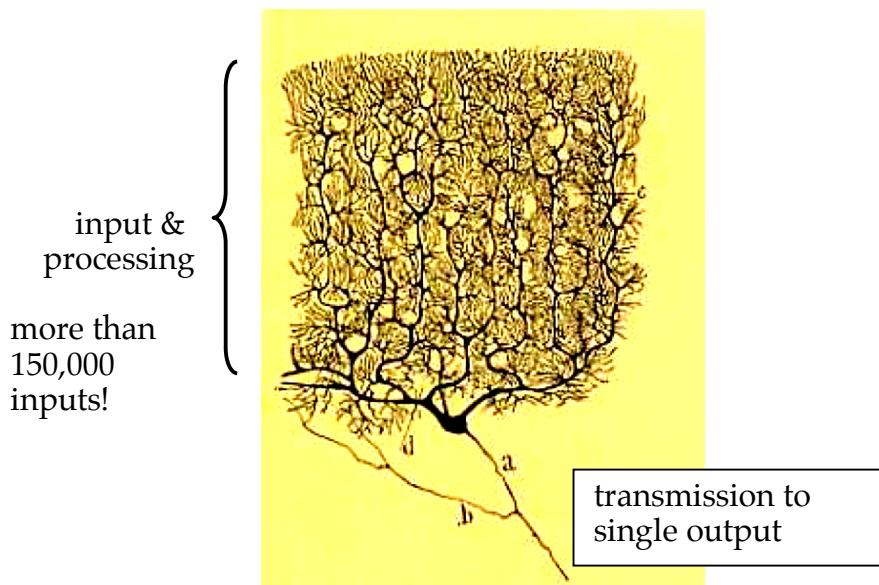


* Acceleration due to gravity is 32 feet per second per second. Therefore, the distance fallen (in inches) = $192 \times (\text{time in seconds})^2$.

Neurons: the active cells in the nervous system

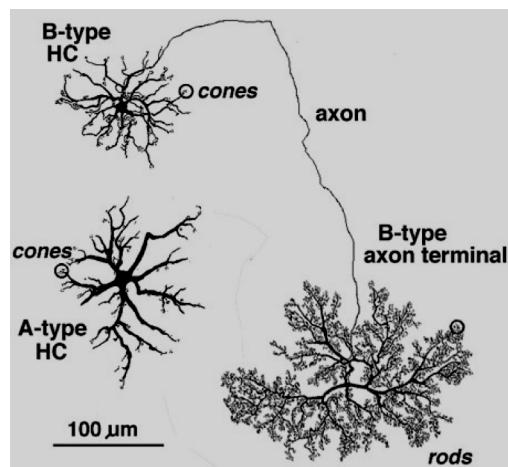


Purkinje cell (from cerebellum: feedback for motor tasks)

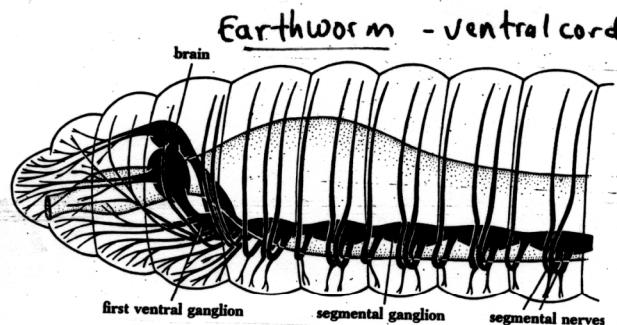
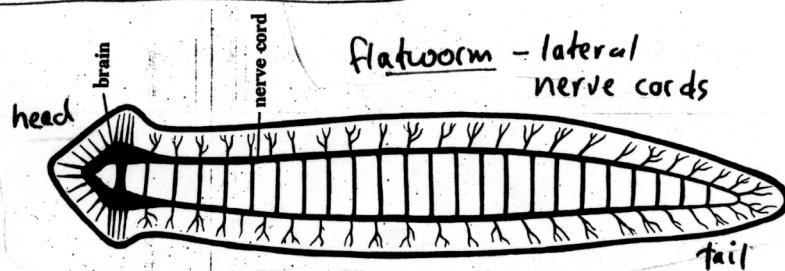
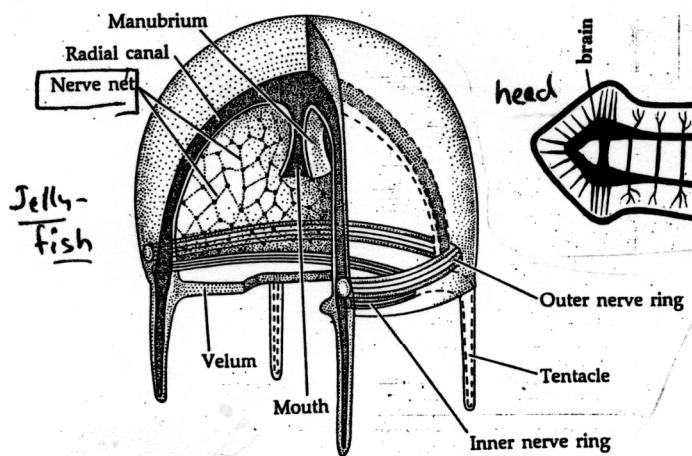


Horizontal Cells (from retina)

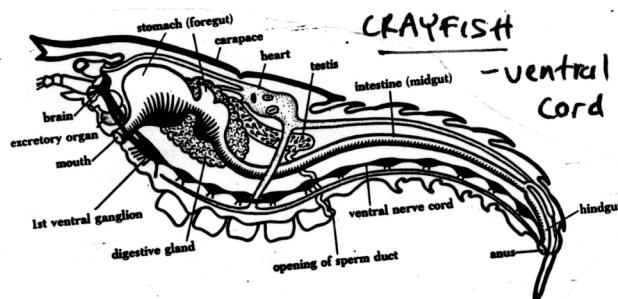
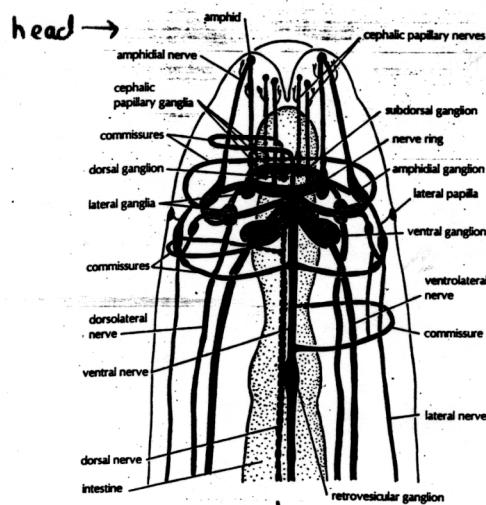
many inputs and outputs



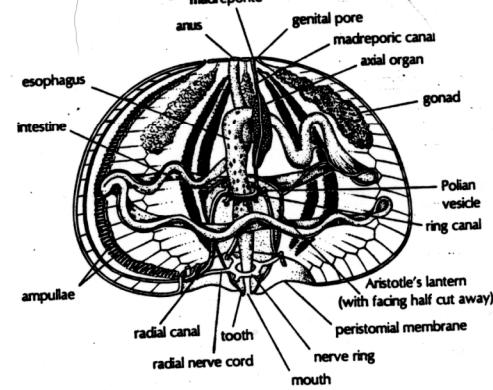
INVERTEBRATE NERVOUS SYSTEMS



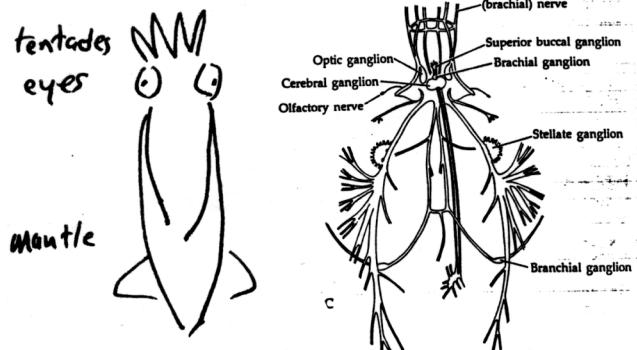
Nematode lateral nerve cords



Sea urchin - radial net



SQUID - complex...



Bio 112 Handout for Physiology 2

This handout contains:

- Today's iClicker Questions
- Handouts for today's lecture

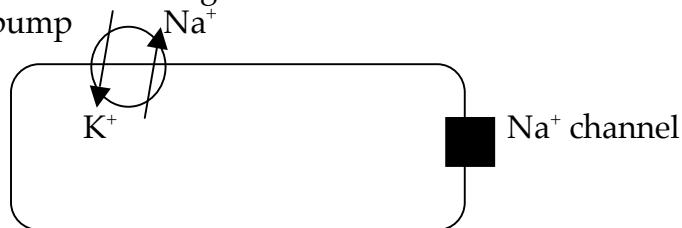
iClicker Question #22A - before lecture

Which of the following are true?

- A. Moving an ion from a low concentration to a high concentration requires energy input.
- B. Moving an ion from a high concentration to a low concentration is spontaneous.
- C. Ions cannot cross a membrane on their own.
- D. All of the above.
- E. None of the above.

iClicker Question #22B - after lecture

Consider the following cell:



If you let the pump pump Na^+ out and K^+ in and then open the Na^+ channel, what will happen?

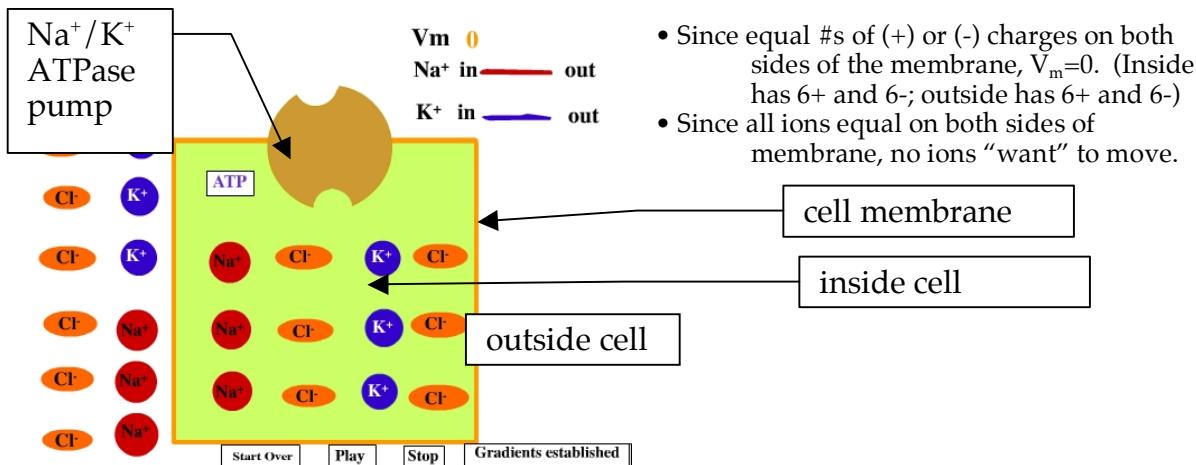
- (A) Na^+ will go out of the cell, making V_m become +.
- (B) Na^+ will go out of the cell, making V_m become -.
- (C) Na^+ will go into the cell, making V_m become +.
- (D) Na^+ will go into the cell, making V_m become -.
- (E) none of the above.

Beaming in your answers

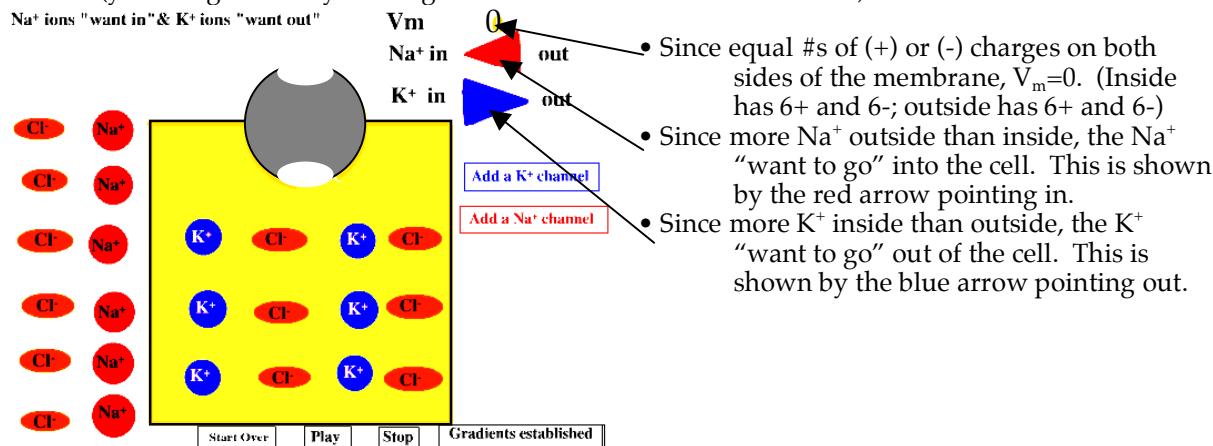
1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should re-send it until you get a green "STATUS" light.

Bio 112: Resting Potential

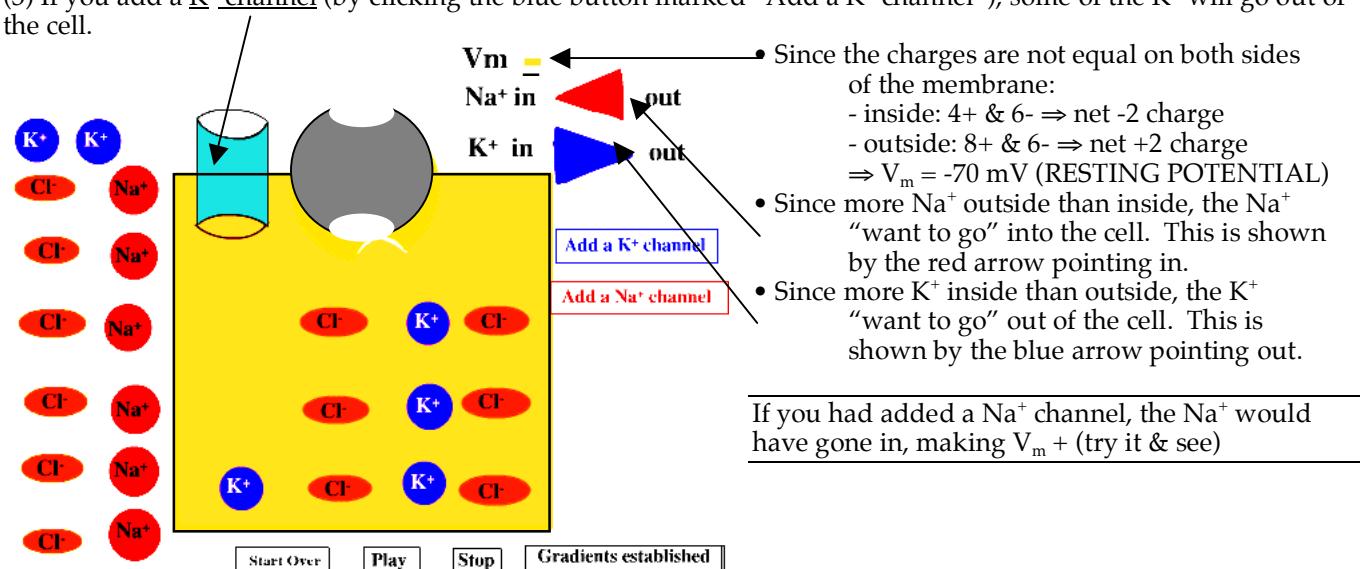
(1) Start: all concentrations equal on both sides of the membrane. Cells are never found in this situation; it is shown only for illustration purposes.



(2) Na⁺/K⁺ ATPase pump uses energy from ATP to pump Na⁺ out and K⁺ in. This gives this situation (you can get here by clicking the "Gradients Established" button):



(3) If you add a K⁺ channel (by clicking the blue button marked "Add a K⁺ channel"), some of the K⁺ will go out of the cell.



Bio 112 Handout for Physiology 3

This handout contains:

- Today's iClicker Questions
- Handouts for today's lecture

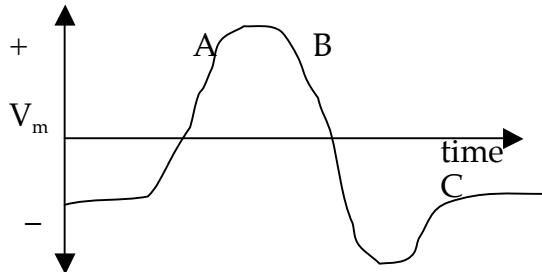
iClicker Question #23A - before lecture

Which of the following are true?

- A. In an action potential, the Na^+ ions move along the axon.
- B. In an action potential, Na^+ channels remain closed.
- C. An action potential is when V_m becomes negative for a short time.
- D. All of the above.
- E. None of the above.

iClicker Question #23B - after lecture

Consider an action potential:



At which point(s) are the voltage-gated Na^+ channels open?

- (A) A, B, and C.
- (B) A and B only.
- (C) B only.
- (D) A only.
- (E) none of the above.

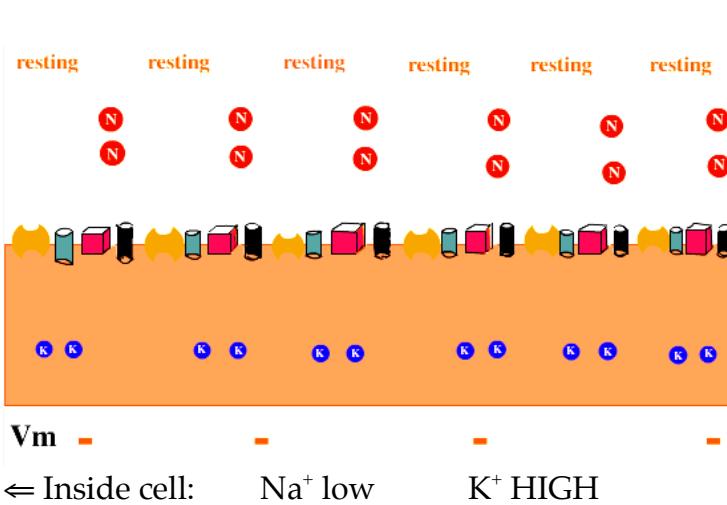
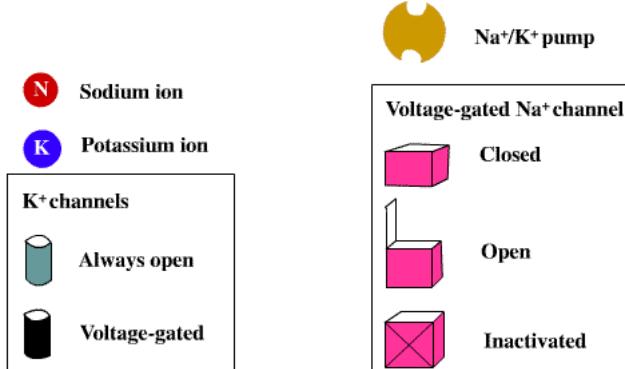
Beaming in your answers

1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should re-send it until you get a green "STATUS" light.

Bio 112 Action Potentials

Shown below is a very short axon (the dendrites, cell body, and terminus are omitted for clarity).

Key:



(1) Resting state: Na⁺/K⁺ pump: running

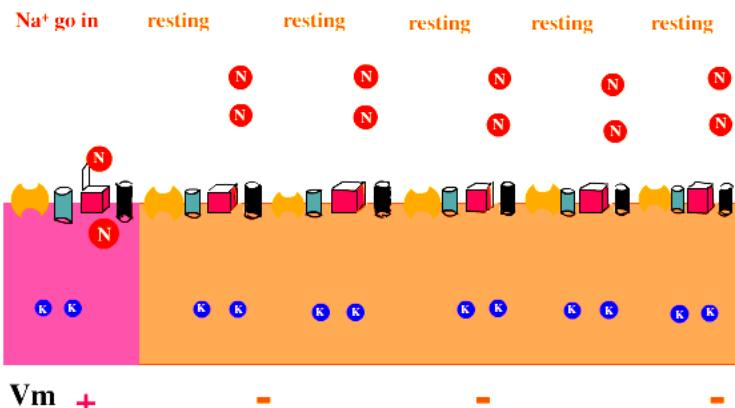
↔ Outside cell: Na⁺ HIGH K⁺ low

↔ cell membrane: Na⁺/K⁺ pump: running

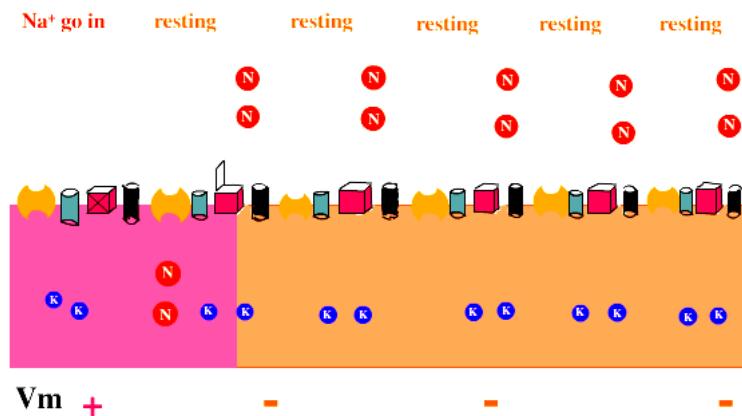
Na⁺ channel closed
K⁺ channel open (V-gated: closed)
⇒ K⁺ leak out ⇒ $V_m = -70\text{mV}$

(2) First Na⁺ channel opens.

⇒ Na⁺ go in faster than K⁺ are going out
⇒ V_m becomes + right near open channel



(3) A (+) V_m near the next Na^+ channel triggers that channel to open $\Rightarrow V_m$ becomes + nearby

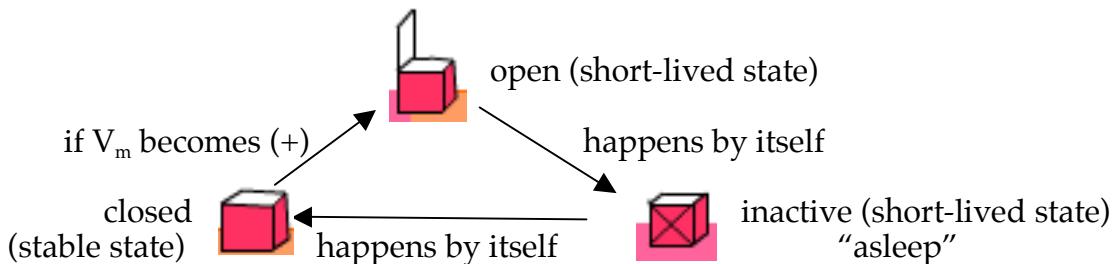


4) Wave of depolarization ($V_m +$) spreads along axon \Rightarrow .
This wave of depolarization = **an action potential**

5) Problem: if Na^+ channels stay open when V_m is (+), then how do you send the next pulse?

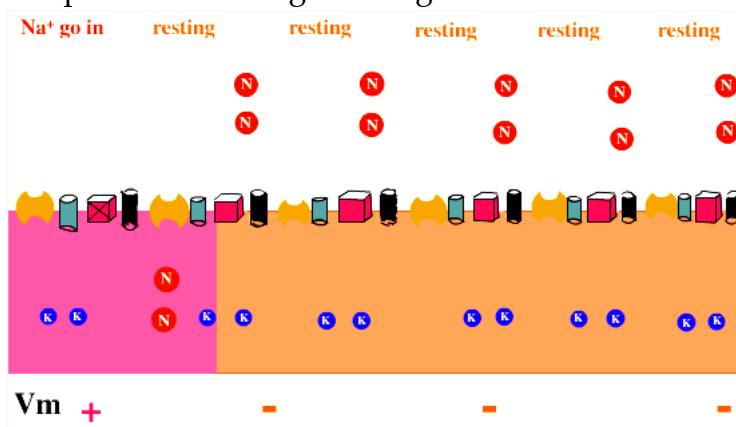
Answer: the Na^+ channel has an **inactive** state.

- After it has been open for about 0.001 seconds, it automatically closes & becomes inactive
(closed no matter what V_m is)
- about 0.001 seconds after that, it becomes closed & ready to be opened again
(by then, the membrane has re-polarized)

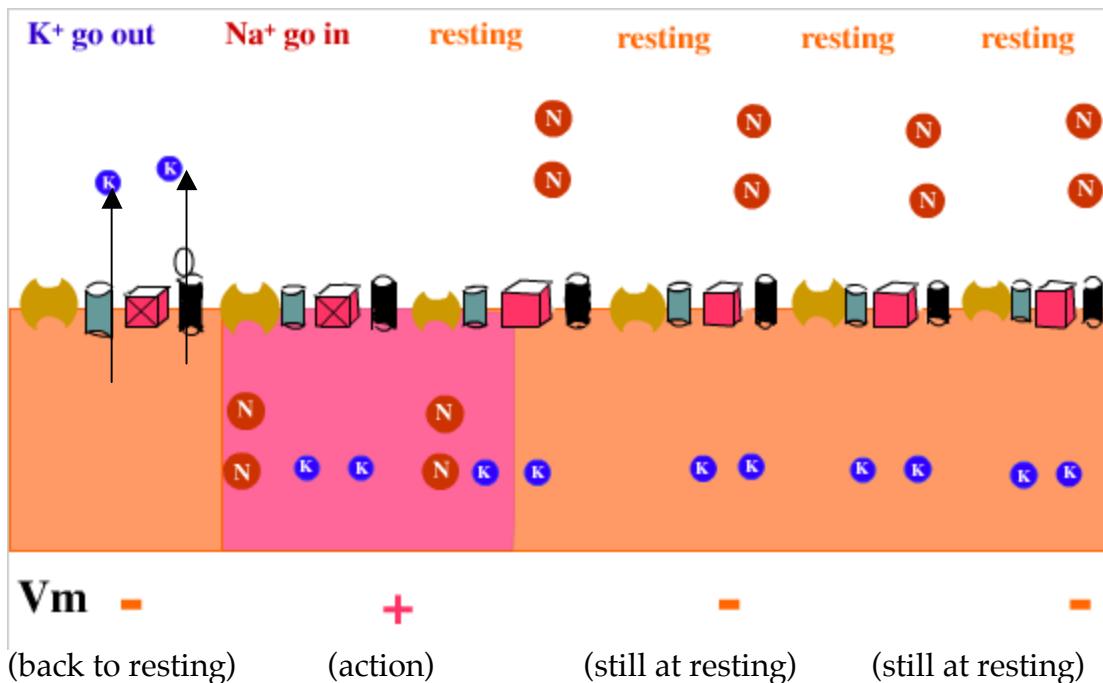


(6) How does this work? Here is an action potential moving \Rightarrow along the axon

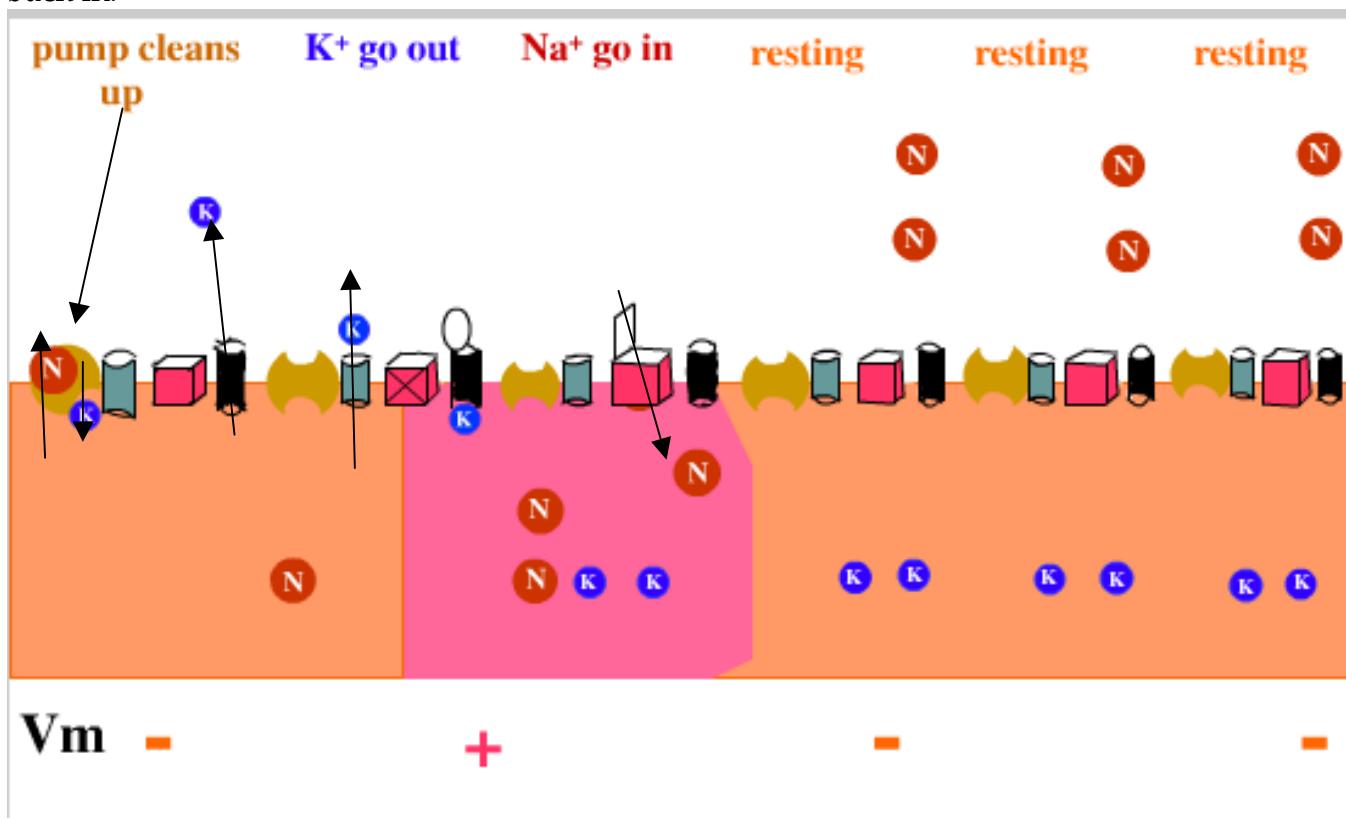
The first Na^+ channel to open is the first to inactivate.



(7) How is the resting potential restored? Lots of K⁺ rush out through K⁺ channels (repelled by + charge inside) and neutralize the + charge inside. Also, voltage-gated K⁺ channels open to allow faster K⁺ out-flow.



(8) Finally, the Na⁺/K⁺ pump “cleans up the mess” by pumping the Na⁺ back out and the K⁺ back in.



What is an action potential? A wave of depolarization going along an axon:

	AFTER		DURING		BEFORE	
State	ready	recharging	inactive	action	ready	ready
V_m	-	-	changing	+	-	-
Na^+/K^+ pump	running	running a lot	running	running	running	running
K^+ channel	open	open	open	open	open	open
Na^+ channel	closed	closed	inactive	open	closed	closed
K^+ flow through pump	small in	large in	small in	small in	small in	small in
K^+ flow through channel	small out	small out	large out	small out	small out	small out
Na^+ flow through pump	small out	large out	small out	small out	small out	small out
Na^+ flow through channel	none	none	none	large in	none	none



Bio 112 Handout for Physiology 4

This handout contains:

- Today's iClicker Questions

iClicker Question #24A - before lecture

Which of the following are true?

- A. During the first part of an action potential, Na^+ ions go in, making V_M (+).
- B. After V_M becomes positive, K^+ ions go out to bring V_M back (-).
- C. The voltage-gated Na^+ channels only stay open for a short time before closing and ignoring V_M for a little while.
- D. All of the above.
- E. None of the above.

iClicker Question #24B - after lecture

Which of the following drugs would have the same anesthetic effect as novocain?

- A. Drug X, which binds to voltage-gated Na^+ channels and plugs the opening so Na^+ ions can't get through.
- B. Drug Y, which binds to K^+ channels and plugs the opening so K^+ ions can't get through.
- C. Drug Z, which makes the voltage-gated Na^+ channels stay inactive longer before becoming ready again.
- D. All of the above.
- E. None of the above.

Beaming in your answers

1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should re-send it until you get a green "STATUS" light.



Bio 112 Handout for Physiology 5

This handout contains:

- Today's iClicker Questions

iClicker Question #25A - before lecture

Which of the following are true?

- A. Nerve cells communicate to one another electrically.
- B. Neurotransmitters are destroyed by the receiving channels after they cause the channels to open or close.
- C. Neurotransmitters "self-destruct" after they have interacted with their receptors.
- D. All of the above.
- E. None of the above.

iClicker Question #25B - after lecture

Consider the imaginary neurotransmitter, neurotransmitter X (NT-X). Suppose that there is a NT-X-gated Na^+ channel that has the following behavior:

- with no NT-X around the channel is OPEN.
- with NT-X around, the NT-X binds to this channel and CLOSES it.

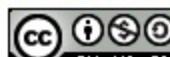
Suppose further that these NT-X-gated Na^+ channels are located on the dendrite of a neuron - neuron Y. Which of the following statements is true:

- A. If another neuron sprays NT-X on these NT-X-gated Na^+ channels on the dendrite of neuron Y, an action potential will be MORE likely in neuron Y (a stimulatory synapse).
- B. If another neuron sprays NT-X on these NT-X-gated Na^+ channels on the dendrite of neuron Y, an action potential will be LESS likely in neuron Y (an inhibitory synapse).
- C. If another neuron sprays NT-X on these NT-X-gated Na^+ channels on the dendrite of neuron Y, there will be NO EFFECT on neuron Y.
- D. I don't know.

Beaming in your answers

1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should resend it until you get a green "STATUS" light.

For further reading, if you are interested in the history of these discoveries, you might want to read *The War of the Soups and the Sparks : The Discovery of Neurotransmitters and the Dispute Over How Nerves Communicate* by Elliot S. Valenstein.





Bio 112 Handout for Physiology 6

This handout contains:

- Today's iClicker Questions
- Handouts for today's lecture

iClicker Question #26A - before lecture

Which of the following are true?

- A. Scented molecules are detected by cells on the tongue.
- B. Scented molecules bind to channels in the membrane of receptor cells and open them, leading to an action potential.
- C. Scented molecules bind to receptors in the membrane of certain sensory cells.
- D. All of the above
- E. None of the above

iClicker Question #26B - after lecture

Suppose there were a drug Q that binds to the cAMP-gated Na^+ channels found on OSN's and prevents these channels from opening. What effect would this drug have on your sense of smell?

- (A) No effect on your sense of smell.
- (B) It would make your sense of smell more sensitive.
- (C) It would make your sense of smell less sensitive.
- (D) I don't know.

Beaming in your answers

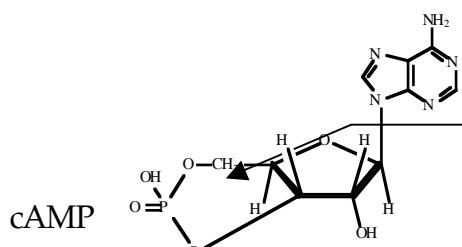
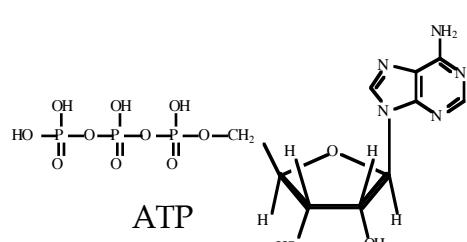
1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should re-send it until you get a green "STATUS" light.

Bio 112 Smells

Key players:

These are all described in Campbell pages 206-217.

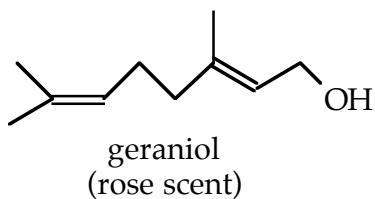
1. Scent Molecule a small molecule (see below) that has a scent (a.k.a. an "odorant"). Roughly equivalent to the "growth factor" in the Cancer section of Bio 111.
2. Odorant Receptor Protein (ORP) a protein that is embedded in the membrane. The outside-the-cell part of the receptor binds the scent molecule - receptors bind only one kind of scent molecule (or a closely-related family of molecules). Once the scent molecule is bound, the inside-the-cell portion of the receptor becomes active and activates G-proteins. Roughly equivalent to the "receptor" in the Cancer section of Bio 111.
3. G-protein a protein that is activated by an active receptor; it has a time-delayed deactivation mechanism. Active G-protein activates ATCase. Roughly equivalent to the "ras protein" in the Cancer section of Bio 111. See Campbell fig. 11.7
4. Adenylyl cyclase (ATCase) a protein which, when activated by active G-protein converts the small molecule ATP to the small signaling molecule cAMP. See Campbell fig. 11.9 and 11.10
5. ATP the same ATP from glycolysis, etc. See figure 11.9.
6. cAMP (cyclic AMP) a modified form of ATP that is used as a signal inside some cells (see below). See figure 11.9



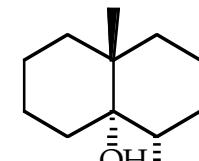
Notice the ring - that's why it's "cyclic".

7. cAMP-gated Na⁺ channels sodium channels that open when cAMP is present.

Some scented molecules:



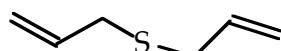
geraniol
(rose scent)



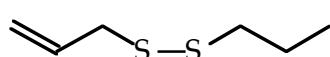
geosmin
(beets & earthy smell)



allicin
(garlic scent in actual garlic)



di-allyl sulfide
(smells like garlic)



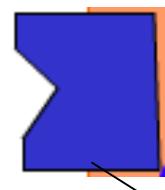
allyl-propyl disulfide
(onion smell in onions)

Bio 112 Scent Transduction

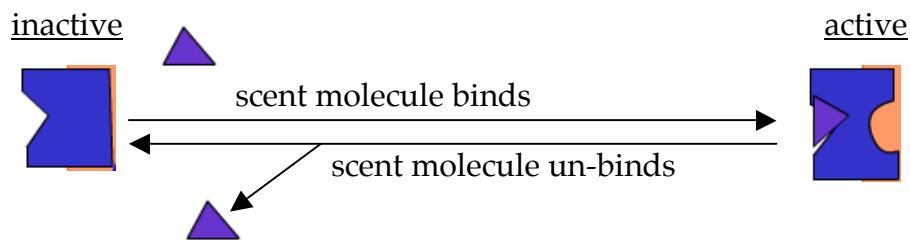
Cast of Characters Note that each has a turn-on and a turn-off mechanism.



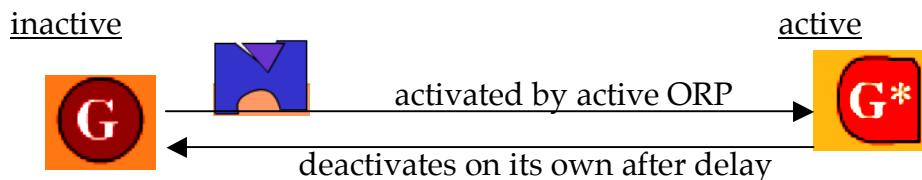
1) **Scent Molecule:** one of millions of molecules that we can smell.



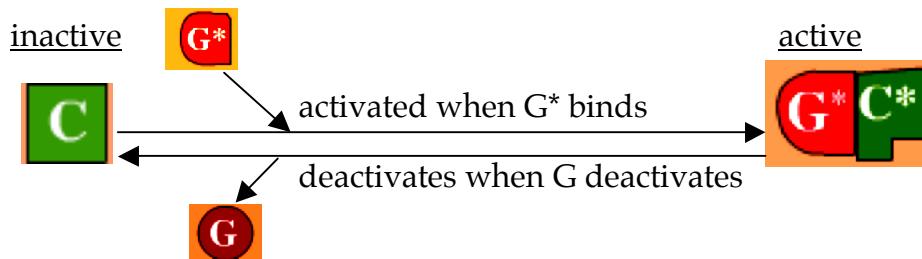
2) **ORP (odorant receptor protein).** Specialized to bind one scent molecule or a set of related scent molecules. It has two forms:



3) **G-protein.** A signal transduction protein used in many systems. Catalytically activated by active ORP; deactivates spontaneously after a short time.

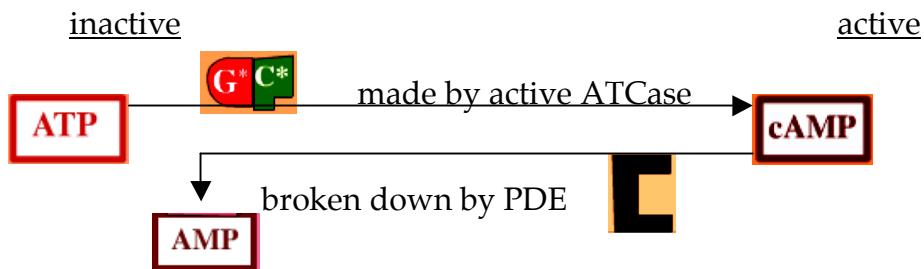


4) **ATCase (adenylate cyclase).** Another signal transduction protein used in many systems. Individually and reversibly activated by active G-proteins. When active, it converts ATP to cAMP (cyclic AMP).

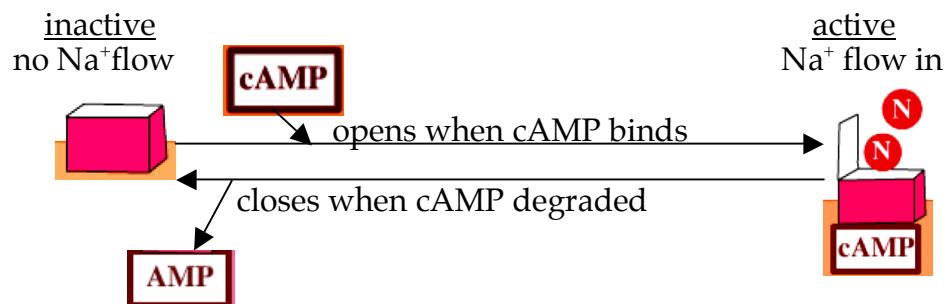


cAMP

5) cAMP (cyclic AMP). A signaling molecule used in many systems. Catalytically synthesized from ATP by ATCase; broken down by PDE (phosphodiesterase) to AMP.



6) cAMP-gated Na⁺ channel. A Na⁺ channel that is individually gated by cAMP. When cAMP binds, it opens; when cAMP is absent, it closes.



Bio 112 Handout for Physiology 7

This handout contains:

- Today's iClicker Questions

iClicker Question #27A - before lecture

Which of the following are true?

- A. Muscle cells can only pull; they cannot push.
- B. Muscle cells use the chemical energy of ATP to move.
- C. Muscle cells are signaled to move by nerve impulses.
- D. All of the above
- E. None of the above

iClicker Question #27B - after lecture

Consider the hypothetical drug C. Drug C inserts itself into all membranes and allows Ca^{++} ions to flow freely through the membranes. It does not allow any other ions to move. It is like adding an always-open Ca^{++} channel to all membranes in all cells. What would happen if you added this drug to a muscle in a living animal?

- (A) the muscle would be unable to contract
- (B) the muscle would contract even if it had not been stimulated by a nerve
- (C) it would have no effect (the muscle would only contract if stimulated by a nerve)
- (D) I don't know.

Beaming in your answers

1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should resend it until you get a green "STATUS" light.



Bio 112 handout for Physiology 8

This handout contains:

- Today's iClicker Questions

iClicker Question #28A - before lecture

Which of the following are true?

- A. Water and ions can cross a membrane freely.
- B. Water "wants" to move from salty solution to a dilute solution.
- C. Only ions can cross a membrane freely.
- D. All of the above
- E. None of the above

iClicker Question #28B - after lecture

The cytoplasm of human cells has an intermediate "saltiness". Suppose that you put a human cell in seawater, which is substantially saltier than the cytoplasm of the human cells. What would happen?

- (A) Water would leave the cell and the cell would shrink.
- (B) Water would enter the cell and the cell would swell.
- (C) Salts would enter the cell and the cell would swell.
- (D) Salts would leave the cell and the cell would shrink.
- (E) I don't know.

Beaming in your answers

1. Figure out your answer and select the appropriate letter (A-E).
2. Turn on your iClicker by pressing the "ON/OFF" button; the blue "POWER" light should come on. If the red "LOW BATTERY" light comes on, you should replace your batteries soon.
3. Transmit your answer as follows:
 - a. Press the button corresponding to the answer you've selected (A thru E).
 - b. The "STATUS" light will flash green to indicate that your answer has been received. If the "STATUS" light flashed red, your answer was not received; you should resend it until you get a green "STATUS" light.

